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Personal Science Teaching Efficacy and the Beliefs and Practices of Elementary Teachers Related to Science Instruction

A dissertation submitted in partial satisfaction of the requirements for the degree of Doctor of Philosophy

in

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by

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The Dissertation of Corinne H. Lardy is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

Chair

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DEDICATION

This dissertation is dedicated to my husband, Matthew, for always believing in me and to our baby boy, due to arrive very soon, for giving me the motivation I needed to finally finish this.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT OF THE DISSERTATION

Personal Science Teaching Efficacy and the Beliefs and Practices of Elementary Teachers Related to Science Instruction

by

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Doctor of Philosophy in Mathematics and Science Education

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In this study, I examined the relationships among Personal Science Teaching Efficacy (PSTE) beliefs, science teaching practices, and the beliefs about these practices within a nationwide diverse sample of inservice elementary teachers. More specifically, the goal of my study was to answer two questions: (1) How do these teachers with varying levels of self-efficacy compare in the ways that they (*a*) describe how science

should be taught, (*b*) describe their *own* science teaching practices, and (*c*) are actually *observed* teaching science?; and (2) In what ways are these areas of belief and practice aligned?

In order to answer these questions, data were collected from thirty-eight inservice elementary teachers from across the United States using the Reformed Teacher Observation Protocol (RTOP), semi-structured interviews, and the Science Teaching Efficacy Beliefs Instrument (STEBI-A). Pearson's correlations and independent sample t-tests of coded qualitative data and quantitative survey data were conducted in order to compare the beliefs and practices regarding science teaching within and across PSTE levels. In addition, eight case profile teachers were chosen with varying combinations of high and low PSTE and RTOP scores in order to examine some of the complexities existing between science teaching self-efficacy beliefs and science teaching behaviors in closer detail.

Results revealed that a majority of the positive behaviors commonly associated with greater science teaching self-efficacy, especially giving students more control over their own science learning, did manifest themselves in participants' *beliefs* about science teaching. However, most of these beliefs did not align with actual *observed* classroom practices. Interviews and observations of case profile teachers revealed how self-efficacy levels manifested themselves in different ways with different teachers. While there do appear to be some overall advantages to increasing elementary teachers' science teaching self-efficacy, the situation is much more complex than it is sometimes portrayed in the literature; by simply increasing elementary teachers' levels of efficacy beliefs, there is no guarantee that they will actually teach science in a more reformed, inquiry-based manner. The results of my dissertation should, therefore, give science teacher education researchers pause when making blanket assumptions about the benefits of increasing elementary teachers' self-efficacy.

CHAPTER 1: INTRODUCTION

Beliefs play a critical role in influencing the instructional practices of teachers (Pajares, 1992; Philipp, 2007; Richardson, 1996). Therefore, if we are to improve the way that science is taught at the elementary level in the United States, we must understand which beliefs, and how these beliefs, impact the ways in which elementary teachers implement instructional strategies in their science lessons.

One set of beliefs that has been consistently suggested to be related to teacher behavior in a variety of educational fields is that of teacher efficacy (Tschannen-Moran, Hoy, & Hoy, 1998; Wheatley, 2005). However, although a positive correlation is generally accepted between the level of science teaching efficacy beliefs and effective science teaching practices [so much so, in fact, that the increase of preservice teachers' science teaching self-efficacy has been promoted as a primary goal of science teacher education (Brand & Wilkins, 2007)], other evidence suggests that this is not necessarily the case. A clearer understanding of the relationships between elementary teachers' science teaching self-efficacy beliefs, their beliefs about science instruction, and their actual science teaching practices is needed in order to effectively and positively influence the ways in which science is taught at the elementary level.

The goal of this study is to examine the relationships between science teaching self-efficacy and science teaching practices for a diverse nationwide sample of inservice elementary teachers. It seeks to examine (a) the beliefs of these teachers regarding elementary science teaching (ideal and personal) and (b) the observed science teaching practices of these teachers, as they relate to the teachers' Personal Science Teaching Efficacy (PSTE) beliefs.

In the first section of this chapter, I describe the general background and personal motivation for this study. Next, I give an overview of the construct of science teaching efficacy beliefs and its importance in research related to science teacher education. In the third section, I discuss the goals of this study and present the research questions. Finally, in the last section of this chapter I present a summary of the contributions of this research to the field of science education.

1.1 General Background and Motivation

1.1.1 The Need to Reform Elementary Science Education

Many policymakers and scientists, as well as the general public (Keegan, 2006; Lemonick, 2006), have voiced concerns about the quality of science education in the United States, citing the relatively low achievement scores of students in this country (National Assessment of Educational Progress, 1990, 2006; National Commission on Excellence in Education, 1983; Provasnik, Gonzales, & Miller, 2009; Third International Mathematics and Science Study, 1996) and the decline of undergraduate students choosing to enter and remain in science-based majors, especially among women and minorities (Seymour & Hewitt, 1997). *Rising Above the Gathering Storm* (National Academy of Sciences et al., 2007), for example, is a recent and influential policy document produced as a joint effort by groups including the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. This document argues that the economic vitality of the United States "is derived in a large part from the productivity of well-trained people and the steady stream of scientific and technical innovations they produce. Without high-quality, knowledge-intensive jobs and the innovative enterprises that lead to discovery and new technology, our economy will suffer and our people will face a lower standard of living" (National Academy of Sciences et al., 2007, p. 1). For these reasons, the report warns of the danger of an American society that does not have a high enough level of scientific or technological literacy to compete in a global economy, and recommends "vastly improving K-12 science and mathematics education" in this country (p. 5).

Of particular concern in the United States is the low quality of elementary science education. Although the elementary level is the time that students build their foundational understandings of science, and the time when students should begin to learn to systematically explore their environment (Tilgner, 1990), evidence shows that elementary science instruction continues to be ineffectual and infrequent (Duschl, 1983; Duschl, Shouse, & Schwingruber, 2008; Fulp, 2002; Weiss, Banilower, McMahon & Smith, 2001).

Research suggests that student learning is best supported by a reformed inquiry-oriented, learner-centered approach[1] to instruction (Duschl et al., 2008; National Research Council [NRC], 1996; Sawada, Turley, Falconer, Benford, & Bloom, 2002). However, in K-6 education (and at higher levels) science is still often taught as a series of facts presented by the teacher to the students for memorization. One reason that has been suggested for this approach is that, because elementary teachers often do not have

[1] A detailed description of the characteristics of reformed inquiry-based science teaching practices is presented in section 2.1 of Chapter 2.

extensive backgrounds in science content or science instruction, it is easier for them to fall back on the teacher-centered, fact-based traditional ways in which they were taught science at the primary, secondary, and undergraduate levels (Luera & Otto, 2005; McGinnis, Watanabe, & McDuffie, 2005; Tilgner, 1990). Additionally, due to social and political constraints promoting reading, writing, and mathematics, many K-6 teachers spend little to no classroom time on science instruction (Goldston, 2005).

1.1.2 Description of the NSEUS Project

In response to the above concerns, The NOVA (NASA Opportunities for Visionary Academics) program was established in 1996 and supported by the National Aeronautics and Space Administration to reform science courses for preservice elementary teachers (Sunal et al., 2001). The reasoning behind this project was that in order to reform elementary science education, we must reform the undergraduate science education of elementary teachers. Teams consisting of STEM (science, technology, engineering, and mathematics) and teacher education faculty, along with administrators from universities nation-wide participated in the NOVA project to help reform undergraduate science content courses experienced by preservice elementary teachers. Following professional development, team members were assisted by a NOVA mentor to develop an action research funding proposal to establish a new course or extensively reform an existing course. As a result of the NOVA project, 167 reformed undergraduate science courses were established at 101 universities across the United States.

In 2006, the National Study of Education in Undergraduate Science (NSEUS) was initiated with the purpose of examining the impact and sustainability of the established NOVA-funded courses (Sunal et al., 2009). Specifically, the NSEUS project was designed to examine the short- and long-term influences of the reformed undergraduate science content courses created through NOVA on the beliefs and behaviors of undergraduate students, particularly preservice elementary teachers, and practicing elementary teachers. In order to accomplish this goal, NSEUS project staff members have collected data from 20 universities across the United States at which NOVA courses were established. At each of these universities, project researchers have collected survey, interview, and observational data from the instructors and students of a NOVA course and a comparable non-NOVA course. In addition, the same types of data were collected from practicing elementary teachers at each site, three who completed the NOVA course as undergraduates and three who did not. As a graduate research assistant working as part of the NSEUS research team, I have been intimately involved in the logistical planning, data collection, and analysis procedures since the beginning of the project.

While a primary goal of the NSEUS project is to examine the impact of reformed undergraduate science content courses on the beliefs and behaviors of practicing elementary teachers, our results have indicated that the situation is much more complex. That is, through my observations I have seen that elementary teachers' beliefs and practices related to science teaching are influenced by much more than their pre-service education. In fact, many of the teachers we have interviewed reported not even remembering their undergraduate science course experiences. In addition, it seems that the teachers' beliefs, knowledge, and science teaching practices interact in complex ways. The next section presents a discussion of some these initial observations as they relate to the motivation for the study presented in this dissertation.

1.1.3 Examples From the NSEUS Project Demonstrating Motivation for the Current Study

Throughout my experiences over the past four years collecting data for the NSEUS project, I have noted many elementary teachers who demonstrate apparent complexities between beliefs and behaviors related to their science instruction. In particular, interesting relationships seem to exist between beliefs regarding confidence in teachers' abilities to teach science and their science teaching behaviors. From my initial observations, these relationships are not always consistent among teachers and seem to be impacted by a variety of factors, as indicated by the following examples of Dawn, Beth, and Luanne.[2]

When we encountered Dawn, she was a first-year teacher of a Kindergarten class. Although only in her first year of teaching, Dawn showed exceptional skill applying inquiry and student-centered teaching practices to the science lesson through which she led her students. In the lesson that we observed, Dawn had her students compare the seeds, growth, and fruit of pumpkins and apples. This topic was of particular interest to the students since it was one week before Halloween. When we interviewed Dawn following this lesson, she expressed a large amount of confidence in her ability to teach science to her students, despite their young age. She also explained

[2] All names used in this document are pseudonyms.

that, as a person who majored in biology as an undergraduate, one of her primary goals in her class was to provide her students with a foundation on which to build future scientific knowledge.

Beth is another teacher who demonstrated many reform-oriented aspects in her teaching of a science lesson to her pre-Kindergarten students. In the lesson that we observed, Beth led her 3- and 4-year-old students in applying what they knew about people to think about what polar bears need to survive. The students then took turns leading their fellow students in demonstrating what skills a mother polar bear might need to teach to her young cubs to survive. At the end of the lesson, Beth read a story about polar bears and their adaptations to the students, as she led them to compare what the students had thought about polar bears to what the book said. While Beth's science teaching showed many of the same characteristics of Dawn's, the beliefs that she expressed in her interview were very different. Beth expressed uncertainty in her ability to teach science to her students, despite the fact that she had several more years of experience than Dawn and a similar background in science. Although Beth claimed that she felt it was important to teach her students about science, she thought that she could really only be confident in her science teaching with older students.

As a third example, Luanne was a teacher we visited who had been teaching fifth grade students for twenty-five years. Her science lesson, in contrast to those of Dawn and Beth, demonstrated a very traditional teacher-centered instruction style. That is, for the most part Luanne presented scientific facts to the students about the water cycle, which the students copied into their notes. In her interview, Luanne explained to us that she had found this particular style of teaching to be the best way to teach science, along with drilling the students about scientific facts with flash cards. In fact, she claimed that she was the best science teacher at her school. According to Luanne, thanks to her ability to teach science, her students had received the highest scores on the state science exam every year. Her administration had even presented her with awards for her students' elevated test scores, and often sent new fourth and fifth grade teachers to observe Luanne's science lessons.

My experiences with many and varied elementary teachers, such as Dawn, Beth, and Luanne, led me to begin to ask questions such as: (a) What is it about these teachers that contributes to their confidence (or lack thereof) in teaching science at their particular grade levels? and (b) How does this confidence relate to the varying levels of reform observed in their teaching of science? These are the types of questions that led me to an interest in the examination of elementary teachers' self-efficacy beliefs, those regarding confidence, as they relate to their instructional practices in science.

1.2 Why the Relationship Between Self-Efficacy and Practice Deserves Attention in Science Education

Related literature has indicated that there are many different factors that influence the behavior of teachers, such as knowledge, beliefs, attitudes, and emotions (Philipp, 2007; Richardson, 1996). According to research of these factors from a variety of academic areas, beliefs have a particularly strong influence on teacher behavior (Pajares, 1992). In science education specifically, beliefs about how students learn, the teacher's role in the classroom, the relative importance of content topics (Cronin-Jones, 1991), the influence of contextual factors (Haney, Lumpe, Czerniak, &

Egan, 2002), and the nature of science as a process and as a discipline to be learned and taught (Brickhouse, 1990; Duschl, 1983; Levitt, 2001; Tobin, Tippins, & Gallard, 1994), have all been suggested to play a role in influencing classroom practices related to science instruction. As previously mentioned, another set of beliefs that has been suggested to be particularly influential on these practices is that of teaching efficacy beliefs (Tschannen-Moran et al., 1998). In fact, according to DeMesquita and Drake (1994) any educational reform effort that does not take teacher efficacy beliefs into account is doomed to fail.

1.2.1 Science Teaching Self-Efficacy Beliefs: An Overview

This study examines self-efficacy beliefs through a lens based initially in social cognitive learning theory (Bandura, 1982, 1986, 1997), and further developed for the examination of teacher behavior by Gibson and Dembo (1984) and of teachers of science by Riggs and Enochs (1990). The theoretical construct of self-efficacy and its development from Bandura's original conceptualization to its application in teacher education research is discussed in detail in Chapter 2. However, I include a brief introduction to the construct as it relates to research regarding teachers of science here.

In general, teacher efficacy beliefs refer to beliefs about the level of confidence individuals have in their ability to influence student learning through their teaching behaviors. This construct is composed of two specific kinds of beliefs corresponding to the two components of Bandura's (1982) model of efficacy beliefs: "personal teaching efficacy" and "teaching efficacy" (Gibson & Dembo, 1984). According to Dembo and Gibson (1985), *personal teaching efficacy* is an individual's "belief that he or she [personally] has the skills and abilities to bring about student learning" (p. 175). *Teaching efficacy* beliefs, in contrast, are the beliefs of an individual related to teachers' abilities, as a general group, to influence student learning, or the extent to which factors outside of a teacher's control limit *any* teacher's ability to bring about change.

The construct of science teaching efficacy beliefs, introduced by Riggs and Enochs (1990), is different from general teaching efficacy beliefs in that it refers specifically to beliefs about the level of confidence individuals have in their ability to influence student learning related to *science*. Like general teaching efficacy beliefs, this construct is composed of two specific types of beliefs: "Personal Science Teaching Efficacy" (PSTE) and "Science Teaching Outcome Expectancy" (STOE). *PSTE* refers to a teacher's belief in his or her own ability to effectively teach science, while *STOE* reflects the extent of a teacher's belief that students will learn science if provided with effective instruction by any teacher.

1.2.2 Self-Efficacy and Science Education Research

Since its introduction by Riggs and Enochs (1990), the construct of science teaching efficacy beliefs has developed into a popular area of research in science education, particularly in examining the beliefs of preservice elementary teachers. The number of studies focusing on science teaching self-efficacy from the past year and a half alone demonstrates the popularity of this topic (e.g. Batiza et al., 2011; Bayraktar, 2011; Bursal, 2010; Buss, 2010; Cantrell, Cantrell, & Patch, 2011; Cartwright & Smith, 2011; Deniz, Orgil, & Carroll, 2011; Gunning & Mensah, 2011; Hechter, 2011; Kazempour, 2011; Lakshmanan, Heath, Perlmutter, & Elder, 2011; Matkins et al., 2011;

McDonnough & Matkins, 2010; Rethlefsen & Park, 2011; Sackes, Hilson, Trundle, & Krissek, 2010; Swars & Dooley, 2010).

In examining the related research literature, there seems to be good reason for this popularity; a long history of evidence exists suggesting a positive link between efficacy beliefs and teacher behavior, both for general and science teaching efficacy beliefs. For example, research has demonstrated that teachers with low general teaching efficacy beliefs expect students to fail and place the responsibility for learning entirely on the student rather than the teacher (Ashton, 1984; Ashton & Webb, 1986). Consequently, teachers with low teaching efficacy beliefs have been shown to use significantly more criticism when responding to incorrect student responses, and less persistence when working with low-achieving students compared to high-efficacy teachers (Ashton & Webb, 1986; Ashton, Webb, & Doda, 1983; Gibson & Dembo, 1984). In addition, teachers with high general teaching efficacy beliefs have been shown to (a) spend less time engaged in discussion unrelated to the objectives of a lesson (Gibson & Dembo, 1984); (b) be more open to new ideas and more willing to try new instructional techniques (Allinder, 1994; Guskey, 1988; Scribner, 1999; Stein & Wang, 1988; Tschannen-Moran & McMaster, 2009); (c) employ a larger amount of planning and organization for their lessons (Allinder, 1994); (d) have greater enthusiasm for teaching (Allinder, 1994; Guskey, 1984; Hall, Burley, Villeme, & Brockmeier, 1992); and (e) be more committed to teaching as a profession (Burley, Hall, Villeme, & Brockmeier, 1991; Caprara, Barbaranelli, Steca, & Malone, 2006; Coladarci, 1992; Evans & Tribble, 1986; Klassen & Chiu, 2010).

Since 1990, researchers have seen similar evidence connecting science teacher efficacy beliefs to science teaching behaviors. For example, Czerniak and Shriver (1994) found significant differences between preservice elementary teachers with high and low self-efficacy in their choices of instructional strategies for science lessons and the ways that they measured success of a science lesson. Specifically, high-efficacy teachers tended to choose activities in which they expected students to use higher-level thinking and problem-solving skills, and were more likely than low-efficacy teachers to use teaching strategies that were based on research or theory. In addition, Czerniak and Shriver found that the teachers with high science teaching self-efficacy were oriented toward the goals of developing students' critical thinking and decision-making skills, and tended to measure success of their science lessons by whether or not they believed these goals were achieved. In contrast, the teachers with low science teaching self-efficacy tended to measure success of a science lesson by their ability to manage student behavior, and the extent to which their students obediently followed a teacher-directed, step-by-step procedure in order to arrive at the correct answer. Preservice elementary teachers with high science teaching self-efficacy have also been shown to be more likely to claim that activity-based instruction, in which students learn through cooperation and experience, is the most appropriate method of teaching science at the elementary level (Enochs, Sharmann, & Riggs, 1995).

Research regarding inservice elementary teachers has also suggested a positive correlation between science teaching efficacy beliefs and reformed teaching practices. Haney et al. (2002), for example, found that elementary teachers with higher Personal Science Teaching Efficacy (PSTE) scores

> were more likely to design lessons that: incorporated inquiry, depicted careful planning, attended to student prior knowledge and experiences, attended to issues of equity, utilized appropriate and available resources, encouraged a collaborative approach, and assessed students in a way that was consistent with the intended purpose. (p. 179)

Other evidence suggests that inservice teachers with higher levels of science teaching self-efficacy (a) claim to ask more open-ended questions (Riggs, Enochs, & Posnanski, 1998); (b) do a better job of connecting science content to students' lives and/or the real world (Haney et al., 2002; Riggs et al., 1998); (c) teach more science per week (Desouza, Boone, & Yilmaz, 2004); (d) report using more hands-on activities (Marshall, Horton, Igo, & Switzer, 2009; Ramey-Gassert, Shroyer, & Staver, 1996); (e) incorporate more inquiry-based activities (Haney et al., 2002; Lakshmanan, et al., 2011; Nolan et al., 2011); (f) present scientific content that is more accurate (Haney et al., 2002); and (g) exhibit more positive attitudes toward science education reform (Czerniak & Lumpe, 1996).

The apparent positive link between science teaching efficacy beliefs and science teaching practices has lead many researchers to focus attention on ways to increase science teaching self-efficacy beliefs of teachers, assuming that by increasing science teaching self-efficacy these teachers will be better, or more reformed, teachers of science. However, research regarding the relationship between science teaching efficacy beliefs and science teaching behavior has neglected to take several important factors into serious account. In addition, several inconsistencies in the results of research regarding the relationship between science teaching efficacy beliefs and practice suggest that there is much more to be learned in this area of research.

1.2.3 Under-addressed Issues in the Current Research Regarding Science Teaching Self-Efficacy and Practice

Although there is alot of evidence suggesting the important influence of science teaching self-efficacy beliefs on science teaching practices, several under-addressed issues in the related research indicate that the intricacies of the relationships between these beliefs and practices are not clear. These under-addressed issues include inconsistencies in existing research results, a lack of consideration of other belief systems as they relate to self-efficacy beliefs, and a deficiency in qualitative data including observations of teachers' actual science teaching practices in self-efficacy research.

Inconsistent Results

A large amount of the current research regarding science teaching self-efficacy beliefs focuses on how these beliefs may be increased in particular populations of pre- and inservice teachers (e.g. Bayraktar, 2011; Bluestone, 2009; Brand & Wilkins, 2007; Carleton, Fitch, & Krockover, 2008; Carrier, 2009; Cone, 2010; Duran, Ballone-Duran, Haney, & Beltyukova, 2009; Gunning & Mensah, 2011; Hechter, 2011; Khourey-Bowers & Simonis, 2004; Liang & Richardson, 2009; McDonnough & Matkins, 2010; Nolan et al., 2009; Nunn & Jantz, 2009; Rethlefsen & Park, 2011; Swackhamer, Koellner, Basile, & Kimbrough, 2009; Swars & Dooley, 2010). This research rests on the assumption that, by increasing teachers' science teaching self-efficacy, their science teaching practices will also improve or will be more reformed. However, several inconsistencies in results regarding the relationship between science teaching efficacy beliefs and science teaching practices, such as those described in the examples from the NSEUS project in section 1.1.3 above, indicate that this may not necessarily be the case.

Haney et al. (2002), for example, found inconsistencies in an overall positive relationship between science teaching self-efficacy and practice for six inservice elementary teachers. For five of their participants, greater self-efficacy scores correlated with more reformed science teaching practices. However, one participant did not follow this pattern; although she demonstrated high self-efficacy beliefs, observations and interviews revealed that her science teaching strategies were primarily teacher-centered and lecture-based with little to no use of inquiry. Similarly, Settlage, Southerland, Smith, and Ceglie (2009) and Bhattacharyya, Volk, and Lumpe (2009) noted that although the preservice elementary teachers whom they studied had relatively high levels of science teaching self-efficacy, the teaching behaviors of several subjects demonstrated a relatively low level of reform. Kind (2009) also observed that preservice secondary science teachers actually did a *better* job of choosing appropriate instructional strategies for scientific topics that they felt *less* confident teaching.

Inconsistencies in the patterns between teaching self-efficacy beliefs and behaviors have been identified in research outside of science education as well. For example, while a positive relationship between general teaching self-efficacy and reformed or constructivist teaching practices is generally accepted in the literature (Tschannen-Moran et al., 1998), Wheatley (2005) claimed that the evidence supporting this relationship is more mixed than many acknowledge. A few studies, in fact, have even found a negative correlation between general teacher efficacy beliefs and reformed teaching practices (Smylie, 1988; Stein & Wang, 1988). Other studies, from the area of mathematics education for example, have noted that teachers with identical levels of self-efficacy beliefs may teach in dramatically different ways (Wheatley, 2005).

Potentially Important Relationships Between Self-Efficacy and Other Belief Systems

Based on his extensive examination of the literature regarding teacher beliefs, Pajares (1992) cautioned against a completely narrow focus in educational research to only one area of beliefs as related to teacher practice due to the complex nature of belief systems.

> Because they are specific enough to be reasonably operationalized and more easily measured, belief subconstructs, such as self-efficacy, lend themselves more readily to educational research. But [...] they offer a limited glimpse into a much broader system and [...] understanding their connections and centrality is essential to understanding the nature of their effect [...] Seeing educational beliefs as detached from and unconnected to a broader belief system, for example, is ill advised and probably unproductive. (p. 326)

Inconsistencies in the patterns between teaching self-efficacy beliefs and practice may therefore be better understood through the examination of the relationships between teachers' self-efficacy and *other* beliefs, such as beliefs about how science should be taught at the elementary level and about how teachers are themselves actually teaching science.

While Haney et al. (2002) and Bhattacharyya et al. (2009) suggested that the inconsistent results that they observed between teachers' self-efficacy and level of reformed teaching may have been due to an inaccuracy of self-reported data or that the observed lesson was not indicative of the anomalous teachers' overall abilities, they also considered other possibilities for these results related to the teachers' additional belief systems. For example, the authors suggested that the teachers' beliefs of what it means to be a successful elementary science teacher and to teach in an inquiry-oriented manner contrasted with how it was measured by the researchers. Since these teachers' self-efficacy beliefs were based upon a different image of effective science teaching than that of the researchers, the teachers had high confidence in their own abilities to teach science well, even though they were not teaching in a reformed inquiry-oriented manner.

Other researchers have suggested that, for some teachers, a mismatch may exist between the ways in which teachers *believe* that they're teaching and the ways in which they are *actually* teaching science (Wheatley, 2005; Roehrig, Turner, Grove, Schneider, & Liu, 2009). If this is the case, teachers may believe that they are being an effective teacher of science, although this is not the case in reality. This is especially possible if, as indicated by some, overly-elevated science teaching self-efficacy beliefs may inhibit the ability of teachers to critically reflect on their lessons, leading them to believe that there is no need for reflection (Czerniak & Schriver, 1994; Kind, 2009; Settlage et al., 2009; Wheatley, 2002).

In addition, teachers' beliefs about how science *should* be taught and how they are actually teaching science may not be aligned, especially if teachers believe that external or contextual factors beyond their control are impacting their ability to teach science (Haney, Czerniak, & Lumpe, 1996; Lumpe, Haney, & Czerniak, 2000). In this case, although an elementary teacher with high science teaching self-efficacy beliefs may have a more reformed view of ideal science teaching than her lower-efficacy colleagues, she may still demonstrate different beliefs about the ways that she is actually teaching science in her classroom, which would be reflected in observations of her teaching practices. A closer examination of the relationships between science teaching self-efficacy beliefs and other sets of beliefs, such as those related to how they surmise science should be taught at the elementary level and how teachers think that they are teaching science in their classrooms, may help to uncover factors mediating the relationships between self-efficacy and practice.

Need For Qualitative Data Including Observations

Several researchers have criticized the apparent over-dependency of research regarding teacher beliefs, especially self-efficacy beliefs, on quantitative and self-reported data. That is, some have argued that research about teacher beliefs must include interview and observational data to support data derived from quantitative survey instruments (Pajares, 1992; Perkins, 2007; Wheatley, 2005). As stated by Pajares (1992):

> If reasonable inferences about beliefs require assessments of what individuals say, intend, and do, then teachers' verbal expressions, predispositions to action, and teaching behaviors must all be included in assessments of beliefs [...] Results [of belief inventory instruments] can help detect inconsistencies and areas that merit attention, but additional measures such as open-ended interviews, responses to dilemmas and vignettes, and observation of behavior must be included if richer and more accurate inferences are to be made. (p. 327)

Of primary concern is the fact that research providing evidence for the link between increased science teaching self-efficacy and more reformed science teaching practices has largely been based on teachers' own accounts of what they do in their classrooms or what they intend to do, rather than on actual observations of their teaching practices. Wheatley (2005) cautioned against the danger of confusing “teacher efficacy beliefs” with “actual teaching effectiveness,” and pointed out that “teachers’ efficacy beliefs may underestimate, overestimate, or accurately reflect actual teaching practices” (pp. 748-749). It is important, if we are to make accurate and informed inferences about the links that exist between science teaching self-efficacy and science teaching practices of elementary teachers, that actual observations of teachers’ science classroom behavior be taken into account (Pajares, 1992).

Unfortunately, due to the limited number of studies examining the relationship between inservice elementary teachers’ self-efficacy beliefs and their observed, as opposed to self-reported, teaching practices (Haney et al., 2002; Lakshmanan et al., 2011; Riggs et al., 1998), many aspects of the relationship between science teaching self-efficacy and science teaching behaviors of practicing teachers remain unclear. Further information is needed in this area, which includes observations of teaching behavior along with interviews and surveys, in order to gain a greater understanding of the relationships between science teaching self-efficacy and practice. Only with these additional research results can researchers, teacher educators, and policymakers successfully implement and sustain reformed inquiry-oriented science teaching practices at the elementary school level (DeMesquita & Drake, 1994).

1.3 Research Goals and Research Questions

Pajares (1992) argued that, in order to more clearly understand individuals’ beliefs related to teaching and the relationships between these beliefs and practices, we must examine *interactions* among specific areas of belief, such as self-efficacy, and behavior. Specifically, he claimed that, "Beliefs must be inferred, and this inference must take into account the congruence among individual's belief statements, the intentionality to behave in a predisposed manner, and the behavior related to the belief in question" (Pajares, 1992, p. 326). This study seeks to examine these relationships as they relate to science teaching self-efficacy beliefs, beliefs regarding ideal and personal science instruction, and observed science teaching practices of inservice elementary teachers.

The overarching question addressed by this study is: What are the relationships among Personal Science Teaching Efficacy (PSTE) beliefs, science teaching practices, and the beliefs about these practices within a nationwide diverse sample of inservice elementary teachers? More specifically, this study seeks to answer the following questions regarding this group of teachers:

1) How do these teachers compare in the ways that they
    a) describe how science *should* be taught at the elementary level and their reasons for this description?
    b) describe their *own* science teaching practices and their reasons for these practices?
    c) actually teach science?
2) In what ways are these teachers' descriptions of ideal science teaching (1a), their descriptions of their own science teaching (1b), and their observed science teaching practices (1c) aligned?

1.3.1 Reasoning for Focusing on PSTE Beliefs

In examining the relationships between science teaching efficacy beliefs and practices of inservice elementary teachers, I chose to concentrate specifically on PSTE beliefs as opposed to Science Teaching Outcome Expectancy (STOE) for several reasons. While STOE has been acknowledged as a potentially powerful influence on science teaching practices, several studies have pointed out the (a) lower reliability coefficient of outcome expectancy beliefs (Enochs & Riggs, 1990; Huinker & Madison, 1997; Plourde, 2002); (b) difficulty of separating outcome expectancy from the construct of locus of control[3] (Guskey & Passaro, 1994; Judge, Erez, Bono, & Thoresen, 2002; Tschannen-Moran et al., 1998); and (c) more accurate role of perceived self-efficacy in predicting behavior than outcome expectancy beliefs or locus of control (Bandura, 1997). For these reasons, it has been argued that outcome expectancy is a less definitive construct than self-efficacy, and thus more difficult to measure accurately (Riggs & Enochs, 1990; Tschannen-Moran et al., 1998) and less valuable to research regarding science teaching self-efficacy (Bursal, 2010; McDonnough & Matkins, 2010; Perkins, 2007; Roberts, Henson, Tharp, & Moreno, 2001).

1.3.2 NSEUS as a Context for Answering the Research Questions

The National Study of Education in Undergraduate Science (NSEUS) project is an appropriate context for examining the relationships among inservice elementary teachers' science teaching self-efficacy beliefs, beliefs regarding ideal and personal science instruction, and science teaching practices for several reasons. The main

[3] See section 2.7.4 of Chapter 2 for a discussion of the construct of locus of control.

reasons for this choice of context are grounded in the size and diversity of the group of elementary teachers currently involved with the NSEUS project. This diversity provides a larger representation of the overall population of practicing elementary teachers in the United States than has been examined in other studies.

The NSEUS project provides a very diverse sample of practicing elementary teachers. The approximately 100 teachers participating in the overall NSEUS project are from a wide geographic region, representing Alabama, Alaska, California, Texas, Massachusetts, Michigan, Connecticut, Oklahoma, Kansas, New Hampshire, North Carolina, Wisconsin, and Indiana, and are of diverse ethnicity and mixed gender. In addition, the teachers were trained at institutions with a variety of Carnegie classifications, and have a wide range of background experiences. This group is also diverse in that teachers within the group currently teach pre-Kindergarten through eighth grade at a range of schools, including public and private schools serving a variety of socioeconomic communities.

In contrast, the majority of past studies regarding science teaching self-efficacy beliefs of inservice elementary teachers utilizing interviews and/or observations have focused on small relatively uniform groups of teachers often participating in a specific professional development project (Bhattacharyya et al., 2009; Haney et al., 2002; Khourey-Bowers & Simonis, 2004; Nolan et al., 2009; Ramey-Gassert et al., 1996). These populations are less generalizable than the NSEUS project population, due to their small size and uniformity. In addition, experienced teachers participating in a professional development program have already demonstrated an interest in reforming their science teaching practices. In comparison, while some teachers in the NSEUS project have participated in professional development to varying extents, others have little to no training in science teaching practices. This diversity of experience and interest level in the NSEUS group allows for many different facets of comparison within the examination of the relationships between science teaching efficacy beliefs and practice, as they may exist in the greater population of United States elementary teachers.

1.4 Contributions to the Field of Science Education

While science teaching efficacy beliefs have been suggested to have a powerful influence on the science teaching practices of elementary teachers, many of the intricacies of the relationships that exist between the two remain unclear. The research base currently existing for self-efficacy of teachers in science education is in need of (a) additional studies involving inservice teachers; (b) in-depth research regarding the relationships among science teaching self-efficacy beliefs, other beliefs regarding science instruction, and science teaching practices, which includes interviews and observations; and (c) data regarding science teaching self-efficacy of large, more generalizable, samples of teachers. Until we have a greater understanding of the relationships between science teaching efficacy beliefs and classroom practice, there is uncertainty in the assumption that by simply increasing elementary teachers' science teaching self-efficacy they will become more effective teachers of science.

The research study presented in this dissertation seeks to add to the field's knowledge of the relationships between self-efficacy and practice by examining the Personal Science Teaching Efficacy (PSTE) beliefs, beliefs regarding science teaching, and science teaching practices of a large diverse nationwide sample of inservice elementary teachers. In addition, through the use of a variety of data sources not frequently used in current research regarding self-efficacy of inservice elementary teachers, including interviews and observations, this study provides richer insights into the important relationships existing between science teaching self-efficacy and classroom practice.

CHAPTER 2: REVIEW OF THE LITERATURE

This chapter reviews the literature with the aim of providing a foundation for conceptualizing the relationships that exist between inservice elementary teachers' self-efficacy beliefs related to science teaching and their science teaching practices. The first section of this chapter provides an overview of elementary science education reform and reformed inquiry-oriented science teaching practices. In the second section, the construct of beliefs is defined as it pertains to the actions of teachers. In the third section, I review the research related to the development of the construct of science teaching efficacy. The next two sections serve as a review of the literature pertaining to the two primary themes of teaching efficacy beliefs research: (1) research regarding the factors influencing the development of teaching efficacy beliefs, and (2) studies involving the relationships between teaching efficacy beliefs and practice. I then present a discussion of inconsistencies in the current findings of science teaching efficacy research and possible reasons for these inconsistencies as discussed by others. Next, I present an overview of the relationships and distinctions between self-efficacy beliefs, as described in the previous sections, and other closely related constructs discussed in relevant research literature. Finally, in the last section I provide an overall summary of the chapter.

2.1 Elementary Science Education Reform

In the United States, policymakers and others (Keegan, 2006; Lemonick, 2006) have voiced concerns about the quality of science education, citing the relatively low achievement scores of students in this country (National Academy of Sciences et al., 2007; National Assessment of Educational Progress, 1990, 2006; National Commission on Excellence in Education, 1983; Provasnik, Gonzales, & Miller, 2009; Third International Mathematics and Science Study, 1996) and the decline of undergraduate students choosing to enter and remain in science-based majors, especially among women and minorities (Seymour & Hewitt, 1997). A primary concern is that students without adequate scientific knowledge will not be able to compete effectively in an increasingly globalized workforce in which people must be able to use critical thinking skills (Byko, 2007; National Center on Education and the Economy, 2007; National Research Council [NRC], 1996; Wise & Leibbrand, 2000). Among the recommendations of *Rising Above the Gathering Storm* (National Academy of Sciences et al., 2007), an extremely influential document on national science and mathematics education reform, is that in order to remedy this situation we must first "increase America's talent pool by vastly improving K-12 science and mathematics education" (p. 5).

In response to the above concerns, several groups have created policies regarding the reform of science classroom curricula and practice under the assumption that past science education practices are not adequate to support student learning or interest in science (American Association for the Advancement of Science, 1989, 1993; NRC, 1996, 2001). These policies outline a reformed research-based, inquiry-oriented approach to instruction rather than the positivist teacher-centered approach that has dominated science instruction in the past (Huffman, Thomas, & Lawrenz, 2008; Tobin, Tippins, & Gallard, 1994). Key characteristics of this reformed inquiry-oriented approach to science instruction are outlined in Table 2.1.

Table 2.1. Characteristics of Reformed Inquiry-Oriented Science Teaching Practices.

Characteristic	**Components / Description**
Student learning is active rather than passive	• Instruction is focused more on understanding of scientific concepts than on memorization of scientific facts. • "Students are encouraged to collaboratively interpret information in light of existing knowledge, and actively construct and reconstruct understandings, rather than receive information from an authoritative source such as a teacher" (Huffman et al., 2008, p. 138).
Instruction takes into account the individual differences in students	• Content and instruction are connected to the real world/ lives of the students. • Content and instruction are guided by the "the interest, knowledge, understanding, abilities, and experiences of students" (NRC, 1996, p. 27).
Instruction is inquiry-based	▪ Teachers "encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterizes science" (NRC, 1996, p. 28). ▪ Students participate in extended investigations. ▪ Students are engaged, at least in part, in the design of scientific investigations, and are involved in asking questions for investigation.
There exist more student talk and interactions among students in the classroom rather than teacher lecturing	▪ Teachers "orchestrate discourse among students about scientific ideas" (NRC, 1996, p. 27). ▪ Teachers encourage participation of all students. ▪ "Teachers display and demand respect for the diverse ideas, skills, and experiences of all students" (NRC, 1996, p. 28). ▪ "Teachers nurture collaboration among students" (NRC, 1996, p. 29).
Teachers engage students in using critical thinking and problem-solving skills	• Teachers "focus on higher order thinking, manipulating information, analyzing, synthesizing, generalizing, explaining, hypothesizing, generating conclusions, engaging students in substantive conversation, and connecting ideas to the real world beyond the classroom" (Huffman et al., 2008. p. 138).

In order to more clearly understand this reformed view of science teaching, it is important to address what is meant by the term "inquiry," since it is a central aspect to this type of instruction. It is difficult to find a common definition of inquiry in the research literature, and even the *National Science Education Standards* (NRC, 1996) uses the term inquiry in several different (often non-specific) ways (Anderson, 2002). There are, however, basic common descriptors of inquiry in the ways that it is explained to teachers for practical use in the science classroom. In general, when a teacher uses inquiry in her science teaching practices, her students are engaged at some level in the processes of scientific investigation and problem solving (NRC, 2000). Banchi and Bell (2008) have described the level of this involvement as a continuum, from the lowest level in which students are engaged in inquiry as *confirmation inquiry* ("students confirm a principle through an activity when the results are known in advance"), to a middle level of *structured* and *guided inquiry*, to the highest level of *open inquiry* ("students investigate questions that are student formulated through student designed/selected procedures") (p. 27). Regardless of which level is employed, the important issue is that in inquiry-oriented instruction the students are engaged in some manner in the primary processes involved in generating scientific knowledge, such as asking questions; hypothesizing; and/or generating, interpreting, and evaluating data (NRC, 2000). During this type of instruction, teachers guide their students to generate their own scientific knowledge through science-based practices, rather than simply transmitting scientific facts to the students through lecture or reading alone (Haury, 1993). This idea of students "doing science" and developing proficiency in important aspects of the scientific process is at the heart of reform for K-8 science education (Duschl, Shouse, & Schwingruber, 2008).

Although measuring the impact of reformed teaching practices on students in science classes has been a challenge, evidence suggests that reformed teaching does make a significantly positive difference in student learning. Sawada and Pilburn (2000), for example, designed the Reformed Teaching Observation Protocol (RTOP) in order to measure the level of reform in mathematics and science classrooms. The RTOP utilizes a definition of reform built from an extensive review of the literature regarding science and mathematics teaching reform. Through the use of this instrument, Sawada, Turley, Falconer, Benford, and Bloom (2002) found correlation coefficients ranging from 0.88 to 0.97 between RTOP scores for secondary and undergraduate science classrooms and mean normalized gain scores for students in those classrooms. More recently, Jong, Pedulla, Reagan, Salomon-Fernandez, and Cochran-Smith (2010) found a similar correlation between RTOP scores for mathematics lessons of first and second-year elementary teachers and their students' performance on a district-mandated mathematics test.

Although a large number of teacher preparation programs today apply the standards recommended in reform documents to the education of new teachers of science, many of the above recommended teaching strategies are still not regularly applied by practicing K-12 teachers to their own science instruction. This is especially true in elementary classrooms where teachers often do not have extensive backgrounds in science content or science instruction, causing them to fall back on the teacher-centered, fact-based traditional ways that they experienced instruction in science classes

(Luera & Otto, 2005; Markic & Eilks, 2010; McGinnis, Watanabe, & McDuffie, 2005). In addition, due to social and political constraints promoting reading, writing, and mathematics, it is not difficult for many K-6 teachers to almost avoid science instruction completely (Goldston, 2005). Consequently, in much of the United States, science instruction continues to be poor, limited, or nonexistent at the elementary school level (Duschl et al., 2008; Fulp, 2002; Weiss, Banilower, McMahon, & Smith, 2001).

2.2 Teacher Beliefs

If we are to ensure that positive changes are made in the ways that science is taught at the elementary level, or at any level for that matter, we must understand why teachers use the instructional strategies that they do, or what factors influence teacher behaviors. That is, if we want teachers to apply reformed inquiry-based teaching strategies to their science lessons as outlined above, we need to understand what causes teachers to implement, or not implement, these teaching strategies.

There are many different factors that influence the behavior of teachers, such as knowledge, beliefs, attitudes, and emotions (Gess-Newsome, 1999; Philipp, 2007; Richardson, 1996). Research from a variety of academic areas suggests that beliefs have a particularly strong influence on teacher behavior, since "the beliefs teachers hold influence their perceptions and judgments, which, in turn, affect their behavior in the classroom" (Pajares, 1992, p. 307). In particular contexts, beliefs may be stronger than knowledge[4] as a predictor of teacher practices (Pajares, 1992; Weiss et al., 2003). It is

[4] The term "knowledge" and various types of teacher knowledge are discussed in greater detail later in this section and in section 2.7.2 of this chapter.

therefore important that beliefs, especially particular sets of beliefs, have a central role in research whose aim is to understand teacher behaviors (Pajares, 1992) and to successfully help teachers to implement educational reform (Eisenhart, Shrum, Harding, & Cuthbert, 1988).

2.2.1 Defining Beliefs

A long philosophical debate exists as to how a "belief" should be defined, particularly in educational research (Kagen, 1992; Pajares, 1992). Defining a "belief" in teacher education research becomes even more complicated, since researchers of teacher thinking often use the terms "belief" and "knowledge" as empirically interchangable (Avraamidou & Zembal-Saul, 2010; Ballone & Czerniak, 2001; Southerland, Sinatra, & Matthews, 2001).

For the purposes of this study, a *belief* is defined as information that an individual accepts to be true (Philipp, 2007), although a truth condition is not required for this judgment (Bryan, 2003; Green, 1971). In this definition, a belief differs from a piece of *knowledge* in that "beliefs, unlike knowledge, may be held with varying degrees of conviction and are not consensual" (Philipp, 2007, p. 259). In other words, individual beliefs, as opposed to knowledge, do not need to be agreed upon as valid or appropriate within the outside community, nor do they require consistency within the individual's belief system (Bryan, 2003; Nespor, 1987). In addition, belief is differentiated from *attitude*[5] or *emotion* in that beliefs are generally more strongly held, and "are more cognitive than emotions or attitudes" (Philipp, 2007, p. 259).

Through a review of research related to the construct of beliefs, Pajares (1992) developed a list of sixteen generalizations regarding this construct, or "fundamental assumptions that may be reasonably made when initiating a study of teachers' educational beliefs" (p. 324). Among these generalizations are the following characterizations of beliefs:

- "Beliefs are formed early and tend to self-perpetuate, persevering even against contradictions caused by reason, time, schooling, or experience" (p. 324).
- The longer a belief has been held, the more difficult it is to change. Therefore changing the beliefs of adults is particularly difficult. In addition, "beliefs about teaching are well established by the time a student gets to college" (p. 326).
- Beliefs serve an important role in "helping individuals define and understand the world and themselves" (p. 325).
- Beliefs influence an individual's interpretation of new information.
- "Beliefs are instrumental in defining tasks and selecting the cognitive tools with which to interpret, plan, and make decisions regarding such tasks; hence, they play a critical role in defining behavior and organizing knowledge and information" (p. 325).

[5] See section 2.7.1 for a more detailed discussion of the concept of teacher attitudes.

- Some beliefs are more central than others, and therefore are more resistant to change and more influential on the processing of new information and decision-making.
- "Beliefs must be inferred, and this inference must take into account the congruence among individual's belief statements, the intentionality to behave in a predisposed manner, and the behavior related to the belief in question" (p. 326).

Beliefs have been found to be a particularly strong predictor of teacher behavior in a variety of academic areas (Muijs & Reynolds, 2002; Solomon, Battistich, & Hom, 1996; Tobin et al., 1994; Weiss et al., 2003). Furthermore, the relationship between teacher beliefs and behavior is not a simple linear one. The relationship is much more complex (Brickhouse, 1990; Fang, 1996; Tobin, 1993) because a teacher's various belief systems may influence his or her teaching practices in multiple ways, depending on a variety of factors (Ogan-Bekiroglu & Akkoc, 2009; Pajares, 1992). In addition, not only do beliefs influence practice, but the converse is also true: teaching experiences influence teacher beliefs (Thompson, 1992).

Beliefs have also been shown to be an important part of the foundation upon which *science* teacher behavior is based (Enochs & Riggs, 1990; Mansour, 2010; Tobin et al., 1994). Several studies have demonstrated how various sets of teacher beliefs may influence different facets of teacher behavior related to their science instruction. For example, Cronin-Jones (1991) identified four categories of beliefs that strongly influenced curriculum implementation of science teachers: beliefs about how students learn, the teacher's role in the classroom, the abilities of students in a particular age group, and the relative importance of content topics. In another example, Haney, Lumpe, Czerniak, and Egan (2002) provided evidence that context beliefs of elementary teachers related to science instruction (teachers' beliefs about how well environmental factors will support his or her ability to teach science) can have a large impact on these teachers' science teaching practices. Evidence has also suggested that teachers' beliefs regarding the nature of science (i.e., viewing science as content or as a process), and science as an academic subject, play a large part in a teacher's science classroom practices (Brickhouse, 1990; Duschl, 1983; Levitt, 2001; Tobin et al., 1994).

Another set of beliefs that has been consistently shown to be related to (a) student achievement and motivation (Angle & Moseley, 2009; Caprara, Barbaranelli, Steca, & Malone, 2006; Guo, Piasta, Justice, & Kaderavek, 2010; Midgley, Feldlaufer, & Eccles, 1989; Moore & Esselman, 1992; Ross, 1992), (b) implementation of research-based instructional techniques (Allinder, 1994; Ghaith & Yaghi, 1997; Guskey, 1988; Scribner, 1999; Stein & Wang, 1988; Tschannen-Moran & McMaster, 2009), and (c) commitment to teaching (Caprara, et al., 2006; Coldarci, 1992; Evans & Tribble, 1986; Klassen & Chiu, 2010; Skaalvik & Skaalvik, 2010; Ware & Kitsantas, 2007) is a teacher's teaching efficacy beliefs. The following sections will address the development of the theoretical constructs of teaching efficacy beliefs and science teaching efficacy beliefs, along with a review of the applicable research literature regarding these constructs.

2.3 Efficacy Beliefs: Construct Development

2.3.1 General Efficacy Beliefs

My study examines efficacy beliefs initially through a lens based in social cognitive learning theory (Bandura, 1977, 1986, 1997, 2001), and then further developed specifically for the examination of teacher beliefs and behavior by Gibson and Dembo (1984) and the beliefs and behaviors of teachers of science by Riggs and Enochs (1990). In his social cognitive learning theory, Bandura (2001) claimed that human agency, the power of an individual to intentionally produce actions for a given purpose, "operates within a broad network of sociocultural influences" (p. 1). These influences include personal/internal factors, behavior, and environmental/external factors (Bandura, 1997). Central to human agency, located in the personal/internal factors category of influence, are efficacy beliefs, the confidence that one can perform an action successfully:

> Unless people believe that they can produce desired results and forestall detrimental ones by their actions, they have little incentive to act or to persevere in the face of difficulties. Whatever other factors may operate as guides and motivators, they are rooted in the core belief that one has the power to produce effects by one's actions. (Bandura, 2001, p. 6)

Bandura differentiates two concepts associated with efficacy beliefs, *self-efficacy* and *outcome expectations*:

> Perceived self-efficacy is a judgment of one's capability to accomplish a certain level of performance, whereas an outcome expectation is the judgment of the likely consequence such a behavior will produce. For example, the belief that one can jump six feet is an efficacy judgment; the anticipated social recognition, applause, trophies, and self-satisfactions for such a performance constitute the outcome expectations. (Bandura, 1986, p. 391)

According to Bandura, when both of these beliefs associated with a particular action or behavior are present, an individual will perform the related action: "In short, people take action when they hold efficacy beliefs and outcome expectations that make the effort seem worthwhile. They expect given actions to produce desired outcomes and believe that they can perform those actions." (Bandura, 1997, p. 24)

2.3.2 Teacher Efficacy Beliefs

The more specific construct of *teacher efficacy beliefs*, the extent to which teachers believe they can influence student learning through their teaching behaviors, was first conceptualized by the RAND Corporation while conducting evaluation studies in the 1970's (Armor et al., 1976; Berman, McLaughlin, Bass, Pauly, & Zellman, 1977; Dembo & Gibson, 1985). This initial conceptualization was based upon the work of Rotter (1966) and was measured with two Likert Scale items: (1) "When it comes right down to it, a teacher really can't do much because most of a student's motivation and performance depends on his or her home environment," and (2) "If I really try hard, I can get through to even the most difficult or unmotivated students" (Tschannen-Moran, Hoy, & Hoy, 1998).

Concerned about the validity of a two-item scale, but interested in the construct of teacher efficacy beliefs, Gibson and Dembo (1984) expanded upon the RAND studies' construct using Bandura's (1977) social cognitive theory in order to create a more extensive and reliable measurement of teacher efficacy beliefs (Tschannen-Moran et al., 1998). Their 30-item "Teacher Efficacy Scale" was based upon "two factors that corresponded to Bandura's two-component model of efficacy," which they labeled *teaching efficacy* (corresponding with Bandura's construct of outcome expectancy) and *personal teaching efficacy* (corresponding with Bandura's construct of self-efficacy) (Dembo & Gibson, 1985, p. 174). According to Dembo and Gibson (1985), *teaching efficacy* beliefs are those related to the general ability of teachers as a group to influence student learning, or the extent to which factors outside of a teacher's control limit any teacher's ability to bring about change. *Personal teaching efficacy* beliefs of an individual, in contrast, are "the belief[s] that [the particular teacher in question] has the skills and abilities to bring about student learning" (Dembo & Gibson, 1985, p. 175).

2.3.3 Science Teaching Efficacy Beliefs

Although teaching efficacy beliefs and personal teaching efficacy beliefs have been praised as a useful tool to examine teacher behavior (Ashton & Webb, 1986; Ashton, Webb, & Doda, 1983; Gibson & Dembo, 1984, Tschannen-Moran et al., 1998), others have argued that these beliefs are too general, and therefore not sufficient to examine teacher behaviors related to specific disciplines, such as science. Arguing that efficacy beliefs are situation-specific (Bandura, 1982), and concerned that research on teaching efficacy did not make a clear distinction between the constructs of self-efficacy and outcome expectancy, Riggs and Enochs (1990) set out to create an instrument to more specifically measure elementary teachers' efficacy beliefs related to science teaching. Using Gibson's and Dembo's (1984) Teacher Efficacy Scale as a model, Riggs and Enochs (1990) created the Science Teaching Efficacy Beliefs Instrument (STEBI; Appendix D). The authors altered and added to the items on the original scale to reflect science teaching in the elementary classroom rather than teaching in general, and “to reflect only self-efficacy or outcome expectancy rather than a combination of both self-efficacy and outcome expectancy” (Riggs & Enochs, 1990, p. 627). They named the two science-specific teaching efficacy constructs measured by the new instrument *Personal Science Teaching Efficacy* (PSTE) and *Science Teaching Outcome Expectancy* (STOE), corresponding with Bandura’s constructs of self-efficacy and outcome expectancy. Specifically, PSTE refers to a teacher’s belief in his or her own ability to effectively teach science, while STOE reflects the extent of a teacher’s belief that “students can learn science given external factors such as their family background, socioeconomic status (SES), or school conditions” (Riggs, 1988, p. 20).

Since Riggs’ and Enochs’ (1990) research developing and describing the STEBI, science teaching efficacy has become a popular topic of research. Research studies regarding science teaching efficacy beliefs have expanded upon Riggs’ and Enoch’s original focus on inservice elementary teachers to preservice elementary teachers (Enochs & Riggs, 1990), and both preservice and inservice secondary science teachers. With a few exceptions (Carleton, Fitch, & Krockover, 2008; Cone, 2009; Czerniak & Shriver,1994; Kind, 2009; Mulholland & Wallace, 2001), the majority of this research has examined teachers’ science teaching efficacy beliefs with the use of the STEBI. In addition, the original STEBI, and the constructs of PSTE and STOE upon which it was based, have been adapted to examine teaching efficacy beliefs specifically related to chemistry (Rubeck, 1990), mathematics (Enochs, Smith, & Huinker, 2000), environmental education (Sia, 1992), scientific inquiry (Smolleck, Zembal-Saul, & Yoder, 2006), and equitable science teaching and learning (Ritter, Boone, & Rubba, 2001).

In recent years, a slight controversy has developed as to the relative importance of and distinction between the constructs of PSTE and STOE in the study of science teaching efficacy beliefs. While STOE has been acknowledged as a potentially powerful influence on science teaching practices, a few recent studies have chosen to focus only on the construct of PSTE (Bursal, 2010; McDonnough & Matkins, 2010; Perkins, 2007; Roberts, Henson, Tharp, & Moreno, 2001). These authors have cited the lower reliability coefficient of outcome expectancy beliefs (Enochs & Riggs, 1990; Huinker & Madison, 1997; Plourde, 2002) and the difficulty of separating outcome expectancy from the construct of locus of control[6] noted in several studies (Guskey & Passaro, 1994; Judge, Erez, Bono, & Thoresen, 2002; Tschannen-Moran et al., 1998). In addition, Bandura (1997) suggested that perceived self-efficacy is a better predictor of behavior than outcome expectancy beliefs or locus of control. These concerns have led some to suggest that outcome expectancy is a less definitive construct than self-efficacy, and thus more difficult to measure accurately (Riggs & Enochs, 1990; Tschannen-Moran et al., 1998). For these reasons, some have argued that it may be more valuable for researchers of science teaching efficacy beliefs to focus their attention on PSTE rather than STOE (Bursal, 2010; McDonnough & Matkins, 2010; Perkins, 2007; Roberts et al., 2001).

The research that has been conducted regarding science teaching efficacy beliefs can be divided into two primary themes: (1) investigations into the factors influencing the development of science teaching efficacy beliefs, and (2) investigations into the relationship between science teaching efficacy beliefs and science teaching practices.

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[6] See section 2.7.4 for further details regarding locus of control.

The following two sections present a review of the literature pertaining to each of these two themes.

2.4 Research Regarding Factors Influencing the Development of Efficacy Beliefs

Much of the research regarding the development of teaching self-efficacy has been rooted in the four sources of self-efficacy postulated by Bandura (1997). These sources are:

- *mastery experiences* – experiences of successfully performing the behavior
- *vicarious experiences* – experiences of watching someone comparable to oneself successfully performing the behavior
- *verbal persuasion* – others convincing one that he or she can successfully perform a behavior
- *physiological or emotional cues* – feelings or emotions that one associates with performing the behavior

Several studies have directly focused on these four sources of efficacy as they relate to the development of teacher efficacy, while others have found additional factors influencing efficacy beliefs that are more indirectly related to these sources.

2.4.1 Factors Influencing Efficacy Beliefs of Preservice Teachers

Studies examining the development of science teaching efficacy beliefs in preservice teachers using Bandura's (1997) four sources of efficacy, have found that all four sources seem to play a role in the extent to which teacher preparation courses positively impact science teaching efficacy beliefs (Brand & Wilkins, 2007; Gunning &

Mensah, 2011; Morrell & Carroll, 2003). However, evidence suggests that mastery experiences may have the greatest impact on the development of science teaching efficacy beliefs during a teacher preparation program (Brand & Wilkins, 2007; Cantrell, Young, & Moore, 2003; Carrier, 2009; Cone, 2009; Ginns & Tulip, 1995; Swars & Dooley, 2010), especially when those experiences are accompanied by extensive mentoring (Bhattacharyya, Volk, & Lumpe, 2009; Gunning & Mensah, 2010; McDonnough & Matkins, 2010). Perkins (2007) confirmed through interviews with preservice teachers nearing the end of their teacher preparation program, that these teachers attributed the increase in their PSTE, to a large extent, to the experience they gained in teaching science during student teaching.

However, while mastery experiences may be one of the most important influences on the development of preservice teachers' science teaching efficacy beliefs, research also suggests that there exists an interrelationship between this and Bandura's other three sources, such that only in courses where students have opportunities to experience all four sources will there be significant gains in science teaching efficacy (Brand & Wilkins, 2007; Morrell & Carroll, 2003). In addition, other factors such as socioeconomic status and ethnicity of students in student teaching classrooms (Wagler, 2009); support of family, mentor teachers, administration, colleagues, and students (Perkins, 2007); attitudes toward science (Gunning & Mensah, 2011; Hechter, 2011); and amount of science background and/or content knowledge (Bhattacharyya et al., 2009; Bursal, 2010; Cantrell et al., 2003; Deniz, Orgill, & Carroll, 2011; Enochs, Scharmann, & Riggs, 1995; Hechter, 2011; Kind, 2009; Perkins, 2007) have all been demonstrated to influence the development of preservice teachers' science teaching efficacy beliefs.

2.4.2 Factors Influencing Efficacy Beliefs of Inservice Teachers

Similar to the findings for preservice teachers, evidence suggests that all four of Bandura's (1997) sources of self-efficacy influence inservice teachers' science teaching efficacy beliefs (Carleton et al., 2008; Lakshmanan, Heath, Perlmutter, & Elder, 2011; Posnanski, 2002). However, there are some inconsistencies as to the extent of impact for each of these sources. Khourey-Bowers and Simonis (2004), for example, found that mastery experiences in a chemistry professional development program for inservice fourth through ninth grade teachers were most important to the enhancement of these teachers' PSTE scores, but that the other three sources contributed more to their STOE scores. In addition, while Liu, Kack, and Chiu (2007) found that the number of years of general teaching experience had a significantly greater impact on both PSTE and STOE scores than number of years of science teaching experience, other results have suggested the opposite to be true (Marshall, Horton, Igo, & Switzer, 2009; Nolan et al., 2009; Rubeck, 1990).

Emotional cues related to science teaching and learning seem to be another important factor influencing the efficacy beliefs of inservice teachers. Evidence has shown that science teaching efficacy can be influenced by both positive and negative experiences as a learner of science (Mulholland & Wallace, 2001). For example, Ramey-Gassert, Shroyer, and Staver (1996) found that PSTE scores of inservice elementary teachers, as measured by the Science Teaching Efficacy Beliefs Instrument

(STEBI), were positively and significantly correlated with attitudes toward science. In addition, through interviews with these teachers, the authors found that a major contributor to negative attitudes toward science was the way in which science had been presented to the teachers as K-12 students: textbook-based, vocabulary-based, and with no relevancy to their lives. In contrast, for those teachers who had a positive attitude toward science and teaching science, interest was kindled by positive science-related experiences outside of the classroom.

Social factors related to vicarious experiences and verbal persuasion have also been shown to significantly impact the efficacy beliefs of inservice teachers for science and general teaching. Factors such as positive reactions of students to science instruction (Angle & Moseley, 2009; Ginns & Waters, 1999; Mulholland & Wallace, 2001); support from administration (Haney et al., 2002; Hoy & Woolfolk, 1993; Ramey-Gassert et al., 1996); parental involvement (Skaalvik & Skaalvik, 2010); and feeling a sense of community in the school (Hipp & Bredeson, 1995; Lee, Dedick, & Smith, 1991), have all been shown to positively contribute to teaching efficacy beliefs. In particular, support from and regular communication with colleagues have been demonstrated to be important contributors to inservice teacher efficacy beliefs (Haney et al., 2002; Rosenholtz, 1989; Webb & Ashton, 1987). In addition, Ramey-Gassert et al. (1996) found that, according to the inservice elementary teachers they surveyed, interest in science and science teaching was often kindled by vicarious experiences from knowledgeable and enthusiastic colleagues. These colleagues contributed to an increase in the teachers' science teaching efficacy beliefs through modeling science teaching strategies, providing emotional support, and encouraging them by telling them they could teach science well.

Another factor that has been found to influence science teaching efficacy beliefs of inservice teachers is level of science content and pedagogical content knowledge.[7] Evidence has shown that teachers who have academic degrees in science (Angle & Moseley, 2009; Desouza, Boone, & Yilmaz, 2004; Ramey-Gassert et al., 1996); fewer misconceptions in science (Schoon & Boone, 1998); more science content courses (Andersen, Dragsted, Evans, & Sorensen, 2007; Ramey-Gassert et al., 1996; Rubeck, 1990); additional science teaching methods courses (Andersen et al., 2007); science content courses emphasizing pedagogy (Swackhamer, Koellner, Basile, & Kimbrough, 2009); and more science-related professional development activities (Khourey-Bowers & Simonis, 2004), have higher levels of science teaching efficacy beliefs than those teachers without such backgrounds in science or science teaching. However, through interviews with inservice elementary teachers, Ramey-Gassert et al. (1996) revealed that even after completing professional development aimed to increase teachers' scientific knowledge and pedagogical content knowledge, experienced elementary teachers may still feel inadequate to teach science because of a *self-perceived* lack of background in science content or science teaching methodology.

There are some exceptions to the positive relationship between scientific background and science teaching efficacy beliefs. For example, Schriver and Czerniak (1999) found that none of their predictor variables (certification, scientific knowledge,

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[7] See section 2.7.2 for a discussion of the distinction between science content knowledge and pedagogical content knowledge.

perceived support, or school type) contributed significantly to their regression equation for self-efficacy. In another study, Nolan et al. (2009) found that PSTE scores of inservice K-8 teachers participating in a professional development program were high, despite the low level of content knowledge. Sackes, Hilson, Trundle, and Krissek (2010) also reported that the change in content knowledge of a group of teachers participating in a professional development program was not significantly related to an increase in their science teaching efficacy beliefs. This leads us to the question of the relationship between science teaching efficacy beliefs and effective science teaching practices.

2.5 Research Regarding Relationships Between Efficacy Beliefs and Teaching Practices

A large portion of the current research regarding science teaching efficacy beliefs has focused upon the factors influencing the development of these beliefs, as discussed in section 2.4 above. In particular, a popular area of research has been the evaluation of the extent to which specific interventions (e.g. science teaching methods courses or professional development programs), or particular components of these interventions, can increase individuals' teaching efficacy beliefs (e.g. Batiza et al., 2011; Bayraktar, 2011; Bluestone, 2009; Brand & Wilkins, 2007; Cantrell, Cantrell, & Patch, 2011; Carleton et al., 2008; Cartwright & Smith, 2011; Cone, 2009; Cone, 2010; Deniz et al., 2011; Duran, Ballone-Duran, Haney, & Beltyukova, 2009; Gunning & Mensah, 2011; Hechter, 2011; Kazempour, 2011; Khourey-Bowers & Simonis, 2004; Liang & Richardson, 2009; McDonnough & Matkins, 2010; Morrell & Carroll, 2003;

Moseley, Reinke, & Bookout, 2002; Nolan et al., 2009; Nolan et al., 2011; Nunn & Jantz, 2009; Sackes et al., 2010; Sterling, Frazier, & Logerwell, 2009; Swars & Dooley, 2010). These types of studies rest on the assumption that the increase of teachers' self-efficacy beliefs will positively impact these teachers' classroom practices. The data upon which this assumption is based for teaching in general, preservice teachers of science, and inservice teachers of science are discussed in the following three sections.

2.5.1 General Teacher Efficacy Beliefs and Practice

To a large extent, related research has suggested that teaching efficacy is closely linked to teacher behavior (Tschannen-Moran et al., 1998). This is true for general teaching efficacy beliefs, and those specific to particular disciplines such as science.

Initial studies of general teaching efficacy beliefs (Ashton, 1984; Ashton & Webb, 1986; Ashton et al., 1983; Gibson & Dembo, 1984) found evidence of connections between these beliefs, and teachers' expectations of and interactions with students. For example, research has shown that high-efficacy teachers are confident in their ability to affect student learning and have positive expectations for student behavior and achievement, even for those students who are historically low-achieving. Teachers with low general teaching self-efficacy, in contrast, have been shown to expect students to fail and place the responsibility for learning entirely on the student rather than the teacher (Ashton, 1984; Ashton & Webb, 1986). Consequently, teachers with low teaching efficacy tend to use significantly more criticism when responding to incorrect student responses, and less persistence when working with low-achieving students than do high-efficacy teachers (Ashton & Webb, 1986; Ashton et al., 1983; Gibson & Dembo, 1984).

General teaching efficacy beliefs have also been suggested to be related to the instructional strategies that teachers employ in the classroom and their attitudes toward the discipline of teaching. For example, Gibson and Dembo (1984) found that teachers with low teaching efficacy spent about 28% of their time in small group versus whole group instruction, while high-efficacy teachers spent 48% of their time in small group instruction. Gibson and Dembo (1984) noted that low-efficacy teachers spent more time than their high-efficacy colleagues engaged in discussion and activities that were not related to the instructional objectives of the lesson. In addition, teachers with higher teaching efficacy beliefs have been shown to be open to new ideas and more willing to try new instructional techniques (Allinder, 1994; Guskey, 1988; Scribner, 1999; Stein & Wang, 1988; Tschannen-Moran & McMaster, 2009); employ a larger amount of planning and organization for their lessons (Allinder, 1994); have a greater enthusiasm for teaching (Allinder, 1994; Guskey, 1984; Hall, Burley, Villeme, & Brockmeier, 1992); feel greater job satisfaction (Klassen & Chiu, 2010; Skaalvik & Skaalvik, 2010); and demonstrate a greater commitment to teaching as a profession (Burley, Hall, Villeme, & Brockmeier, 1991; Coldarci, 1992; Evans & Tribble, 1986).

Moreover, Tschannen-Moran et al. (1998) emphasized that research regarding the relationship between general teaching self-efficacy and teaching practices has demonstrated a cyclical aspect to this relationship:

> [T]he proficiency of a performance creates a new[...]experience, which provides new information that will be processed to shape future efficacy beliefs. Greater efficacy leads to better performance, which in turn leads

> to greater efficacy. The reverse is also true. Lower efficacy leads to less effort and giving up easily, which leads to poor teaching outcomes, which then produce decreased efficacy. (p. 233)

In other words, a lesson that a teacher successfully gives to her students with a level of persistence and effort *influenced* by the teacher's self-efficacy becomes a *source* of new efficacy beliefs.

2.5.2 Science Teaching Efficacy Beliefs and Practice of Preservice Teachers

More recent research has suggested a similar connection between science teaching efficacy beliefs and science teaching practices, as well as beliefs about science teaching practices. This is particularly true for preservice elementary teachers, where much of the science teaching efficacy beliefs and teaching practices research has been based. Bhattacharyya et al. (2009), for example, found a positive correlation between the level of science teaching self-efficacy beliefs as measured by the Science Teaching Efficacy Beliefs Instrument (STEBI) of five preservice elementary teachers and their observed ability to effectively implement inquiry in the classroom based upon the Horizon Research Observation Protocol (HROP) (Horizon Research, 1998).

In another example, Czerniak and Shriver (1994), used data from open-ended questionnaires and videos of student teaching to compare the beliefs and behaviors of preservice elementary teachers with high and low science teaching self-efficacy, as defined by subjects who scored above or below the mean group score on the Science Teacher Self-Efficacy Instrument (Czerniak, 1989). The authors discovered significant differences between the high- and low-efficacy preservice teachers in their choices of instructional strategies for science lessons as well as their reasons for their choices.

High-efficacy teachers tended to choose activities in which they expected students to use higher-level thinking and problem-solving skills, and were more likely than low-efficacy teachers to use teaching strategies that were based on research or theory. The teachers with high science teaching self-efficacy also indicated that they believed inquiry lessons to be a good choice for teaching science at the elementary level because they encouraged "student autonomy in the lessons" (Czerniak & Schriver, 1994, p. 81). In contrast, the authors found that the preservice teachers with low science teaching self-efficacy were more focused on choosing science teaching strategies and activities based on whether or not they thought that the activities would be fun for the students, rather than whether they thought they would promote student learning. Following this, although the teachers with low self-efficacy agreed with those of high-efficacy that inquiry-based activities are best for teaching science to elementary students, they reasoned that this was the case because these types of activities are more enjoyable and interesting for students, rather than due to their ability to promote the development of students' knowledge of science content and processes.

Czerniak and Schriver (1994) also found differences in the ways that the preservice elementary teachers measured success of a science lesson and to whom they credited that success. The teachers with high science teaching self-efficacy were oriented toward the goals of developing students' critical thinking and decision-making skills, and tended to measure success of their science lessons by whether or not they believed these goals were achieved. These teachers were more concerned about whether students were learning than with class control or noise levels. The teachers with low science teaching self-efficacy, in contrast, tended to measure success of a science lesson by their ability to control students and to keep the class orderly and quiet. These teachers were most concerned with following a controlled step-by-step procedure with their students so that students arrived at the correct answers. In addition, the preservice teachers with high science teaching self-efficacy were more likely to take credit for the successes and failures of a science lesson, while the low-efficacy teachers tended to credit students and external influences, such as availability of materials and classroom environment, rather than themselves.

In another study comparing the science teaching practices and beliefs about teaching practices of preservice elementary teachers with high and low science teaching efficacy beliefs, Enochs et al. (1995) found differences in respondents' choices of instructional delivery and pupil control ideology in science. Using results from the STEBI and other quantitative instruments, the researchers found that the preservice teachers with higher science teaching self-efficacy were more likely than low-efficacy teachers to perceive activity-based instruction as the most appropriate instructional approach for teaching science at the elementary school. In addition, high-efficacy subjects tended to believe that students are capable of learning through cooperation and experience, and were more comfortable than low-efficacy subjects with student-to-student interactions in the classroom.

2.5.3 Science Teaching Efficacy Beliefs and Practice of Inservice Teachers

Studies of inservice teachers have also found evidence of a relationship between science teaching efficacy beliefs and practice. For example, in one of the few studies to examine self-efficacy beliefs as they relate to the observed practices of inservice teachers, Haney, et al. (2002) examined the relationship among Personal Science Teaching Efficacy (PSTE) beliefs, context beliefs, and science teaching practices for a group of six inservice elementary teachers. For each of the six teachers, the authors evaluated PSTE beliefs as measured by the Science Teaching Efficacy Beliefs Instrument (STEBI), context beliefs as measured by the Context Beliefs About Teaching Science (CBATS) instrument (Lumpe, Haney, & Czerniak, 2000), and level of reform of subjects' science teaching practices for one science lesson determined by the Horizon Research Observation Protocol (HROP) (Horizon Research, 1998). In addition, the authors conducted pre- and post-observation interviews "to elicit teacher perceptions about the lesson goals, planned activities, intended assessments, future goals, issues regarding the classroom culture, and reflections of the experience" (Haney et al., 2002, p. 177). Results of the study indicate that the elementary teachers with higher PSTE scores

> were more likely to design lessons that: incorporated inquiry, depicted careful planning, attended to student prior knowledge and experiences, attended to issues of equity, utilized appropriate and available resources, encouraged a collaborative approach, and assessed students in a way that was consistent with the intended purpose. (p. 179)

The authors also found that these high-efficacy teachers, as compared to their colleagues with lower PSTE scores, were "more likely to convey science content appropriately by presenting content that was: significant and worthwhile, developmentally appropriate, accurate, dynamic and interdisciplinary in nature, and tied to the real world" (p. 179).

Using the HROP (Horizon Research, 1998), Riggs, Enochs, and Posnanski (1998) also found evidence that inservice elementary teachers with high STEBI scores asked more open-ended questions than their low-efficacy peers, and did a more thorough job of teaching science content and skills. These teachers also provided opportunities to revisit content and processes, checked for student understanding, and helped connect material to students' lives. In addition, Ramey-Gassert et al. (1996) found that teachers with high Science Teaching Outcome Expectancy (STOE) scores, as based on the STEBI, reported that they used "a hands-on, active approach to learning, and [that] their science teaching was not driven by a textbook; rather it was based on their beliefs that students learn best by active involvement" (p. 302).

In another very recent study, Lakshmanan et al. (2011) examined the impact of a professional development program on the science teaching self-efficacy and level of observed inquiry-based practices for 39-58 inservice elementary and middle school teachers over the course of two years, utilizing the STEBI and Reformed Teaching Observation Protocol (RTOP). Their data revealed a positive correlation between participants' changes in self-efficacy and their changes in the use of inquiry-based science instruction. In other words, as participating teachers' levels of self-efficacy increased, so did the amount of inquiry that they incorporated into their science lessons. Similarly, Nolan et al. (2011) found that, for the twelve inservice elementary and middle school teachers participating in their professional development course, teachers who had higher gains in PSTE scores were more likely to write lesson plans that incorporated aspects of scientific inquiry.

Other research related to the relationship between inservice teachers' science teaching efficacy beliefs and behavior has provided evidence that high-efficacy elementary and middle school teachers report that their students spend a greater percentage of time engaged in inquiry during a typical science lesson (Marshall et al., 2009), express a greater preference for teaching science, and claim to teach more science per week (Desouza et al., 2004; Riggs, 1988; Rubeck, 1990). Inservice elementary and middle school teachers with higher science teaching efficacy beliefs have also been shown to (a) be more likely to seek out professional development opportunities (Ramey-Gassert et al., 1996); (b) feel less constrained in their ability to teach science by external factors such as students' home lives and availability of materials (Carleton et al., 2008; Ramey-Gassert et al., 1996; Rubeck, 1990); (c) have more positive attitudes toward science education reform (Czerniak & Lumpe, 1996); (d) feel less anxious about teaching science (Czerniak, 1989); and (e) tend to continue teaching science in their career for a longer period of time (Andersen et al., 2007).

2.6 Inconsistencies in the Findings of Science Teaching Efficacy Research

While common trends do exist in the current results of science teaching efficacy research, there are some inconsistencies in both the factors that impact individuals' science teaching efficacy and the relationship between science teaching efficacy and practice. These inconsistencies, which are described in the next two sections, indicate that there is still much to be learned in this area of research.

2.6.1 Inconsistencies in Results Related to Factors Influencing the Development of Science Teaching Efficacy Beliefs

As discussed in section 2.4.2, many inconsistencies exist in the extent to which various factors, such as past experiences, emotional cues, and level of scientific background, impact the science teaching efficacy of inservice teachers. A partial explanation for this may come from Bandura (1986, 1997), who emphasized that the four sources of efficacy that he proposed do not act on all individuals with equal strength, and that they only act as sources of self-efficacy if they are recognized and reflected upon by the individual.

> Therefore, a distinction must be drawn between information conveyed by experienced events and the information as selected, weighted, and integrated into self-efficacy judgments. A host of personal, social, and situational factors affect how direct and socially mediated experiences are cognitively interpreted. (Bandura, 1997, p. 79)

Ramey-Gassert et al. (1996) found evidence for this to be the case in the development of science teaching efficacy beliefs of inservice elementary teachers. Through interviews with the teachers, the authors found differences in the ways that similar experiences affected the teachers' science teaching efficacy beliefs, and that these differences came from the ways in which individual teachers perceived and reflected upon the experiences. Labone (2004) argued that in order to more clearly understand the development of teacher efficacy beliefs, more studies such as that by Ramey-Gassert et al. (1996) are needed; teacher efficacy research must incorporate additional qualitative exploration to more closely examine the factors impacting the selection of and attention to various sources of efficacy information.

Results of other research suggest that demographic factors, such as gender and age (Angle & Moseley, 2009; Bursal, 2010; Kind, 2009; Perkins, 2007), may also cause different teachers' self-efficacy to be impacted in varying ways. Some data have suggested that there are differences in the development of science-related self-efficacy beliefs for males and females. In the area of science *learning* self-efficacy, for example, Britner (2008) found that for high school boys, mastery experiences were the only significant source of self-efficacy beliefs. However, for girls, mastery experiences significantly predicted science learning self-efficacy in Earth science, while social persuasion, vicarious experiences, and psychological states predicted self-efficacy in life and physical science classes. Zeldin, Britner, and Pajares (2008) identified similar gender differences in the sources of science self-efficacy beliefs of professionals with careers in STEM-related (science, technology, engineering, and mathematics) disciplines. In the area of science *teaching* self-efficacy, gender differences have also been noted, although one gender has not been found to have consistently higher levels of self-efficacy than the other (Bursal, 2010; Evans & Tribble, 1986; Gencer & Cakiroglu, 2007; Kiviet & Mji, 2003; Mulholland, Dorman, & Odgers, 2004).

The particular classroom context of an individual's science teaching may also impact a teacher's science teaching efficacy beliefs. That is, depending upon the situation, one teacher may have very different levels of efficacy beliefs with different sources for these beliefs. For example, several studies have demonstrated that the same teacher may have different levels of science teaching self-efficacy for different groups of students, depending upon the perceived academic abilities of those students (Angle & Moseley, 2009; Ramey-Gassert et al., 1996; Raudenbush, Rowan, & Cheong, 1992). Teachers tend to also have different levels of efficacy beliefs based upon the area of science (e.g. chemistry vs. general science) (Kind, 2009; Perkins, 2007; Ross, Cousins, Gadalla, & Hannay, 1999; Rubeck, 1990), and the academic level (e.g. elementary school vs. high school) (Perkins, 2007) being taught. This may be of particular importance for impacting the development of science teaching efficacy beliefs of elementary teachers, many of whom are expected to teach multiple areas of science, and who may change grade levels multiple times during their careers.

2.6.2 Inconsistencies in Results Related to Relationships Between Science Teaching Efficacy Beliefs and Science Teaching Practices

A positive correlation is generally accepted between the level of science teaching efficacy beliefs and effective or more reformed science teaching practices; so much so, in fact, that the increase of preservice teachers' science teaching self-efficacy has been promoted as a primary goal of science teacher education (Brand & Wilkins, 2007). However, some evidence suggests that this is not always the case. These inconsistencies in results regarding science teaching efficacy beliefs and practice are not entirely surprising, since even the results associating general teaching efficacy beliefs and practice are more mixed than many may acknowledge (Wheatley, 2005). A few studies, in fact, have even found a negative correlation between teacher efficacy beliefs and reformed teaching practices (Smylie, 1988; Stein & Wang, 1988). In addition, other studies, such as from the area of mathematics education for example, have noted that teachers with the same levels of self-efficacy beliefs may teach in significantly different ways (Wheatley, 2005).

Haney et al. (2002) found inconsistencies in an overall positive relationship between science teaching self-efficacy and practice for six inservice elementary teachers. Although the authors found that generally higher Personal Science Teaching Efficacy (PSTE) scores correlated with more reformed science teaching practices for these teachers, one participant did not follow this pattern. While this teacher scored high on the PSTE portion of the Science Teaching Efficacy Beliefs Instrument (STEBI), observations and interviews revealed that the teaching strategies were more like the teachers with low efficacy beliefs. The authors claimed that possible reasons for this anomaly were an inaccuracy of self-reported data or that the science lesson observed was not representative of the individual's teaching abilities. However, the authors also considered other explanations, such as the possibility that "this teacher's strong [self-efficacy] and context beliefs were rooted without proper reflection or feedback" (Haney et al., 2002, p. 181). The authors suggested that the teacher's perceptions of what it means to be a successful science teacher contrasted with how it was measured by the researchers.

> In her eyes, success was evident by how many great activities she included, by how many vocabulary words she introduced that were not part of the 'inadequate kit curriculum,' or by how many resources she purchased and brought in on her own. And these perceived successful actions would then deepen her belief in her ability to teach. (Haney et al., 2002, pp. 181-182)

Since this teacher's self-efficacy beliefs were based upon a different image of effective science teaching than that of the researchers, the fact that the teacher had high confidence in her own ability to teach science well was not transformed into teaching in a reformed inquiry-oriented manner.

In a study similar to that of Haney et al. (2002), Bhattacharyya et al. (2009) found a positive relationship between STEBI scores and the ability to effectively implement inquiry in the classroom as measured by the Horizon Research Observation Protocol (Horizon Research, 1998) for five of the seven preservice elementary teachers that they studied. However, two out of the seven participants had high STEBI scores and low observation scores. Bhattacharyya et al. (2009) suggested that the teachers who did not follow the normal trend had a view of inquiry inconsistent with that of the authors. Therefore, like the anomalous teacher observed by Haney et al. (2002), these two teachers based their confidence levels on an image of effective science teaching that was very different from the way that the researchers measured such teaching.

Although these examples presented by Haney et al. (2002) and Bhattacharyya et al. (2009) are only anomalies of one and two teachers in a group of six and seven, they highlight the fact that the generally accepted positive relationship between science teaching self-efficacy and practice may not necessarily hold true, and may be more complicated than others have recognized.

Another possible reason for inconsistencies in the results regarding science teaching efficacy beliefs and practice may come from the level of ability one has to judge one's own efficacy and the skills that one believes impact one's efficacy. Wheatley (2005) pointed out that "teacher efficacy beliefs" should not be confused with "actual teaching effectiveness," and that "teachers' efficacy beliefs may underestimate, overestimate, or accurately reflect actual teaching practices" (p. 748-749). This is especially true for teachers who may not understand what reformed teaching looks like, causing them to *believe* that they are implementing inquiry-based teaching practices, when observations indicate the use of only superficial aspects of these practices (Bhattacharyya et al., 2009; Wheatley, 2005); although an individual may believe that they are an extremely effective science teacher, this may not be the case in reality. In addition, Bandura (1997) claimed that, "Evaluation of one's self-diagnostic skills requires not only self-knowledge of capabilities but also understanding of the types of skills needed for different activities" (p. 115). For example, teachers who do not believe that extensive knowledge of the scientific process is critical to their ability to teach third grade science will not feel that their ability to teach science is impacted by their lack of scientific knowledge. This, in turn, may lead to an overestimation of their efficacy as teachers of science.

Some evidence has suggested that high efficacy beliefs may inhibit the ability of teachers to critically reflect upon their own science teaching practices. Czerniak and Schriver (1994) found that preservice elementary teachers with high science teaching self-efficacy "stated nearly four times as much as low-efficacy teachers that there were no weaknesses, no changes that needed to be made, or that the [science] lesson was perfect" (p. 83). Similarly, Settlage, Southerland, Smith, and Ceglie (2009) found that, although the preservice teachers whom they examined scored relatively high on the STEBI, these teachers only superficially reflected on their own science teaching practices. Kind (2009) also observed that preservice secondary science teachers did a better job of choosing appropriate instructional strategies for scientific topics that they felt less confident teaching. That is, the individuals in Kind's (2009) study spent less time planning for and reflecting upon lessons for scientific topics for which they felt they had already mastered the content knowledge. Wheatley (2002) claimed that this is one of the dangers of focusing too narrowly on the elevation of teacher efficacy beliefs; if teachers have no doubts regarding their teaching efficacy, then they will not experience a perturbation, leading them to feel no need to reform their teaching practices even if reformation would improve student learning.

Unfortunately, due to the limited number of studies examining the relationship between preservice and inservice elementary teachers' science self-efficacy beliefs and their actual *observed*, as opposed to *self-reported*, science teaching practices (Bhattacharyya et al., 2009; Haney et al., 2002; Lakshmanan et al., 2011; Marshall et al., 2009; Nolan et al., 2011; Ramey-Gassert et al., 1996; Riggs et al., 1998), many aspects of the relationship between science teaching self-efficacy and science teaching behaviors of practicing teachers remain unclear. Moreover, as mentioned in the beginning of section 2.5, a majority of the current research has turned away from studying this relationship, and instead has primarily focused on researching the *development* of science teaching self-efficacy beliefs. Further investigation is needed in this area, including observations of teaching behavior along with self-reporting measures (Wheatley, 2005), in order to gain a greater understanding of the relationship between science teaching self-efficacy and practice. Only with this understanding can researchers, teacher educators, and policymakers make accurate and informed decisions regarding the successful implementation and sustainment of reformed inquiry-oriented science teaching practices at the elementary school level (DeMesquita & Drake, 1994).

2.7 Related Concepts

This section serves to provide an overview of the relationships and distinctions between self-efficacy beliefs, as described in the previous sections, and other closely related constructs discussed in relevant research literature. In addition, the following discussion highlights some of the relationships between these additional constructs and science teaching practices.

2.7.1 Teacher Attitudes

Attitudes, like beliefs, influence teacher behavior. In science teaching, for example, evidence has suggested that elementary teachers who have a negative attitude toward science are less likely to spend time teaching science (Cobern & Loving, 2002; Goodrum, Hackling, & Rennie, 2001; Harlen & Holroyd, 1997) and will be more likely to employ teacher-centered strategies (Appleton & Kindt, 1999; Bencze & Hodson, 1999). As discussed in section 2.2, however, beliefs are generally more strongly held and "are more cognitive than [...] attitudes" (Philipp, 2007, p. 259). Although these constructs of beliefs and attitudes are distinct from one another, important relationships exist between the two. For example, an elementary teacher may generally dislike teaching science (an attitude) and judge herself as an ineffective science teacher (a belief). While the attitude and belief in this example are technically different, they clearly can influence one another.

In the area of science teaching efficacy beliefs, research has demonstrated a particularly important connection between efficacy beliefs and attitudes, especially those related to science and the value of science in education. For example, Ramey-Gassert et al. (1996) found that Personal Science Teaching Efficacy (PSTE) scores were positively correlated with attitude toward science for inservice elementary teachers. In addition, Czerniak (1989) found that elementary teachers' science teaching efficacy and anxiety were negatively correlated. That is, those teachers who had less anxiety or a more positive attitude toward teaching science also had greater confidence in their ability to teach science. Results of other studies have also suggested that preservice and inservice elementary teachers with negative attitudes toward science, often developed during their experiences as learners (Tosun, 2000), lack confidence in their abilities to teach science (Akerson & Flanigan, 2000; Hechter, 2011; Yates & Goodrum, 1990). In addition, a low level of self-efficacy in science teaching may influence a teacher's negative attitude toward science teaching. That is, a teacher may have a general dislike of science partially *because* he or she does not feel confident in her ability to teach science.

2.7.2 Teacher Knowledge

As discussed earlier, knowledge is different from beliefs or attitudes in that it is more cognitive and less affective. However, knowledge is not entirely separated from beliefs. In fact, some have argued that while knowledge and belief are theoretically distinct concepts, there are many intersections between the two at the empirical level, often making the two almost indistinguishable in research regarding teacher education (Avraamidou & Zembal-Saul, 2010; Southerland et al., 2001). According to Philipp (2007), pieces of knowledge are "beliefs held with certainty or justified true belief[s]. What is knowledge for one person may be belief for another, depending upon whether one holds the conception as beyond question" (p. 259). Knowledge, like beliefs and attitudes can therefore have an important impact on teacher behavior (Philipp, 2007).

Shulman (1986) distinguished three different types of knowledge that teachers' possess: (1) subject-matter knowledge, (2) pedagogical or curricular knowledge, and (3) pedagogical content knowledge. *Subject-matter knowledge* is an individual's knowledge related to a particular subject, such as science. Within the subject of science, individuals also have subject-matter knowledge pertaining to specific concepts, such as the rock cycle or natural selection. *Pedagogical* or *curricular knowledge* is the knowledge of an individual pertaining to teaching in general. This knowledge includes, for example, how to manage a group discussion for a class of second-graders, or how to organize time in the classroom. The third type of knowledge that Shulman (1986) described, *pedagogical content knowledge*, is an individual's knowledge of teaching as it pertains to a specific area of subject matter, such as science.

Pedagogical content knowledge (PCK) is "in a word, the ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, p. 9). It can be thought of as the area of knowledge where subject-matter knowledge and pedagogical knowledge overlap (Gess-Newsome, 1999), the knowledge of "subject matter *for teaching*" (Shulman, 1986, p. 9, emphasis in original). PCK includes knowledge regarding student thinking and learning related to the particular subject, including "an understanding of what makes the learning of specific topics easy or difficult, the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons" (Shulman, 1986, p. 9). *Science-related* PCK of a teacher is therefore comprised of knowledge of how to most effectively present particular scientific concepts to particular groups of students, including the teacher's knowledge regarding his or her students' thinking and learning about the scientific concepts being taught.

All three types of knowledge have been shown to influence one another and the classroom practices of elementary teachers, including those related to science (Magnusson, Krajcik, & Borko, 1999). Mulholland and Wallace (2005), for example, found that over a 10-year period the development of one elementary teacher's PCK and the relationships between this knowledge and classroom practice were sometimes more dependent on the teacher's scientific knowledge, while at other times more dependent on the teacher's general pedagogical knowledge.

In addition, both science content and pedagogical content knowledge have been suggested to play a role in the development of science teaching efficacy beliefs. Evidence has shown that teachers who (a) have academic degrees in science (Desouza et al., 2004; Ramey-Gassert et al., 1996); (b) have fewer alternative conceptions in science (Schoon & Boone, 1998); and (c) have participated in more science-related professional development activities (Khourey-Bowers & Simonis, 2004), have higher levels of science teaching efficacy beliefs than those teachers without such backgrounds in science or science teaching. Similarly, teachers who have taken more science content courses (Andersen et al., 2007; Hechter, 2011; Ramey-Gassert et al., 1996; Rubeck, 1990), science content courses emphasizing pedagogy (Swackhamer er al., 2009), and more science teaching methods courses (Andersen et al., 2007) have been found to have greater confidence in their ability to effectively teach science.

2.7.3 Collective Efficacy Beliefs

Collective efficacy beliefs is a much more recently developed construct, representing a type of efficacy beliefs distinct from, although related to, teaching self-efficacy as discussed in the above sections. This type of efficacy refers to the beliefs that *groups* of educators hold about the efficacy of their school as a *community* of educators (Bandura, 1997; Goddard, Hoy, & Woolfolk Hoy, 2004; Posnanski, 2002; Tschannen-Moran et al., 1998). In other words, for schools, perceived collective efficacy refers to the extent to which the faculty as a whole believe that they have the capabilities to "organize and execute the courses of action required to have a positive effect on students" (Goddard et al., 2004, p. 4).

Although links have been suggested between collective teaching efficacy beliefs and student achievement (Bandura, 1993; Chong, Klassen, Huan, Wong, & Kates, 2010; Goddard, 2001; Goddard, Hoy, & Woolfolk Hoy, 2000), as well as to teachers' individual teaching efficacy beliefs and behavior (Ware & Kitsantas, 2007), very little research has been conducted involving groups of educators working in a common academic discipline such as science. However, some conclusions of the research based in general education may apply to science education. For example, Goddard et al. (2004) state that research suggests a "relationship between teachers' sense of efficacy and perceived collective efficacy [such] that organizational socialization involves the communication of influential normative expectations for achievement" (p. 10). In other words, general expectations for student achievement within a school that are associated with collective efficacy may become the expectations, and thus part of the self-efficacy, of individual teachers in that school. This may apply to science instruction, since the science teaching efficacy beliefs of individual teachers might be influenced by the overall beliefs regarding science instruction of the school. For example, in a low socioeconomic status urban school, a belief of the overall faculty community may be that this community does not have the capabilities or resources to effectively impact students' science learning. This generalized expectation could impact the way that an individual teacher in that school perceives her own capabilities to teach science. Indeed, research of collective efficacy beliefs related to general education have suggested "that a strong sense of collective efficacy enhances teachers' self-efficacy beliefs while weak collective efficacy beliefs undermine teachers' sense of efficacy, and vice versa" (Goddard et al., 2004, p. 10).

In one study based on elementary teacher cognition related to science, Haney et al. (2002) examined Ford's (1992) motivational theory, including teacher capability beliefs and context beliefs, as they relates to the teaching of science. Lumpe et al. (2000) claim that, "capability beliefs are synonymous with Bandura's (1997) concept of self-efficacy" (p. 277), while Ford's idea of context belief is similar to Collective School Efficacy as outlined by Bandura (1997). Contextual factors, in effect, are just another way of looking at how "the total school environment has an effect on teacher's beliefs since teachers do not operate in isolation" (Lumpe et al., 2000, p. 278). Contextual factors that form a part of a school's collective efficacy beliefs "include administrative support, student and teacher characteristics, and parental involvement" (Lumpe et al., 2000, p. 278). Through their research, Haney et al. (2002) demonstrated that elementary teachers' beliefs about these factors as outlined by Lumpe et al. (2000), in combination with self-efficacy beliefs, impact the ways in which elementary teachers think about teaching science and actually teach science.

2.7.4 Locus of Control

Locus of control refers to the degree to which individuals attribute the outcome of particular events to their own actions (Rotter, 1966, 1990). Like efficacy beliefs, this construct is context-specific. For example, a teacher's locus of control related to teaching would be the extent to which she believes her actions in the classroom impact her students' learning. Therefore, a teacher with a high *internal* locus of control would tend to believe that his or her actions in the classroom have the most powerful influence on student learning, while a teacher with a high *external* locus of control would believe that external influences, such as students' home lives, have a much greater impact.

Locus of control is very similar to Bandura's (1997) outcome expectancy beliefs aspect of efficacy beliefs, as discussed earlier in section 2.3.1. Some have argued that locus of control and outcome expectations are distinct constructs, claiming that, as a broader construct, locus of control has less power for predicting behavior than outcome expectancies (Rubeck, 1990). However, others disagree and argue that the distinction between locus of control and outcome expectancies is not clear (Guskey & Passaro, 1994; Judge et al., 2002). Indeed, the first attempts to measure teacher efficacy were grounded in the construct of locus of control (Tschannen-Moran & Woolfolk Hoy, 2001). Because of the close similarities between locus of control and outcome expectancies, there is little to no treatment of the first construct as separate from the latter in the research literature regarding science teacher efficacy beliefs.

2.7.5 Self-Concept / Self-Esteem

In general terms, self-concept is "what an individual believes he is" (Combs, 1962, p. 62) or "a person's perception of himself" (Shavelson, Hubner, & Stanton, 1976). However, more recent definitions of self-concept, like self-efficacy, have emphasized the domain-specificity, as opposed to a global view, of the construct (Bong & Skaalvik, 2003). That is, "self-concept represents one's general perceptions of the self in *given domains* of functioning" (Bong & Skaalvik, 2003, p. 5, emphasis added).

Due to this domain-specific aspect, also like self-efficacy, self-concept is multidimensional. In other words, one individual can have different self-concepts for different areas of his or her life, which are organized in a hierarchical fashion (Shavelson & Marsh, 1986). An elementary teacher, for example, can have a total self-concept, as well as separate situation-specific self-concepts of herself as a teacher, as a teacher of science, as a teacher of reading, as a mother, as a daughter, etc.

Self-esteem, on the other hand, is one's evaluative perception of his or her self-concept (Pajares & Schunk, 2001). Therefore, because self-concept is domain-specific, self-esteem is also specific to particular areas of an individual's life; an individual may have very different levels of self-esteem for many different areas. In addition, Pajares and Schunk (2001) argue that "descriptive and evaluative perceptions of self have not been empirically separated in research studies and may not be empirically separable" (p. 4). For this reason, self-concept and self-esteem are often used interchangeably, at least as they relate to academic achievement.

Like self-efficacy, the development of a self-concept is influenced by past experiences, social comparison, and verbal reinforcement from other individuals (Bong & Skaalvik, 2003). Self-concept is also influenced by causal attributions, or the factors individuals attribute to their successes and failures (Skaalvik, 1997).

Although self-efficacy and self-concept share several characteristics, there are some important differences between the two constructs. Pajares and Schunk (2001), for example, make the following distinction between self-efficacy and self-concept:

> Self-efficacy is a judgment of the *confidence* that one has in one's abilities; self-concept is a description of one's own perceived self accompanied by an evaluative judgment of *self-worth*. Because self-

> concept beliefs involve evaluations of self-worth, self-concept is particularly dependent on how a culture or social structure values the attributes on which the individual bases those feelings of self-worth. Self-efficacy beliefs are not as tightly bounded by cultural considerations. (p. 4)

In other terms, evaluating one's own self-efficacy involves asking "questions of *can*" (e.g. Can I teach science?), while evaluating one's self-concept requires one asking "questions of *being* and *feeling*" (p. 4) (e.g. Who am I as a science teacher? How do I feel about myself as a teacher of science?).

Applying this comparison to an example, an elementary teacher's view of himself as a teacher of science is his self-concept related to science teaching, which is accompanied by a judgment as to whether he sees himself as a good teacher of science. This is different from his self-efficacy beliefs related to science teaching, which is the extent to which he is confident in his abilities to teach science. However, while technically this teacher's self-concept and self-efficacy are different, and there is no defined fixed relationship between the two; they have been shown to influence one another (Pajares & Schunk, 2001).

2.7.6 Identity

Similar to the construct of self-concept, identity can be thought of as the way that one views oneself, or how one imagines that others view them, in a particular context (Gee, 2000). Also similar to self-concept and self-efficacy, identity is often thought of as multi-dimensional and hierarchical; an individual may have multiple identities depending upon context (Gee, 2000; Holland, Lachiocotte, Skinner, & Cain, 1998). In addition, evidence suggests that identity plays an important role in shaping one's actions (Sfard & Prusak, 2005).

Recent research has demonstrated that the identities of teachers can and do greatly influence their behaviors and beliefs as science teachers. For example, Creighton (2009) found that preservice elementary teachers' views of science, how they felt science connected to their lives, and their sense of themselves as *science people* were closely linked. The author also purported that the development of these aspects depended primarily on the preservice teachers' academic experiences with science and science-related experiences outside of school, and that emotions generating from these events played a large role in the development of the teachers' *science identities*.

In a few studies, researchers have attempted to make sense of the relationship between preservice elementary teachers' self-efficacy beliefs and identities. For example, in a pilot study using 27 elementary teacher majors, Finson (2001) measured science teaching self-efficacy and perceptions of self as a science teacher at the beginning and end of a science methods course. The authors used the STEBI in order to measure PSTE and STOE, and the Draw-A-Science-Teacher Teaching Checklist (DASTT-C) in order to measure how the subjects perceived (1) their role as a teacher, (2) their students' roles, and (3) the role of the ethos of the classroom in an elementary science lesson. In the DASTT-C, subjects were given a single prompt: "Draw a picture of yourself as a science teacher at work." These drawings were then scored using a checklist. Results of the pretest indicated an overall positive correlation between PSTE and DASTT-C scores; preservice teachers with higher science teaching self-efficacy viewed the roles of the teacher and students in a more reformed manner than those with lower self-efficacy. However, when the posttest comparison was made, results were more mixed. The authors suggested that other measures may be more appropriate than the DASTT-C to examine teachers' perceptions of themselves as a science teacher in comparison to self-efficacy.

In a more recent study, Settlage et al. (2009) attempted to examine the relationships among preservice elementary teachers' science teaching self-efficacy beliefs, teacher identities, and science instruction in culturally diverse classrooms. The authors hypothesized that the teachers' self-efficacy and outcome expectancy beliefs related to science teaching, and specifically to teaching science in diverse classrooms, would increase following a semester of student teaching in culturally diverse elementary classrooms. However, it was discovered that teachers' self-efficacy scores, at all levels, increased little, if at all; STEBI scores began high and remained high. In addition, Settlage et al. (2009) found that "interviews revealed no discernable influence upon the teacher candidates' perceptions of science teaching selves that could be attributed to demographics of their field placements" (p. 102). While the subjects felt high confidence in their abilities to teach science and a positive view of their role as science teachers in these classes, the preservice teachers' beliefs about science teaching and their science teaching practices revealed a more traditional than reformed view of science instruction. Furthermore, subjects' views of their identities as science teachers aligned with their teaching practices. The authors emphasized the importance of recognition in how an experience influences an individual's beliefs, identity, and practices; particular aspects of any experience will not influence a teacher's confidence in or beliefs about teaching science if those aspects are not recognized by the individual as important.

2.8 Chapter Summary

This chapter has provided an all-encompassing overview of the existing research literature regarding science teaching efficacy beliefs and related constructs. While it is clear that a large amount of research regarding science teaching self-efficacy has already been conducted, this review does highlight the importance of such research as well as some critical areas of need within the current research base. In particular, several important themes emerge from this review:

- There is a demonstrated need for reform in elementary science education, and science teaching self-efficacy research has the potential to aid these reform efforts.
- Much of the current research regarding science teaching efficacy beliefs has involved examining the extent to which particular interventions (e.g. science teaching methods courses or professional development programs) can increase science teaching self-efficacy beliefs, especially of preservice elementary teachers, as opposed to the relationships between self-efficacy and teaching practices.
- While some evidence does exist suggesting that there is a positive relationship between science teaching self-efficacy beliefs and more reformed teaching practices, much of this evidence comes from self-reported measures, as opposed to observations of teachers' actual practices.
- Of the science teaching self-efficacy research that does utilize observations of teachers' actual classroom practices related to science instruction, the samples of teachers in the vast majority of these studies are small and uniform.

- Many different factors may impact the relationships between teachers' science teaching efficacy beliefs and classroom practices, including knowledge, attitudes, and other types of beliefs.

These key themes within the reviewed literature set the stage for the research presented in this dissertation by demonstrating a critical need for further research examining the relationships among science teaching efficacy beliefs, beliefs regarding science teaching, and *actual* science teaching practices for a large diverse sample of inservice elementary teachers, which includes interviews and observations. This literature also forms a basis for the methodology designed to answer the research questions, as described in the next chapter.

CHAPTER 3: RESEARCH METHODS

This chapter will present the methodology for studying the relationships between science teaching self-efficacy and science teaching practices for a diverse nationwide sample of inservice elementary teachers. The first section of this chapter provides an overview of the methodology. I then describe the data collection procedures, including sample selection and instrumentation. Next, the methods of analysis are presented for answering each of the research questions. Finally, in the last section, I provide a summary of the chapter.

3.1 Overview of Methodology

To reiterate, the overarching question addressed by this study is: What are the relationships among Personal Science Teaching Efficacy (PSTE) beliefs, science teaching practices, and the beliefs about these practices within a nationwide diverse sample of inservice elementary teachers? As has been discussed in the previous chapters, the relationships between teachers' beliefs and classroom practices are complex, as are the assessment of these relationships (Pajares, 2002; Philipp, 2007; Wheatley, 2005). Therefore, care must be taken in attempting to answer research questions regarding the association between beliefs and practices, such as those presented by this study. It is not enough to rely solely on quantitative survey instruments in research regarding teacher beliefs. Such research must include qualitative data such as interviews and observations (Pajares, 1992; Perkins, 2007; Wheatley, 2005). In addition, Pajares (1992) argued that, in order to more clearly understand individuals' beliefs related to teaching and the relationships between these beliefs and practices, we must examine interactions among specific areas of belief, such as self-efficacy, and behavior. More specifically, he stated, "Beliefs must be inferred, and this inference must take into account the congruence among individual's belief statements, the intentionality to behave in a predisposed manner, and the behavior related to the belief in question" (Pajares, 1992, p. 326). Therefore, in order to meaningfully examine the relationships among beliefs, such as those related to PSTE and teaching practices, one must conduct interviews with teachers and make observations of teaching behaviors along with the administration of survey instruments (Wheatley, 2005).

In addition to addressing the issue of complex data, attending to sample size and participant composition are also important when attempting to answer research questions such as those presented by this study. An in-depth analysis of the relationships among self-efficacy beliefs, contextual beliefs, and science teaching practices of a few teachers (e.g., Haney, Lumpe, Czerniak, & Egan, 2002) can provide new insights into these relationships and generate new research questions. However, the generalizability of results from such small sample sizes, especially when teachers within the sample are relatively uniform in demographic characterization, is uncertain.

Following these concerns, in order to provide valid and useful answers to my research questions, the methodology for this study includes a variety of data sources from a large diverse sample of inservice elementary teachers. A rich mix of data, including results from observations, interviews, and surveys, allows me to gain a deeper understanding of the relationships in question as compared to relying solely on surveys.

In addition, the large nationwide sample of practicing elementary teachers with very diverse backgrounds from which I drew for this study, allows me to explore how the relationships between science teaching self-efficacy and science teaching practices play out over an extensive sample of teachers that reflects our current teacher population. Due to the wide variety of data collected through the NSEUS project for this diverse group of teachers, I have also had the opportunity to examine how some of the characteristics of teachers within the group of subjects may impact these relationships.

3.2 Data Collection

3.2.1 Subjects

Subjects for this study include a total of 38 inservice elementary teachers from whom we gathered data for the National Study of Education in Undergraduate Science (NSEUS[8]) between Spring 2009 and Fall 2010. Two to seven teachers were recruited from within the vicinity of each of eight cities: Anchorage, AK; Nacogdoches, TX; Chico, CA; Pomona, CA; Boston, MA; Wheeling, WV; La Crosse, WI; and Marquette, MI. Recruitment took place through coordination in each city with a faculty member at a local university acting as a NSEUS research associate. Out of the two to seven teachers at each location, approximately 50% had taken a reformed undergraduate course (the NOVA course) at the local university and 50% had not.[9] Since the subjects were recruited through the NSEUS project, the NOVA/non-NOVA distinction is the only selection criterion that was applied for recruitment in each geographic location.

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[8] See section 1.1 of Chapter 1 for a description of the NSEUS project.
[9] See section 1.1 of Chapter 1 for a description of NOVA courses.

Teachers who participated in this study taught a variety of grade levels (Kindergarten through eighth grade) and had a wide range of years of teaching experience (one to thirty-eight years). Teachers also varied in the extent of their science content and science education backgrounds (university coursework and professional development). Teachers were of mixed gender and ethnicity, and received their pre-service education at a wide variety of universities and colleges. In addition, participants taught at a diverse mix of elementary schools across the country including: (a) public and private schools; (b) rural, urban and suburban locations; and (c) lower, middle, and upper-socioeconomic status communities. (See Appendix A for specific information about the characteristics of participating teachers.)

3.2.2 Data Collection Process

All data were collected in conjunction with the NSEUS project by trained staff, including myself, using a standardized protocol. For each of the 38 elementary teachers, we conducted an observation of a science lesson presented by the teacher followed by a semi-structured interview with the teacher. Each teacher also completed the Science Teacher Efficacy Beliefs Instrument – Form A (STEBI-A; Riggs, 1988; Riggs & Enochs, 1990) at the time of the interview. In order to keep the data confidential, the name of each teacher was replaced by a four-digit numerical code on all recorded data. Of the 38 teachers, I personally collected observation, interview, and STEBI data for all but four of these teachers.

Observations

It has been argued that observations are a critical component of research regarding teachers' beliefs, especially self-efficacy beliefs (Pajares, 1992; Wheatley, 2005). In addition, a large portion of current studies regarding science teaching self-efficacy beliefs have focused on factors impacting the development of these beliefs, although there is a dearth of first-hand observational data relating science teaching self-efficacy to science teaching practices (Haney, et al., 2002). For these reasons, observations of participants actually teaching science to their students play an important role in this study.

At least two trained NSEUS project staff observed each participant teaching one science lesson of the teacher's choice, lasting between thirty and ninety minutes. Data collection during these observations was structured by the Reformed Teacher Observation Protocol (RTOP; Sawada & Pilburn, 2000). (See Appendix B.)

The RTOP is an instrument that was designed by the Evaluation Facilitation Group of the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) as a tool for systematically measuring the level of reform in a science or mathematics lesson as outlined in national standards for science and mathematics education (Sawada et al., 2002). The RTOP begins with spaces to fill in background information and lesson context, including a diagram of the classroom layout and a description of classroom materials. Next, the RTOP includes an area for field notes of a chronological narration of the events that occurred in the classroom during the observation. Following the section of the RTOP for field notes is a Likert-scale inventory, in which the observer completes a five-level response rating (0 = never occurred; 4 = very descriptive of the lesson) for 25 items evenly spread over five categories related to the reform level of the lesson observed. These categories are based on national standards for science and mathematics education and include: (1) *Lesson Design and Implementation*, (2) *Content: Propositional Knowledge*, (3) *Content: Procedural Knowledge*, (4) *Classroom Culture: Communicative Interactions*, and (5) *Classroom Culture: Student Teacher Relationships* (Sawada & Pilburn, 2000). Through extensive training with the RTOP, NSEUS project staff members have achieved 95% inter-rater reliability for the rating section of this instrument.

Following observations, NSEUS onsite project staff worked together to transcribe all field notes for each observation into a word processing document, along with entering all numerical RTOP scores into a spreadsheet.

Interviews

Following the observation, within the same day, each teacher was interviewed using the "NSEUS Elementary Teacher Interview Questions" (Appendix C). Interviews, approximately 40 minutes in length, were conducted in private classrooms at the teachers' schools where their responses could not be overheard by others. Two trained NSEUS project staff were present at each interview, one to conduct the interview and the second to maintain a written record of the subject's responses. In addition, each interview was audio-recorded and transcribed.

Although a common set of questions was asked in all interview sessions, interviews were semi-structured to allow for clarification questions in particular instances (Bernard, 1988). Interviews included questions related to teachers' backgrounds in science and science education, as well as general beliefs about elementary science education, and specific beliefs as they pertain to the teachers' own instructional practices. In addition, teachers were asked questions connecting their beliefs about elementary science education to the events in the specific lesson observed. Kagen (1992) noted that teachers may not be able to fully explain their beliefs about science teaching when asked directly. Therefore, semi-structured interview tasks in which the teachers in this study were asked to connect beliefs to particular events in the classroom allowed me to gain a more indirect view of these teachers' beliefs, and thus gain a better picture of the teachers' belief systems as they relate to classroom practice.

Because the interview protocol has been designed to answer a variety of research questions asked by the NSEUS project, not all interview questions are applicable to the goals of the study presented here. However, all interview questions that prompted subjects to provide responses related to their science teaching beliefs and practices were considered for analysis. (See Appendix C.)

Survey Instrument (STEBI-A)

The Science Teaching Efficacy Beliefs Instrument – Form A (STEBI-A) is a survey designed by Riggs and Enochs (1990) to measure the level of science teaching efficacy of inservice elementary teachers (Appendix D). It has its origins in two sources: Bandura's social cognitive learning theory (Bandura, 1977, 1986) and Gibson's and Dembo's (1984) "Teacher Efficacy Scale." The survey is composed of 25 Likert-scale items, each of which has five response ratings: strongly agree (5 points), agree (4 points), uncertain (3 points), disagree (2 points), and strongly disagree (1 point).

Thirteen of these items are designed to measure Personal Science Teaching Efficacy (PSTE) of respondents, while the remaining twelve measure Science Teaching Outcome Expectancy (STOE).[10] High reliability and validity have been determined for the STEBI-A (Riggs & Enochs, 1990), particularly for the construct of PSTE as measured by the survey (Perkins, 2007).

While the STEBI-A is designed to measure both PSTE and STOE, only teachers' responses for those items measuring PSTE were utilized as a basis for determining teachers' levels of science teaching self-efficacy. As I stated in Chapter 1, I chose to only examine teachers' levels of PSTE, or science teaching self-efficacy, in this study for several reasons. While STOE has been acknowledged as a potentially powerful influence on science teaching practices, several studies have pointed out the lower reliability coefficient for outcome expectancy beliefs (Enochs & Riggs, 1990; Huinker & Madison, 1997; Mulholland et al., 2004; Plourde, 2002) and the difficulty of separating outcome expectancy from the construct of locus of control (Guskey & Passaro, 1994; Judge, Erez, Bono, & Thoresen, 2002; Tschannen-Moran, Hoy & Hoy, 1998). In addition, Bandura (1997) suggested that perceived self-efficacy is a better predictor of behavior than outcome expectancy beliefs or locus of control. These concerns have led some to suggest that outcome expectancy is a less definitive construct than self-efficacy, and thus more difficult to measure accurately (Riggs & Enochs, 1990; Tschannen-Moran et al., 1998).

[10] See section 2.3 of Chapter 2 for more detail concerning the constructs of PSTE and STOE.

3.3 Data Analysis

The data were analyzed in a manner that allowed for the answering of the two research questions. Therefore, the following descriptions of analytical procedures are organized according to these questions. Because the second research question essentially asks about particular patterns within the results of the first research question, the analyses used to answer Question 1 formed a foundation for the analyses applied to Question 2.

3.3.1 Question 1

The first research question asks: How do teachers with varying levels of Personal Science Teaching Efficacy (PSTE) compare in the ways that they: (1a) describe how science *should* be taught at the elementary level and their reasons for this description; (1b) describe their *own* science teaching practices and their reasons for these practices; and (1c) actually teach science? In order to answer this question, I utilized both coded qualitative data from interviews and observations, and statistical comparisons among quantitative data sets.

To answer this question through the examination of interview and observation data, I first examined the PSTE score distribution (based on relevant STEBI-A items) for the 38 participating teachers. This was done in order to determine which groups of participants, based on their levels of PSTE, were most relevant and feasible to make comparisons between for the purposes of this study. I then coded portions of interview and observation transcripts related to the categories set up by the three parts of this research question. The coding scheme was one that I created based upon standards-based characteristics of reformed inquiry-oriented science teaching practices, existing research literature regarding the relationships between self-efficacy and teaching behaviors, and the qualitative data generated by this study. Finally, I compared the frequencies of codes for the categories laid out by the three parts of the research question among the teachers with different levels of PSTE scores, as determined by STEBI-A results.

Quantitative data were used to gain additional information regarding the answer to part (1c) of this research question; I determined whether a statistical correlation existed between participants' Personal Science Teaching Efficacy level as measured by the STEBI-A, and the reform level of observed lessons as measured by the RTOP.

PSTE Score Distribution

Following Haney et al. (2002) and Lumpe et al. (2000), I had originally planned to divide the statistical distribution of teachers' PSTE scores (as determined by the STEBI-A) into equal thirds in order to divide subjects into groups of high, medium, and low levels of PSTE. However, the distribution of PSTE scores within the study sample was heavily skewed, indicating that this was not an appropriate method for group assignment (Figure 3.1). Because of this skewed distribution of PSTE scores, I chose to treat these scores as a continuous rather than discreet data set for my initial comparisons. That is, I determined whether coding frequencies within the data correlated with PSTE scores. In addition, the seven participants at each extreme end of the PSTE score distribution were grouped together in order to make comparisons between the teachers with the highest and the lowest levels of science teaching self-efficacy (Figure 3.1).

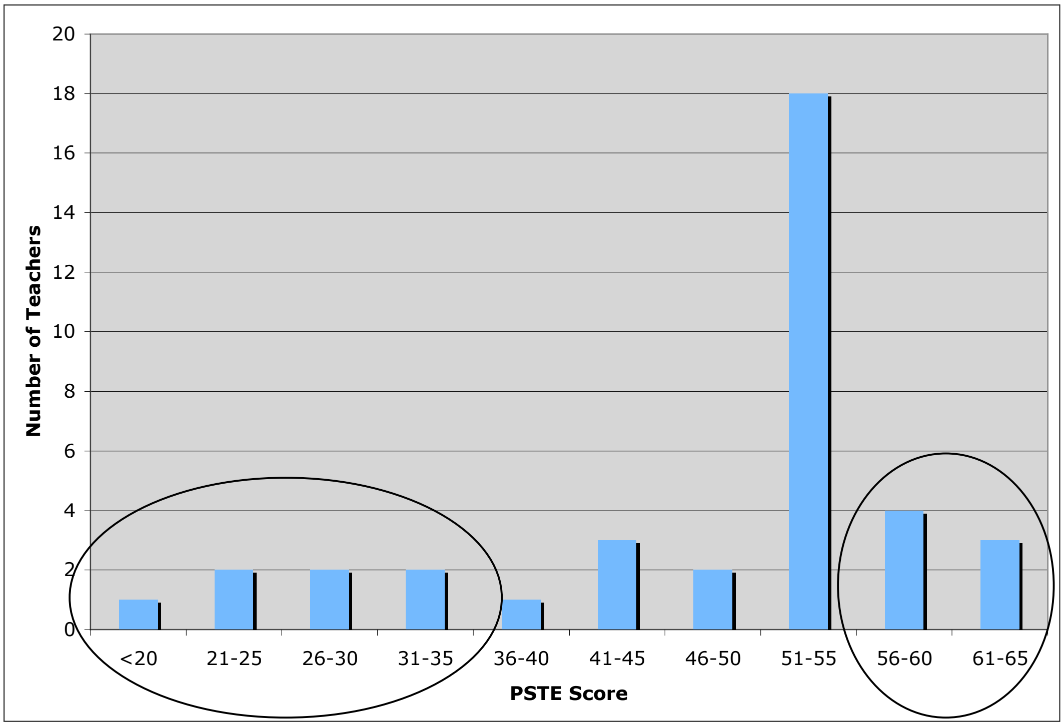

Figure 3.1. PSTE Score Distribution for Participants (*N* = 38).
Note: Circles indicate participants falling within groups with the highest and lowest PSTE scores.

Coding of Interviews and Observation Field Notes

According to Miles and Huberman (1994), "Coding is [...] to review a set of field notes, transcribed or synthesized, and to dissect them meaningfully" (p. 56). For this study, I developed a coding scheme guided by pre-determined categories based on my research questions, in order to code interviews and observation field notes in a manner that allowed me to produce meaningful answers to my questions. The development and utilization of this code is elaborated on in the following sections.

Development of the Coding Scheme. On the inductive to *a priori* continuum of approaches to coding qualitative data (Miles & Huberman, 1994), the coding scheme utilized for this study lands in the middle and is comparable to typological analysis as described by Hatch (2002). Prior to data collection, I identified five general categories, or typologies, based upon my research questions within which to analyze the data from interview transcripts and observation field notes:

1. *Ideal elementary science teaching practices* (The ways that participants describe how science should be taught.)
2. *Reasons for ideal elementary science teaching practices*
3. *Personal science teaching practices* (The ways that participants describe how they teach science in their classrooms.)
4. *Reasons for personal science teaching practices*
5. *Observed science teaching practices* (The ways that we observed the participants teaching a science lesson.)

Categories 1-4 apply to the subjects' interview transcripts (what the teachers noted about general and personal elementary science teaching). Category 5 applies to observation field notes (what the observers noted about the teachers' science teaching).

Based upon review of the actual interview and observational data of participants, the above five categories were modified following data collection into a more appropriate 4 categories:

1. *Perceived* <u>*ideal*</u> *elementary science teaching practices* (The ways that participants describe how science should be taught.)
2. *Perceived* <u>*general personal*</u> *science teaching practices* (The ways that participants describe how they generally teach science in their classrooms and their reasons behind their choices.)
3. *Perceived* <u>*observed personal*</u> *science teaching practices* (The ways that participants describe how they taught science during the observed lesson and the reasons behind their choices.)
4. *Observed science teaching practices* (The ways that we observed the participants teaching the science lesson.)

This modification was done for several reasons. First, participants were not always clear in their delineation between beliefs about science teaching practices and their reasons for those beliefs. Therefore, coding of participants' different areas of beliefs (ideal science teaching and personal science teaching) were amalgamated with participants' reasoning for these beliefs, since the teachers themselves lumped the two together. Additionally, teachers often demonstrated in their interviews beliefs about their general science teaching practices that varied from those specifically used in the observed lesson. For this reason, the category "personal science teaching practices" was divided into two separate categories: "perceived *general* personal science teaching practices" and "perceived *observed* personal science teaching practices" (categories 2 and 3).

Although the above four general categories were primarily developed *a priori* based upon the research questions of this study in order to facilitate the coding of the data, determination of specific codes within these categories (Appendix E) was guided by the data itself as well as by pertinent research literature. This coding scheme was developed via cyclic coding (Strauss & Corbin, 1998), a process in which the coding scheme is modified appropriately as further data are analyzed, and grounded in the interview transcripts and field notes. At the same time, however, the development of codes was informed by (a) the items on the RTOP (Appendix B); (b) characteristics of reform-based inquiry-oriented science teaching practices as defined in national science education standards and recommendations (Table 2.1); and (c) existing research literature regarding the relationships between science teaching efficacy beliefs and classroom behaviors. In addition, the coding schemes used within the categories were developed in parallel and informed by one another. By creating coding schemes for these categories that are parallel to one another, it facilitated comparisons made between these categories among participants with similar PSTE scores when answering Research Question 2. (See Appendix E for descriptions and examples of all specific codes, the reasons for inclusion of each code, and the relationships between interview and observational codes.)

Because inquiry plays such a central role in reformed science teaching, it is important to describe how the particular components of inquiry (*fundamental abilities of inquiry*; Appendix E) were chosen to be included as part of the coding scheme for this study. *Inquiry and the National Science Education Standards* (National Research Council [NRC], 2000) describes the most important components of inquiry in two ways: the "fundamental abilities necessary to do scientific inquiry" (*fundamental abilities*; p. 19) and "the essential features of classroom inquiry" (*essential features*; p.

25). Several researchers have based their own coding schemes for the characteristics of inquiry on the *essential features* (e.g. Blanchard, Southerland, & Granger, 2009; Bodzin & Beerer, 2003; Leonard, Barnes-Johnson, Dantley, & Kimber, 2010). Yet, in many of these studies the focus has been on the particular characteristics of inquiry present in the lab activities that teachers use in their science lessons. For the purposes of my study, however, it was my intention to examine characteristics of inquiry that are evident in any aspect of an elementary science lesson, not just during lab activities, and to explore which particular *fundamental abilities* necessary for a student to be able to take part in scientific inquiry are being supported by participating teachers. In addition, the *fundamental abilities* for scientific inquiry are based on specific national science education standards for K-8 students, while the *essential features* are more composite characteristics to determine whether or not students are participating in inquiry-based activities in the science classroom. As a result, the *fundamental abilities* are more specific and so more easily identified in all areas of observed classroom practices and in the interview responses of participants.

Throughout the development and application of the coding scheme, multiple coders, all of whom have expertise in science and/or mathematics education, were consulted in order to aid in the validation and inter-rater reliability of the coding scheme (Mills, 2010). Based on discussions with these consultants, the coding scheme was revised several times before reaching its final form. Validity and inter-rater reliability of the final coded data set was confirmed by three science and mathematics education researchers, other than myself, who independently coded approximately 25% of the data (10 out of the 38 participating teachers). Overall agreement among coders for observation codes was calculated by hand to be 85% using Holsti's (1969) coefficient of reliability. Inter-rater agreement for coded interview transcripts was calculated to range from 71% to 100% for individual codes, with Cohen's kappa values ranging from 0.36 to 1.00 (Cappozzoli, McSweeney, & Sinha, 1999), using the NVivo 8 computer program (QSR International, 2008). Although the exact level of inter-rater reliability that must be achieved to assure reliable coded qualitative data has not been clearly established (Rourke, Anderson, Garrison, & Archer, 2001), the values presented for my dissertation study appear to be fair to excellent (Cappozzoli, et al., 1999; Landis & Koch, 1977; Riffe, Lacy, & Fico, 1998); this is especially true considering the overly-conservative nature of kappa values for coding protocols with many different categories, as is the case in my study (Potter & Levine-Donnerstein, 1999).

Application of the Codes. Systematic organization and management of coded data are critical elements of effective qualitative analysis (Hatch, 2002; Miles & Huberman, 1994). Therefore, all coding of interview data was organized through the computer program NVivo 8 (QSR International, 2008). The NVivo 8 software program allows a researcher to organize and analyze complex non-numerical data sets, such as interview transcripts, by providing a tool with which a user can classify and sort specific pieces of data and examine complex relationships within the data (Welsh, 2002).

It is important to emphasize that software packages such as NVivo are not meant to code the data *for* the researcher. That is, while an individual could theoretically use software to search full interview transcripts, or parts of transcripts, for key words and then create categories solely based on these search results, this strategy is generally inappropriate and unadvisable (Hatch, 2002; Welsh, 2002). Instead, "Qualitative data analysis software is designed to carry out administrative tasks of organizing the data more efficiently and should therefore be exploited to the full on this basis" (Welsh, 2002, p. 7). For this reason, it is critical that NVivo be used only as a tool to help the researcher sift through and organize data as he or she creates and organizes codes and themes within the data.

Using the NVivo 8 program, I first examined the interview transcript for each participant and classified sections that fit into the first three of the aforementioned four pre-determined categories[11] (those pertaining to interview data). All responses that reflected the essence of any of categories 1-3 were included for analyses. In addition, portions of interview transcripts falling into each category were not mutually exclusive; in a response to a single interview question, a participant may have described their beliefs about ideal science teaching together with the ways they believe themselves to teach science in their own classrooms.

The process of coding observational data was slightly different from that used for interview data. Coding of observations was not organized by NVivo 8. Instead, I found it more useful to code observation field notes in a separate matrix. (See Appendix F for examples.) In this coding process, I began by first dividing each lesson into a series of *lesson segments*. The time span of each lesson segment was based on teacher initiated tasks and the goal of the segment; when students were required to do a different task or focus on a new goal, a new lesson segment began. In this way, I was

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[11] Refer to p.86 for a description of the four general categories.

able to determine the general characteristics of the instructional tasks used by each teacher in the observed lesson as well as the relative lengths of time of these characteristics for each lesson.

Following the separation of sections of the interview transcripts based upon the four pre-determined categories, and the division of observer field notes based upon lesson segments, data were then coded using the coding system that was created as described in the previous section (Appendix E). For interview transcripts, each code (with the exception of *External Influences*) was applied to each participant's response to each individual interview question only once. This was done in order to control for variation in the lengths of responses given by different teachers. In the case of the code *External Influences* each unique influence was tallied, in order to create a value for the total number of different influences cited by each teacher. For observation field notes, each code was applied to each lesson segment only once. (See Appendix F for selected examples.)

Analysis of the Coded Data. Once all interview transcripts and observation field notes were coded, interview and observation codes within each of the four pre-defined categories (perceived ideal, perceived general personal, perceived observed personal, and actual observed science teaching) were then compared in order to determine key differences and similarities among participants with varying PSTE levels. These comparisons were accomplished through the calculation of Pearson product-moment correlation coefficients between PSTE scores and the frequency of each of interview code and relative length of time each observation code was observed during the lesson. In order to calculate this relative length of time for observation codes, duration of lesson segments designated with each code were divided by total time of the lesson, or by total time spent engaged in a particular type of task (e.g. out of the total amount of time during a lesson spent engaged in whole-class discussion, what percentage of this discussion time was spent with students engaged in high-level thinking?)

In some cases, where correlations were not appropriate, independent sample *t*-tests were conducted to compare the average PSTE scores of participants who did or did not exhibit certain coding categories during their interviews and observations.

In addition, independent-sample *t*-tests were conducted in order to calculate the difference in the mean frequency of each code between the seven participants with the highest PSTE scores and the seven with the lowest scores. This was done in order to determine whether a difference in the references to particular codes existed between those participants with the highest and lowest levels of science teaching self-efficacy (Figure 3.1).

Along with quantitative comparisons among code frequencies, descriptions of the key similarities and differences within and among teachers with varying levels of PSTE were created, supported by teachers' and observers' quotes from the interview transcripts and observation field notes. In this way, I have applied the qualitative data sets in order to make general comparisons among study participants based upon their science teaching self-efficacy levels for parts (1a), (1b), and (1c) of research question 1.

Participants' Perceived Success of the Observed Lesson

Previous research has indicated that preservice elementary teachers with different levels of science teaching self-efficacy vary in the ways that they measure success of their science lessons and to whom they credit that success (Czerniak & Shriver, 1994). In order to determine whether inservice elementary teachers in my sample also differed in the ways that they measured the success of the observed lesson, participants' responses to the final interview question ("Overall, how successful do you think the lesson was today? Why?") were coded and analyzed independently from the rest of the interview data. This portion of the analysis served to answer, in part, part (1b) of the first research question in examining some of the key differences and similarities among participants' perceptions of their observed science lessons.

In order to address this component of the study, participants' responses to the final interview question were examined for common themes. Each interview response was then coded to identify which theme(s) the response addressed. Finally, independent-sample *t*-tests were conducted to determine whether a statistical significance existed between the mean PSTE scores of teachers who did and those who did not cite each of the themes in their responses.

Statistical Correlations Between PSTE and RTOP Scores

In addition to comparisons using coded data from observational field notes, Pearson product-moment correlation coefficients between RTOP and PSTE scores were also utilized to answer part (1c) of the first research question. Pearson correlations were used to assess: a) to what extent overall RTOP scores correlate with PSTE scores, and

b) to what extent scores within specific categories of the RTOP[12] correlate with PSTE scores. In addition, a large number of studies have suggested that a variety of teacher characteristics impact the level of PSTE beliefs an elementary teacher has (e.g. Andersen, Dragsted, Evans, & Sorensen, 2007; Angle & Moseley, 2009; Bursal, 2010; Carleton, Fitch, & Krockover, 2008; Posnanski, 2002; Ramey-Gassert et al., 1996). Therefore, in order to determine whether particular teacher characteristics (e.g. gender, grade level currently teaching, years of experience teaching in general, years of experience teaching at current grade level, number of undergraduate science courses taken, and number of science education undergraduate courses taken) impacted self-efficacy and/or the level of reform observed during the science lessons, correlations and *t*-tests were calculated, as appropriate, comparing these various participant characteristics with RTOP scores, as well as with PSTE scores.

3.3.2 Question 2

The second research question addressed by this study asks: In what ways are the parts of question 1 [(1a) these teachers' descriptions of ideal science teaching, (1b) their descriptions of their own science teaching, and (1c) their observed science teaching practices] aligned? In order to answer this question, I applied an almost parallel method as outlined for research question 1. The data resulting from the coding procedures for interview transcripts and observational field notes as described for research question 1 are the same data that were used to answer research question 2. In the case of research question 2, however, Pearson product-moment correlation coefficients were calculated

[12] Refer to section 3.2.2 for a list of these categories.

among code frequencies within the data. In addition, correlation coefficients previously calculated between PSTE scores and code frequencies were examined to determine how they compared across the four general categories of (1) *Perceived ideal elementary science teaching practices*, (2) *Perceived general personal science teaching practices*, (3) *Perceived observed personal science teaching practices*, and (4) *Observed science teaching practices*. These comparisons were used to generate descriptive themes in the data, and supported by teachers' and observers' quotes from the interview transcripts and observation field notes.

Teacher Case Profiles

In addition to examining overall comparisons among survey and coded interview and observation data, as described in the previous sections of this chapter, eight teachers (four among those with the highest PSTE scores and four among the lowest scores) were chosen as case profiles to be described in greater depth. Of these eight case profiles, 50% had high RTOP scores and 50% had low scores. Case profiles of all eight teachers were examined holistically for descriptive themes in order to provide a more detailed picture of potentially important relationships among science teaching self-efficacy beliefs, beliefs about science teaching, and practices of the inservice elementary teachers in this study.

3.4 Chapter Summary

This chapter has described the methodology used to examine the relationships among the beliefs and practices regarding science teaching for a diverse nationwide sample of inservice elementary teachers, as related to their personal science teaching efficacy beliefs. Through the use of survey data and rigorously coded interview transcripts and observation field notes for a larger sample of 38 teachers, as well as in-depth descriptive examples of a small subset of eight teachers, I have revealed some of the potentially important ways self-efficacy beliefs do and do not relate to science teaching practices.

The next two chapters will discuss the results of the analyses described above. Chapter 4 presents the results the total data set, focusing on survey data and coded interview transcripts and observation field notes, while Chapter 5 describes key themes in the relationships among beliefs and practices for the eight case profile teachers.

CHAPTER 4: RESULTS FOR ALL PARTICIPATING TEACHERS

This chapter will describe the results of this study regarding coded interview transcripts and observation field notes, and supported by survey data and quotes from participating teachers. The first section of this chapter presents the results for the first research question, examining how participating elementary teachers with varying levels of science teaching self-efficacy compared in the ways that they (1) described how science should be taught, (2) described their own science teaching, and (3) were observed actually teaching science. In the second section, I describe the results for the second research question, focusing on what patterns emerged between these three areas and comparing these patterns to results of related existing research literature. Finally, the last section provides a summary of the chapter including a discussion of the potential ramifications of the results presented therein.

4.1 Results for Research Question 1

The first research question in this study asks: How do teachers with varying levels of Personal Science Teaching Efficacy (PSTE) compare in the ways that they: (1a) describe how science *should* be taught at the elementary level and their reasons for this description; (1b) describe their *own* science teaching practices and their reasons for these practices; and (1c) actually teach science? This section addresses patterns emerging in the data within each of these parts by providing results for Pearson correlation coefficients and independent sample *t*-tests, and supported by quotes from participants.

4.1.1 Participants' Self-Efficacy

Participants' PSTE scores were overall relatively high ($M = 47.47$, $SD = 11.87$), but comparable to other research (Lakshmanan, Heath, Perlmutter, & Elder, 2011), and ranged from 17 to 63 out of a maximum possible score of 65 points (Figure 3.1). PSTE scores did not correlate with current grade level teaching [$r(36) = -0.07$, $p = 0.691$], total number of years teaching experience [$r(36) = -0.04$, $p = 0.828$], number of years teaching experience at current grade level [$r(36) = -0.09$, $p = 0.583$], amount of professional development [$r(36) = -0.19$, $p = 0.257$], number of undergraduate science content courses taken [$r(36) = 0.15$, $p = 0.360$], or number of undergraduate science education courses taken [$r(36) = 0.16$, $p = 0.348$]. In addition, significant differences in PSTE scores were not found when participants were grouped by gender [$t(36) = 0.302$, $p = 0.764$], whether or not teachers were science specialists (taught only science) [$t(36) = 1.179$, $p = 0.246$], or whether or not teachers majored or minored in science as undergraduates [$t(36) = 1.227$, $p = 0.228$].

4.1.2 Perceived Ideal Science Teaching

Out of all of the coded characteristics used to quantify the ways that participants described how science should ideally be taught at the elementary level during their interviews (Appendix E), only one correlated statistically significant with PSTE levels: *Student Control*; $r(36) = 0.34$, $p = 0.037$. That is, teachers participating in this study with higher levels of science teaching self-efficacy made more statements in their interviews indicating that science should be taught in a way in which students have control and/or responsibility for their own learning. This sentiment is demonstrated in the following quotes from teacher interviews:

> "[Science] should be something they're doing on their own. Sometimes there's no right or wrong answer. It's what they come up with themselves. They have control over things somewhat."

> "I think kids do best when they pose questions of their own and then set up an investigation, or help them find the tools to investigate what their questions are. [...] They come up with a question, then they do their own research and investigate. That's the way I'd like to do it all the time."

> "But when they come up with the question, I think the teacher needs to be prepared at that time to take the teachable moment and go with it as far as you can."

> "[Science] isn't about [the teacher] giving you the answer. It's about [the student] figuring it out and learning from that."

Although the frequency of the code *Student Control* was the only one regarding beliefs about ideal science teaching that correlated with PSTE at a statistically significant level ($p < 0.05$), there were several other characteristics that correlated at a level of $p < 0.2$. Because the sample size of this study is relatively small ($N = 38$), I believe that it is relevant and worthwhile to examine these close-to-significant correlations in greater detail in order to explore and speculate about some other facets of beliefs regarding ideal science teaching (as well as teachers' own science teaching and observed classroom behaviors), to which PSTE may be related.

One such correlation that was close-to-significant was that between PSTE and *Content Connections* [$r(36) = 0.25$, $p = 0.138$], that scientific content taught at the elementary level should be connected to the real world, students' lives, and/or other related scientific content. For example, teachers with higher PSTE scores made slightly more statements such as:

> "When you teach science you've got to bring in stuff that's not in [the curriculum]. It's what's happening right now. OK. Hurricane Katrina. Let's talk about flooding. Let's talk about what's going on in the world, bring that in, and tie it into the standards."

> "And at that age, just to teach them in science to get them to think about life, and about weather, and about things that are around them in their daily lives. Like everyday aspects, how can they relate to that is going to get them interested in it, and then you can get into the deeper stuff when they get older."

> "You kind of have to teach [scientific concepts] all tied together because they're all tied in no matter where you go. In biology you still have your forces. It's everything tied together. It's not really separate."

Participants' with higher PSTE scores also made slightly fewer references to *Managerial*, aspects relating to classroom management and/or the controlling of student behavior, when describing how science should be taught; $r(36) = -0.24$, $p = 0.154$. That is, teachers with lower science teaching self-efficacy made more comments during their interviews such as:

> "There's such a mix of ability levels and behaviors. You always have to anticipate that something's going to happen because if you don't and it does and you're not prepared…"

> "[The best way to teach science is with] hands-on materials. Be well organized. Have things laid out. Think about it in your head before and anticipate problems with them doing the experiments. I think that's the biggest part."

> "There have to be limits. Because, you know, what kids want to do best with materials is beat them. It's awful. You can't give them the materials until you're ready."

Finally, although all but three of the 38 teachers referred to *Hands-on* activities when describing their beliefs about ideal science teaching, higher PSTE scores correlated with more references during their interviews to the six *Fundamental Abilities* *of Inquiry*[13] when describing how the participants believed science should be taught [$r(36) = 0.23$, $p = 0.17$], such as:

> "I think kids do best when they pose questions of their own and then set up an investigation, or help them find the tools to investigate what their questions are." (*Students Ask Questions* and *Students Plan Investigations*)

> "Bring it in and have them make observations. Let them try it out and see what happens. I feel like that's the best way for them to actually see it and sense it and feel it. […] They can try it and if it fails, why? And have them talk about why they think it wouldn't work and what they do see." (*Students Gather Data*, *Students Formulate Explanations*, and *Students Communicate Ideas*)

> "Really getting them to find a love of science and really be able to experience freely and ask the questions, to understand what a hypothesis is and make predictions. I think those are important." (*Students Ask Questions* and *Students Make Predictions*)

All other coded characteristics (*Direct Instruction*, *Student Thinking*, *Student-Student Communication*, *Interdisciplinary*, *Multiple Approaches*, *Student Enjoyment*, and *Student Learning*) were referenced an approximately equal number of times when describing beliefs about ideal science teaching, regardless of PSTE level. To elaborate, the data indicate that participants with varying PSTE levels were equally likely to make statements indicating that elementary science teaching should: (a) incorporate elements of direct instruction such as lecture and memorization; (b) involve students communicating with one another; (c) connect the scientific content to other academic disciplines such as mathematics and literacy; and (d) utilize a variety of approaches in order to reach multiple types of learners. Teachers of varying PSTE levels also made an equal number of references to students having fun and to students' learning when describing their beliefs about ideal science teaching.

[13] See Appendix E for a list and description of the six *Fundamental Abilities of Inquiry*.

4.1.3 Perceived Personal Science Teaching

As indicated in Chapter 3, participating teachers differed in their descriptions of their beliefs about how they generally teach science and their beliefs about how they taught during the observed science lesson. For this reason, descriptions of the relationships found between PSTE scores and interview coding categories are divided into two sections: *Perceived General Personal Science Teaching* and *Perceived Observed Personal Science Teaching*.

Perceived General Personal Science Teaching

Teachers' PSTE scores did not significantly correlate ($p < 0.05$) with any of the coded categories (Appendix E) that teachers referenced when describing how they perceived to generally teach science in their own classrooms. However, when an independent sample t-test was performed to compare the mean number of references to the code *Student Control* between the participants with the seven highest PSTE scores and those with the seven lowest PSTE scores[14], a statistically significant difference was found. In other words, the participants with the seven highest PSTE scores made more references to giving students control over their own science learning when describing their general science teaching practices than the seven teachers with the lowest PSTE scores; $t(12) = 2.27$, $p = 0.042$. Also, the correlation between PSTE and the number of references participants made to *Student Control* when discussing their general teaching practices was close-to-significant [$r(36) = 0.22$, $p = 0.193$], further indicating its potential importance. Teachers' references to *Student Control* in this case were similar

[14] See section 3.3.1 for a description of how the highest seven and lowest seven PSTE scores were determined.

to those referred to in ideal science teaching, but were focused on teachers' general practices:

> "If it's something where *they* come up with the question. Like I've got one little girl who really wants to have a worm farm in the classroom. Well, that's a second grade theme, but there's no reason why we can't have a worm farm. So we're going to have a worm farm, you know? I try to do things like that when I can."

> "You need to do it for yourself. Like we planted bean seeds and I think that if I had just planted them, it would have been different. The kids check them every morning and they're much more interested since they're the ones doing it."

In addition, as in the case of perceived ideal science teaching, there were a few coding categories of perceived general personal science teaching that correlated with PSTE scores on a significance level of $p < 0.2$, indicating potential importance. Those categories with positive correlations were *Interdisciplinary* [$r(36) = 0.25$, $p = 0.137$] and *Student Thinking* [$r(36) = 0.22$, $p = 0.182$]. In other words, teachers with higher PSTE levels referenced more statements that indicated, as part of their general science teaching practices, they believe that they incorporate other academic disciplines (e.g. mathematics, literacy, music) into their science. Examples of interview quotes expressing this idea are:

> "There is a limited amount of time in the primary grades to teach science. Most time is spent teaching reading and language arts and math. By integrating and teaching by themes you are able to cover so much more and the kids get so much more out of it. I try to teach this way as best I can."

> "We always incorporate reading [with science]. We're always reading."

> "If I could integrate the entire day and do all of the subject areas while I was teaching a specific subject area, then I'd be in heaven. I try to do that as much as I can. For example, we've got a sunrise/sunset chart that we're

> working on and all of a sudden we have daylight savings time so that changed our whole mathematical approach to it."

Participants with higher PSTE scores also indicated that they make use of strategies to encourage their students to utilize critical-thinking skills, by making slightly more statements such as:

> "I'm really big into, 'Why do you think that?' And it's sad because when you ask kids that they think that they're wrong. Their initial thinking is, 'Oh, I don't know. It's just because.' No. I'm asking you that because I want to know what you're thinking."

> "I tell [my students] all the time that they need to think about things, especially in science where there might not be a clear cut answer. I say, 'What do you think? Why do you think that?'"

> "I want to see what their thought processes are. What are they thinking? How can they get that on paper and how can they show me what they're thinking? That's what I'm looking for, rather than if they followed all the different little procedures."

There was also a close-to-significant negative correlation between PSTE score and the number references teachers made to different *External Influences* that they believed impacted their ability to generally teach science in their classrooms; $r(36) = -0.25$, $p = 0.129$. Teachers with higher science teaching self-efficacy cited slightly fewer factors outside of their control, such as lack of time, lack of materials, and large class sizes, as impacting their general science teaching. Furthermore, when the PSTE scores were truncated to remove all participants outside of two standard deviations from the mean (the three individuals at the lowest end of the PSTE distribution), the correlation between PSTE and number of references to different external influences becomes statistically significant; $r(33) = -0.36$, $p = 0.033$.

All other coded characteristics (*Direct Instruction*, *Managerial*, *Fundamental Abilities of Inquiry*, *Student-Student Communication*, *Content Connections*, *Multiple Approaches*, *Student Enjoyment*, and *Student Learning*) were referred to approximately equally by participants regardless of PSTE score. In other words, teachers with high or low science teaching self-efficacy were just as likely to describe their own science teaching as (a) including aspects of direct instruction such as lecturing and note-taking; (b) focusing on classroom management strategies and/or control of student behavior; (c) incorporating the six *Fundamental Abilities of Inquiry* as described in *Inquiry and the National Science Education Standards* (NRC, 2000); (d) connecting scientific content to the real world, students' lives, and/or other scientific content; and (e) applying multiple approaches to the teaching of science content in order to address students' diverse learning needs. When describing their general science teaching strategies participants also talked about students learning and having fun at the same frequency, regardless of PSTE score.

Perceived Observed Personal Science Teaching

General Code Comparisons. As was the case with teachers' perceived *general* science teaching practices, there were no coding categories for teachers' perceived teaching *during the observed science lesson* that correlated statistically significant ($p < 0.05$) with PSTE scores. There were, however, two coding categories that were found to correlate with PSTE scores at a close-to-significant level ($p < 0.2$). Again, while these correlations were not statistically significant, the values were close enough to significance that these factors warrant further examination.

The first coding category with close-to-significant correlation to PSTE scores was, once again, *Student Control*. Participating teachers with higher PSTE scores made more references to giving students control and/or responsibility over their own learning in the observed science lesson; $r(36) = 0.29$, $p = 0.08$. Examples include:

> "I wanted them to take some time to think about which material would probably absorb the most on their own."
>
> "We've done a couple of hands-on [activities] this year, but this is the first time that I really let them go to do things on their own. Usually, the activities are a little bit more structured."
>
> "I knew [my students] would get more out of the lesson and new information if they were the ones conducting the experiment."
>
> "I let them pick out whatever they wanted, even though we have some duplicates in the other room too. I just wanted them to find something that they wanted to do research on […]. It's their project, something they could really be an expert on."

In addition, statistically significant results were found when a *t*-test was performed to compare the mean number of references to the coding category *Student Control* between the participants with the seven highest PSTE scores ($N = 7$, $M = 1.44$, $SD = 1.11$) and those with the seven lowest scores ($N = 7$, $M = 0.28$, $SD = 0.49$); $t(8.23) = 2.18$, $p = 0.049$ (equal variances not assumed). In other words, those teachers with the highest PSTE scores made on average more statements indicating that they gave students' control over their science learning during the observed lesson (such as those quoted above) than those teachers with the lowest PSTE scores.

The second coding category for perceived observed science teaching that correlated with PSTE scores at a close-to-significant level was *Interdisciplinary*; $r(36) = 0.29$, $p = 0.071$. As was the case with teachers' descriptions of their general science teaching practices, participants with higher PSTE scores made more references to connecting the science content in the observed lesson to academic disciplines outside of science, such as literacy, mathematics, art, and/or music.

No statistically significant or close-to-significant correlations were found between PSTE scores and frequencies of any of the remaining coding categories related to teachers' perceived observed science teaching (*Direct Instruction*, *Managerial*, *Student Thinking*, *Fundamental Abilities of Inquiry*, *Student-Student Communication*, *Content Connection*, *External Influences*, *Multiple Approaches*, *Student Enjoyment*, and *Student Learning*). That is, regardless of their PSTE score, participants were equally likely to claim that in their observed science lesson they (a) included aspects of direct instruction such as lecturing and note-taking; (b) focused on classroom management and/or controlling student behavior; (c) promoted students' thinking skills; (d) incorporated the six *Fundamental Abilities of Inquiry* as outlined by *Inquiry and the National Science Education Standards* (NRC, 2000); (e) had students communicate with each other; (f) connected the science content to the real world, students' lives, and/or other scientific content; (g) were influenced by factors outside of their control such as lack of materials or lack of time; and (h) integrated multiple approaches to address the diverse learning needs of their students. Participants at all PSTE levels were also equally likely to describe their students learning the content and having fun during the observed lesson.

Perceived Success of the Observed Lesson. In addition to the general coding categories (Appendix E), the final interview question ("Overall, how successful do you think the lesson was today? Why?") was coded independently from the rest of the interview questions to determine what specific factors participants perceived to influence the success of the observed lesson. Based on this analysis, the teachers participating in this study described several factors as influencing their beliefs regarding whether or not the lesson was successful (Table 4.1).

Table 4.1. Factors Influencing Success of Observed Lesson in Descending Frequency.

Factor	**% Participants who Cited Factor (*N* = 38)**	**# Participants who Cited Factor out of the Highest 7 PSTE Scores**	**# Participants who Cited Factor out of the Lowest 7 PSTE Scores**
Students Learned	47.4	2	1
Teacher Played Role in Success*	44.7	5	1
Students had Fun*	34.2	4	0
Students Participated	23.7	2	1
External Constraints Impacted the Lesson	21.1	2	0
Students were Engaged in the Fundamental Abilities of Inquiry	21.1	1	1
Students Behaved Well	15.8	3	1
Students were Thinking	7.9	1	0

*Factors for which a statistically significant difference was found between the mean PSTE scores of those participants who did and did not reference the factor ($p < 0.05$)

Independent-sample *t*-tests were conducted to determine whether a statistical significance existed between the mean PSTE scores of teachers who did and who did not report each of the various factors perceived to impact the success of the lesson (Table 4.1). There was a significant difference between PSTE scores for teachers who did ($N = 17$; $M = 51.71$, $SD = 9.08$) and who did not ($N = 21$; $M = 44.05$, $SD = 12.92$)

refer to their own role in the success of the observed lesson; $t(35.39) = 2.14$, $p = 0.039$ (equal variances not assumed). There was also a significant difference found between PSTE scores for teachers who did ($N = 13$; $M = 53.46$, $SD = 2.85$) and who did not ($N = 25$; $M = 44.36$, $SD = 13.55$) cite whether students had fun as a criterion for how successful they perceived the lesson to be; $t(27.85) = 3.23$, $p = 0.003$ (equal variances not assumed). These results suggest that participants with higher science teaching self-efficacy were more likely to (a) take credit for their role in the successes and failures of the lesson, and (b) perceive whether or not their students had fun as a factor impacting the success of the lesson.

Excluding these two factors, participating teachers cited all other factors perceived as impacting science lesson success equally, regardless of PSTE. To elaborate, teachers with high and low PSTE scores were equally likely to cite whether or not students (a) were engaged in the *Fundamental Abilities of Inquiry*; (b) learned the scientific concepts addressed in the lesson; (c) actively participated in the lesson; (d) used higher-level thinking skills; and (e) behaved in an acceptable manner, as criteria for assessing the success of the observed lesson.

4.1.4 Observed Science Teaching

Comparisons of Coded Observed Lessons Among Participants

Overall Lesson Format and Segment Characteristics. Observed science lessons ranged in length from 25 to 90 minutes and were made up of two to eleven different lesson segments. There was no statistically significant difference in length of the lesson or number of segments when comparing teachers with different PSTE scores.

Regarding overall lesson format, there were no statistically significant correlations between PSTE scores and the percentage of time spent during the observed lesson engaged in small group activities, individual activities, whole-class activities, whole-class discussion, direct instruction, or classroom management. However, participants with higher PSTE scores did spend a slightly greater percentage of time in their observed science lessons engaged in activities where students were actively doing something related to the content, rather than talking, listening, or writing notes. This was reflected by the close-to-significant correlation between PSTE scores and percent lesson time engaged in small group, individual, or whole class activities; $r(36) = 0.28$, $p = 0.095$.

No significant correlation was found between PSTE scores and percentage of time during the lesson in which students alone had primary control over the focus and direction of the lesson segment. However, teachers with higher PSTE scores were more often observed giving students primary control or sharing control with their students over lesson segments [$r(36) = 0.22$, $p = 0.178$] and over individual, small group, and whole-class activities [$r(36) = 0.27$, $p = 0.098$] by allowing students to make choices about procedures and pursue their own questions, asking students open-ended questions, and centering instruction on students' ideas. In addition, when compared to teachers with lower PSTE scores, participants with higher PSTE scores spent a smaller percentage of the total lesson time engaged in lesson segments in which they had total control over the focus and direction of the segment; $r(36) = -0.23$, $p = 0.160$. There were, however, no differences found for teachers with different PSTE scores regarding whether the students, teacher and students, or teacher held a majority of control over the focus and direction of whole-class discussions.

There were no statistically significant correlations found between PSTE scores and the percentage of total time spent during the observed lessons engaged in lesson segments that involved high-, medium-, or low-level student thinking. There were also no correlations seen between PSTE scores and level of student thinking required during activities. However, there was a close-to-significant negative correlation between PSTE scores and percentage of total discussion time involving low-level student thinking [$r(36) = -0.27$, $p = 0.096$]; participants with lower PSTE scores spent slightly more class time in whole-class discussions in which students' contributions to the discussion involved only recalled factual information.

***Fundamental Abilities of Inquiry* Observed During Lessons.** There was no correlation between PSTE scores and the total number of *Fundamental Abilities of Inquiry* (out of the six possible) observed in the entire lesson, nor during small-group, individual, and whole-class activities, nor during whole-class discussions.

In order to determine whether teachers with higher PSTE scores were more likely than teachers with lower PSTE scores to be observed incorporating any of the six specific *Fundamental Abilities of Inquiry* into their lessons, independent-sample *t*-tests were conducted comparing the mean PSTE scores between teachers who did and did not incorporate each ability. Of the six abilities, only one was found to be statistically significant; participating teachers who had students plan aspects of an investigation during the observed lesson had higher PSTE scores ($N = 6$, $M = 54.83$, $SD = 4.36$) than those teachers who did not have students plan investigations ($N = 32$, $M = 46.09$, $SD = 12.35$); $t(23.010) = -3.104$, $p = 0.005$ (equal variances not assumed).

Other Characteristics Demonstrated in Observed Lessons. Teachers who were observed using student-student communication during their lessons had slightly higher PSTE scores ($N = 25$, $M = 49.36$, $SD = 10.64$) than teachers who had no observed student-student communication ($N = 13$, $M = 43.85$, $SD = 13.64$), at a close-to-significant level; $t(36) = -1.375$, $p = 0.178$. In addition, teachers with higher PSTE scores spent a larger percentage of the total time in their observed lessons engaged in activities (small group, individual, or whole-class) in which students were encouraged to communicate with each other about their ideas; $r(36) = 0.28$, $p = 0.094$. There was no correlation between PSTE scores and percent of total discussion time in which students communicated with each other.

Regardless of PSTE scores, teachers were equally likely to be observed connecting the scientific content of the lesson to students' lives, the real world, other scientific content, and/or other academic disciplines. This lack of difference held true for the percentage of total activity and discussion time during which participating teachers were observed incorporating these aspects. There was also no statistically significant difference found between the mean PSTE scores of those teachers who did and did not perpetuate scientific misconceptions during the observed lessons.

Relationships Between RTOP and PSTE Scores

Participants' Reformed Teaching Observation Protocol (RTOP) scores ranged from 23 to 84 (out of a possible 100 points) (Figure 4.1) and did not correlate with current grade level teaching [$r(36) = -0.22$, $p = 0.231$], total number of years teaching experience [$r(36) = 0.14$, $p = 0.388$], number of years teaching experience at current grade level [$r(36) = 0.26$, $p = 0.224$], amount of professional development [$r(36) = -0.06$, $p = 0.730$], number of undergraduate science content courses taken [$r(36) = -0.06$, $p = 0.735$], or number of undergraduate science education courses taken [$r(36) = 0.20$, $p = 0.232$]. In addition, mean RTOP scores did not differ significantly based on gender [$t(36) = 0.245$, $p = 0.808$], whether or not teachers were science specialists (taught only science) [$t(36) = -0.420$, $p = 0.677$], or whether or not teachers majored or minored in science as an undergraduate student [$t(36) = 0.001$, $p = 0.999$]. Also, no significant correlations were found between the individual subscales of the RTOP and any of the characteristics of teachers mentioned above.

Overall RTOP scores for the 38 participating elementary teachers were found to correlate statistically significant with PSTE scores [$r(36) = 0.33$, $p = 0.046$]; teachers with higher self-efficacy levels were overall observed to teach in a more reformed manner than teachers with lower self-efficacy levels. However, when the RTOP scores were broken down into the instrument's three primary scoring categories ("Lesson Design and Implementation," "Content," and "Classroom Culture"), it was revealed that the majority of this positive correlation came from the category of "Classroom Culture." That is, there was a statistically significant correlation between PSTE and "Classroom Culture" [$r(36) = 0.42$, $p = 0.009$], but not the other two RTOP scoring categories.

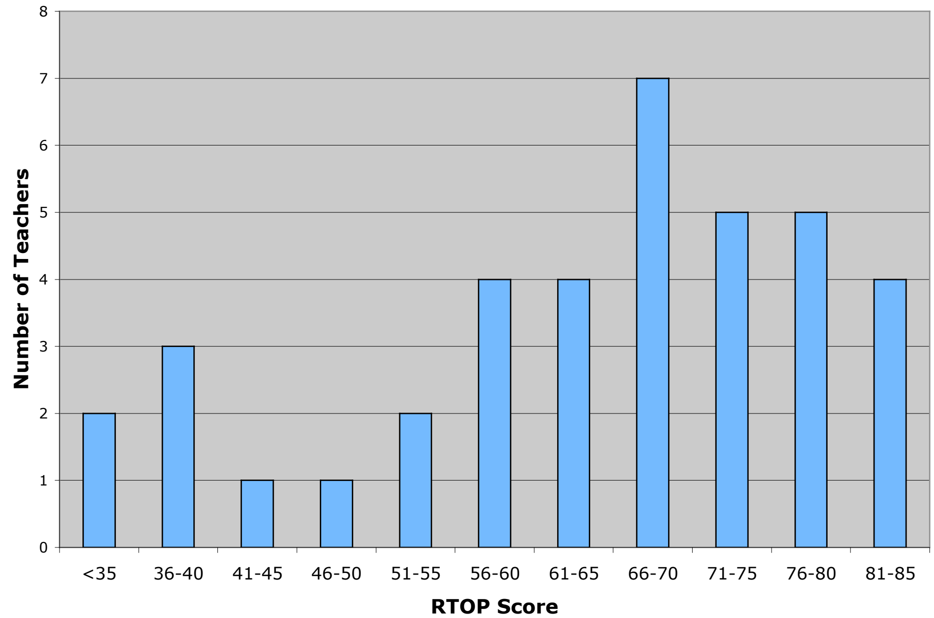

Figure 4.1. RTOP Score Distribution for Participants (*N* = 38).

In examining the ten items included in the "Classroom Culture" category of the RTOP, which is broken into two separate sections of "Communicative Interactions" and "Student-Teacher Relationships" (Appendix B), this correlation seems to support the results from coded categories of observations as described above. Many of the specific RTOP items within "Classroom Culture" that correlated with PSTE scores (Table 4.2) are intimately related to the close-to-significant relationships observed between PSTE scores and the coded observation field notes. These items, especially the one within "Communicative Interactions," refer or are connected to the extent to which the teacher gave students more control over the focus and direction of the lesson by providing students with more opportunities to actively participate, then listening to students' ideas and using those to guide instruction. These are all important aspects of reformed teaching and connect back to the close-to-significant correlation seen between PSTE scores and (a) the percentage of total lesson time in which students were actively participating in activities; (b) the percentage of total *lesson* time in which the students had control, or the students and teacher shared control, of the focus and direction of the segment; and (c) the percentage of total *activity* time in which the students had control, or the students and teacher shared control, of the focus and direction of the segment.

Table 4.2. "Classroom Culture" RTOP Items Significantly Correlating with PSTE Scores.

RTOP Subsection	RTOP Item	Pearson Correlation
Communicative Interactions	Student questions and comments often determined the focus and direction of classroom discourse.	$r(36) = 0.453$ $p = 0.004$
Student/Teacher Relationships*	Active participation of students was encouraged and valued.	$r(36) = 0.477$ $p = 0.002$
	Students were encouraged to generate conjectures, alternative solutions strategies, and ways of interpreting evidence.	$r(36) = 0.358$ $p = 0.027$
	In general the teacher was patient with students.	$r(36) = 0.462$ $p = 0.003$
	The metaphor "teacher as listener" was very characteristic of this classroom.	$r(36) = 0.456$ $p = 0.004$

*In addition, this section as a whole significantly correlated with PSTE; $r(36) = 0.474$, $p = 0.003$.

4.2 Results for Research Question 2

Now that comparisons among the participating elementary teachers based on PSTE levels have been described *within* each of the parts of Research Question 1, the second research question needs to be addressed: How do the participating teachers compare *across* these three parts? The second section of this chapter addresses the answer to this question by describing important themes that emerged from the data spanning across the three categories. This section also serves to discuss some of the ways that the themes emerging from this study compare to the results of other studies.

4.2.1 Student Control, Student Thinking, and Student-Student Communication

A critical characteristic of reformed inquiry-oriented science teaching is that the student, not the teacher, is at the center of instruction (Huffman, Thomas, & Lawrenze, 2008; National Research Council [NRC], 1996). As part of this characteristic, the students in a science lesson (a) have control over their own learning and on the focus and direction of the lesson; (b) develop and use higher-level thinking skills; and (c) communicate their ideas with one another in a collaborative context. Past research studies have suggested a link between science teaching self-efficacy and this characteristic; teachers with higher levels of self-efficacy have been shown to (a) encourage greater student autonomy in their lessons (Czerniak & Shriver, 1994; Enochs, Scharmann, & Riggs, 1995); (b) be more likely to choose activities where students are expected to use higher-level thinking and problem solving skills (Czerniak & Shriver, 1994); and (c) do a better job promoting student-student interactions and student collaboration in the science classroom (Enochs et al., 1995; Haney, Lumpe, Czerniak, & Egan, 2002). The following sections address patterns within and among these aspects for the group of teachers participating in my study.

Patterns Within Coding Categories

Student Control. For the 38 elementary teachers participating in my dissertation study, the category of *Student Control* (the idea that students have control over their own science learning) emerged as potentially the most important characteristic related to science teaching self-efficacy. As described in section 4.1, this characteristic correlated with PSTE scores at a significant or close-to-significant level in every category of teachers' beliefs about science teaching (ideal, general personal, and observed personal) and field notes for the actual observations of teachers' science lessons. In addition, teachers with higher PSTE scores seemed to make fewer references to the management of student behavior when describing ideal science teaching, and were more likely to be observed having students plan aspects of investigations.

When the relationships were examined for participants' references to *Student Control* across the three beliefs described in their interviews, statistically significant or close-to-significant correlations were found between all categories of beliefs (Table 4.3); within the total group of 38 teachers, those who referred to *Student Control* in any one of the categories of perceived science teaching (ideal, general personal, or observed personal) were equally likely to refer to it in the other categories of beliefs. However, no significant relationships regarding *Student Control* were found among beliefs for the seven teachers with the highest PSTE scores, nor for those with the lowest (Table 4.3). In addition, there were no significant correlations between *perceived* observed science teaching and *actual observed* science teaching regarding *Student Control* (Table 4.3); those participants who described their observed lessons as giving students control over their own learning were just as likely to be observed doing this as teachers who did not describe their lessons in this way. This indicates that while participants with higher PSTE levels were more likely to talk about and be observed giving students control over their science learning, overall, *individual* teachers with higher PSTE scores were not necessarily more likely to be consistent between beliefs and practices.

Table 4.3. Correlations Among Perceived and Observed *Student Control*.

	All Teachers (N = 38)	**Teachers with 7 Highest PSTE Scores**	**Teachers with 7 Lowest PSTE Scores**
***Perceived* Science Teaching**			
Ideal vs. General	$\mathbf{r = 0.59, p < 0.001^{**}}$	$r = 0.21, p = 0.650$	$r = 0.26, p = 0.576$
General vs. Observed	$\mathbf{r = 0.28, p = 0.090^{\bullet}}$	$r = 0.00, p = 1.000$	$r = -0.30, p = 0.513$
Ideal vs. Observed	$\mathbf{r = 0.26, p = 0.112^{\bullet}}$	$r = -0.06, p = 0.892$	$r = -0.26, p = 0.576$
***Perceived* vs. *Observed* Science Teaching**			
Perc. Observed vs. Obs. Student or Teacher-Student Control (% of Total Lesson Time)	$r = 0.18, p = 0.270$	$r = -0.01, p = 0.980$	$r = 0.00, p = 0.997$
Perc. Observed vs. Obs. Teacher Control (% of Total Lesson Time)	$r = -0.20, p = 0.235$	$r = 0.01, p = 0.981$	$r = -0.02, p = 0.974$

$^{\bullet}p < 0.2$, $^{**}p < 0.01$

Student Thinking. Participating teachers with higher PSTE scores made more references to developing students' thinking when describing the ways that they *generally* teach science in their classrooms, but not when describing *ideal* science teaching. In addition, while teachers with higher PSTE scores spent *less* time engaged in discussions that involved low-level thinking, there was no difference between the number of references teachers with high or low PSTE scores made to *Student Thinking* when describing their observed lessons. In other words, *beliefs* about the level of students' thinking in observed lessons did not seem to agree with the *actual* observed level of students' thinking.

Table 4.4. Correlations Among Perceived and Observed *Student Thinking*.

	All Teachers (N = 38)	**Teachers with 7 Highest PSTE Scores**	**Teachers with 7 Lowest PSTE Scores**
***Perceived* Science Teaching**			
Ideal vs. General	**$r = 0.59, p < 0.001$****	**$r = 0.93, p = 0.003$****	$r = -0.17, p = 0.721$
General vs. Observed	**$r = 0.22, p = 0.187^{\bullet}$**	$r = 0.44, p = 0.325$	**$r = 0.78, p = 0.040$***
Ideal vs. Observed	**$r = 0.51, p = 0.001$****	$r = 0.37, p = 0.411$	$r = 0.05, p = 0.912$
***Perceived* vs. *Observed* Science Teaching**			
Perc. Observed vs. Obs. High Level Student Thinking (% of Total Lesson Time)	$r = 0.17, p = 0.314$	$r = -0.05, p = 0.915$	$r = -0.07, p = 0.877$
Perc. Observed vs. Obs. High/Medium Level Student Thinking (% of Total Lesson Time)	$r = 0.19, p = 0.255$	$r = -0.10, p = 0.824$	$r = -0.05, p = 0.918$
Perc. Observed vs. Obs. Activities with High /Medium Level Student Thinking (% of Total Activity Time)	**$r = 0.29, p = 0.083^{\bullet}$**	$r = 0.46, p = 0.299$	$r = -0.10, p = 0.839$

$^{\bullet}p < 0.2$, $^{*}p < 0.05$, $^{**}p < 0.01$

In the examination of relationships among areas of teachers' beliefs and observations, it was found that the three categories of belief (ideal, general personal, and observed personal) were generally consistent regarding beliefs about *Student*

Thinking; the correlations between these three categories were significant or close-to-significant for the total group of 38 teachers (Table 4.4). However, while a small amount of consistency was found between the use of *Student Thinking* in the *descriptions* teachers gave of the observed lesson and the *actual* lesson that was observed for the whole group, there were no such correlations for teachers with the highest or lowest PSTE scores (Table 4.4). That is, among the participants with the highest and lowest seven scores, those who did and did not refer to having students use thinking skills during the observed lesson were just as likely to be observed actually having students use higher-level thinking skills.

Student-Student Communication. PSTE scores did not correlate with the number of references teachers made to *Student-Student Communication* (having students communicate with one another) when describing ideal science teaching, the ways they generally teach science, or the ways that they taught science during the observed lesson. However, teachers with higher PSTE scores were more likely to include student-student communication during the actual observed lesson, and were observed to spend more time having students engage in student-student communication during activities. In other words, as was noted before, *beliefs* about student-student communication did not seem to agree with *actual* observed student-student communication.

When making comparisons across areas of belief (ideal, general personal, and observed personal), significant or close-to-significant correlations can be seen between beliefs about general and observed science teaching for the whole group of teachers and for those with the highest seven PSTE scores, but not for those with the lowest seven PSTE scores (Table 4.5). That is, for participants with the highest, but not the lowest science teaching self-efficacy, if they described the ways that they generally teach science as including having students talk to one another, they also described the observed lesson in this way. However, although there was a close-to-significant correlation between perceived observed and actual observed *Student-Student Communication* for the overall group of teachers, there was no such correlation for those groups with the highest and lowest PSTE scores (Table 4.5)

Table 4.5. Correlations Among Perceived and Observed *Student-Student Communication*.

	All Teachers (N = 38)	**Teachers with 7 Highest PSTE Scores**	**Teachers with 7 Lowest PSTE Scores**
***Perceived* Science Teaching**			
Ideal vs. General	$r = 0.11, p = 0.485$	$r = 0.30, p = 0.513$	$r = -0.09, p = 0.856$
General vs. Observed	$\mathbf{r = 0.25, p = 0.129^{\bullet}}$	$\mathbf{r = 0.93, p = 0.002^{**}}$	$r = -0.51, p = 0.243$
Ideal vs. Observed	$r = 0.10, p = 0.535$	$r = 0.50, p = 0.257$	$r = -0.19, p = 0.680$
***Perceived* vs. *Observed* Science Teaching**			
Perc. Observed vs. Obs. Student-Student Communication (% of Total Lesson Time)	$\mathbf{r = 0.28, p = 0.094^{\bullet}}$	$r = 0.24, p = 0.604$	$r = -0.11, p = 0.809$

$^{\bullet}p < 0.2$, $^{**}p < 0.01$

Patterns Across Coding Categories

As described earlier, *Student Control*, *Student Thinking*, and *Student-Student Communication* are not isolated categories, but instead are all part of student-centered science instruction. This type of instruction encourages students to have control over their own learning by being given the opportunity to think critically for themselves and to learn to solve problems through collaboration with their peers. Indeed, participants in this study (those in the whole sample as well as those with the highest and lowest PSTE scores) made several links during their interviews between these ideas (Table 4.6). For example, when describing how science should be taught versus their own science teaching practices, teachers indicated that students have control of their own learning of science by developing the skills to think and solve problems on their own:

> "It should be getting students, or children really, to figure things out for themselves and use their own mind and use their own thinking."

> "You have to use higher level questions and try to get them to be thinking on their own rather than just repetitive things, just repeating back words."

> "I like for them to think on their own because if you just tell them everything… That's how science was taught to me and it was really, really, really boring in elementary school."

In some cases, teachers explicitly described how they make a point to take what their students are thinking and use it to direct instruction or class discussion. For example:

> "If I do have a problem in some area, we stop. 'Well, what's going on here? What are you thinking? Why are you thinking that? Can somebody help out here? How would you describe this?' And go from there. That's the best kind of teaching moment, in my opinion. And this class has gotten to a point where they are really a bunch of conversationalists and they know at any second I could stop and say, 'We're going to talk about that. Let's go here.' And they're ready and willing to go with it."

Participants also described a connection between giving students control during the lesson and having students communicate with one another. For example, during her interview one teacher said:

> "I chose for students to explore the objects in the bags in groups because I think the most meaningful learning occurs when students are able to touch it, do, and discover on their own. They are able to run their ideas by their peers and can add to and learn more through these discussions. However, it was important that I was not simply telling the students, but letting them see for themselves. *They* come up with the ideas and develop them together."

Table 4.6. Correlations Between Perceived *Student Control*, *Student Thinking*, and *Student-Student Communication*.

	All Teachers ($N = 38$)	**Teachers with 7 Highest PSTE Scores**	**Teachers with 7 Lowest PSTE Scores**
Student Control vs. Student Thinking	Ideal vs. Ideal $r = 0.41, p = 0.010$** Ideal Control vs. General Thinking $r = 0.30, p = 0.073$* General vs. General $r = 0.26, p = 0.112^{\bullet}$	Ideal vs. Ideal $r = 0.81, p = 0.026$* Ideal Control vs. General Thinking $r = 0.60, p = 0.154^{\bullet}$	Ideal vs. Ideal $r = 1.00, p < 0.001$** General vs. General $r = -0.65, p = 0.117^{\bullet}$
Student Control vs. Student-Student Communication	---	Observed vs. Observed $r = -0.73, p = 0.060$* Observed Control vs. General Communication $r = -0.79, p = 0.035$*	Ideal Control vs. Observed Communication $r = 0.80, p = 0.031$*
Student-Student Communication vs. Student Thinking	Observed Communication vs. Ideal Thinking $r = 0.25, p = 0.125^{\bullet}$ Ideal Communication vs. Observed Thinking $r = 0.25, p = 0.133^{\bullet}$ Ideal vs. Ideal $r = 0.26, p = 0.123^{\bullet}$ General vs. General $r = 0.26, p = 0.112^{\bullet}$	Observed Communication vs. Ideal Thinking $r = 0.73, p = 0.062^{\bullet}$ Observed Communication vs. General Thinking $r = 0.73, p = 0.060^{\bullet}$	Observed Communication vs. Ideal Thinking $r = 0.80, p = 0.031$*

$^{\bullet}p < 0.2$, *$p < 0.05$, **$p < 0.01$

In addition, connections among student control, student thinking, and student-student communication were also seen in the ways participants were observed teaching science. These are particularly apparent in the relationships seen between PSTE scores and RTOP scores; all individual RTOP items that significantly or close-to-significantly correlated with PSTE scores were within the RTOP category of "Classroom Culture," and were closely connected to the idea of giving students more power in the lesson by allowing them opportunities to actively participate with one another and by listening to students' ideas in order to build upon them (Table 4.2).

4.2.2 Hands-on Versus Inquiry

Beliefs About Hands-on Compared to Observed Hands-on

Past research studies have suggested that elementary teachers with higher levels of science teaching self-efficacy claim to do more hands-on activities in their science lessons than teachers with lower levels of self-efficacy (Marshall, Horton, Igo, & Switzer, 2009; Ramey-Gassert et al., 1996). Those with higher levels of self-efficacy are also more likely to claim that activity-based instruction, in which students learn through cooperation and experience, is the most appropriate method of teaching science at the elementary level (Enochs, Sharmann, & Riggs, 1995). For the teachers in the study presented in this dissertation, however, there was no difference in the number of times teachers of varying PSTE levels referred to *Hands-on* activities. In other words, a majority of participants, regardless of self-efficacy level, referred to *Hands-on* in reference to their beliefs about ideal elementary science instruction (92%), beliefs regarding the ways they generally teach science in their own classrooms (87%), and beliefs about how they taught the observed science lesson (55%).

When comparing teachers' *beliefs* regarding *Hands-on* and their *observed* teaching behaviors, however, there was a difference. That is, while there was no difference among the *beliefs* of teachers with different PSTE scores regarding *Hands-on*, teachers with higher PSTE scores were actually *observed* to spend a greater percentage of total lesson time engaging in individual, small group, or whole-class activities (as opposed to discussions or direct instruction).

Beliefs About Hands-on Compared to Observed Inquiry

While past research has suggested that teachers with higher science teaching self-efficacy are more likely to incorporate inquiry into their lessons (Bhattacharyya, Volk, & Lumpe, 2009; Haney et al., 2002; Lakshmanan et al., 2011; Nolan et al., 2011), teachers in the current study with higher PSTE scores overall did not reference significantly more *Fundamental Abilities of Inquiry* when *describing* their own science teaching, or when actually being *observed* teaching a science lesson. In addition, there was no correlation found between the number of times teachers (all 38, those with the highest seven PSTE scores, or those with the lowest seven PSTE scores) referenced *Hands-on* when describing their general science teaching practices and the amount of inquiry observed during their science lessons. In other words, regardless of PSTE level, teachers who described ideal science teaching and the ways that they generally teach science as "hands-on" were equally likely to be observed using inquiry characteristics in their classrooms.

When comparing the number of times teachers referenced *Hands-on* when *describing* their observed lessons and the number of inquiry abilities that were *actually observed* during the lesson, there was no correlation found for the total group of 38 teachers, nor for the seven teachers with the lowest PSTE scores. However, a close-to-significant negative correlation was found between these two variables for those teachers with the highest seven PSTE scores; $r(5) = -0.702$, $p = 0.078$. In other words, while there was no relationship between what teachers said and what they were observed doing for the general group or for those with the lowest PSTE levels, those teachers with the highest PSTE scores who described their lesson as "hands-on" actually incorporated *fewer* inquiry abilities into their observed lessons. This result suggests that teachers with the highest science teaching self-efficacy levels do not necessarily have an equal understanding of what "hands-on" or "inquiry" means as it applies to teaching science in the elementary classroom, which potentially has important ramifications for the relationships between science teaching self-efficacy and practice.[15]

Beliefs About Inquiry Compared to Observed Inquiry

Overall Comparisons. Correlation values between teachers' number of references to *perceived Fundamental Abilities of Inquiry* during their interviews and abilities of inquiry *actually observed* during the lessons are shown in Table 4.7. As we can see, several significant positive correlations exist between perceived and observed inquiry for the overall group of participants. On the other hand, when examining these correlations among teachers with the highest and lowest PSTE scores, no statistically

[15] In Chapter 5 this topic is discussed in greater detail as it relates to examples of specific teachers.

significant correlations exist. There are, however, a few correlations that were found to be close-to-significant ($p < 0.2$), signifying relationships that may be of potential interest and importance for future study. For example, among the participants with the lowest seven PSTE scores, there was a negative correlation found between the number of times teachers referenced abilities of inquiry when *describing* their general science teaching practices and both the number of inquiry abilities [$r(5) = -0.58$, $p = 0.172$] and the total percentage of time engaged in inquiry [$r(5) = -0.75$, $p = 0.054$] *actually observed* during their lessons (Table 4.7). In other words, for teachers with the *lowest* self-efficacy, those who *described* using *more* inquiry abilities in their classroom in general were *observed* applying *fewer* inquiry abilities in their observed lessons. For those teachers with the *highest* PSTE levels, however, there was a positive correlation between the number of references they made to inquiry abilities when describing ideal science teaching, and the total number of inquiry abilities they were actually observed using in the classroom; $r(5) = 0.58$, $p = 0.176$ (Table 4.7).

It is important to note that, for teachers with the highest and lowest PSTE scores, there was no correlation found between teachers' *perceived* amount of inquiry used during the observed lesson and the *actual* amount of inquiry observed during the lesson (Table 4.7). That is, those teachers with the highest and lowest PSTE scores who described or did not describe using abilities of inquiry during their observed lesson were just as likely to be actually observed applying abilities of inquiry in the classroom. Thus, ultimately, for those with the highest and lowest PSTE scores, there was no significant relationship between what they said and what they did regarding inquiry in the observed lesson, and the amount of inquiry they were actually observed to use. Just as there was no significant correlation between PSTE scores and the number of references teachers made to their *perceived* use of inquiry in the observed lessons, there was no correlation between PSTE scores and the amount of inquiry teachers were *observed* to use during the lesson.

Table 4.7. Correlations Between Perceived and Observed Abilities of Inquiry.

	# Inquiry Abilities *Observed* During Lesson (out of 6)			**% *Observed* Lesson Time Spent in Segments with any Inquiry Abilities**		
Total # References to Abilities of Inquiry when Describing:	*All Teachers (*N = *38)*	*Teachers with Lowest 7 PSTE Scores*	*Teachers with Highest 7 PSTE Scores*	*All Teachers (*N = *38)*	*Teachers with Lowest 7 PSTE Scores*	*Teachers with Highest 7 PSTE Scores*
Perceived Ideal Science Teaching	***r* = 0.39** ***p* = 0.016***	*r* = -0.13 *p* = 0.780	***r* = 0.58** ***p* = 0.176**$^{\bullet}$	***r* = 0.37** ***p* = 0.024***	*r* = -0.28 *p* = 0.538	*r* = 0.10 *p* = 0.824
Perceived General Personal Science Teaching	***r* = 0.29** ***p* = 0.078**$^{\bullet}$	***r* = -0.58** ***p* = 0.172**$^{\bullet}$	*r* = 0.48 *p* = 0.277	*r* = 0.09 *p* = 0.604	***r* = -0.75** ***p* = 0.054**$^{\bullet}$	*r* = 0.26 *p* = 0.575
Perceived Observed Personal Science Teaching	***r* = 0.47** ***p* = 0.003****	*r* = 0.44 *p* = 0.319	*r* = -0.14 *p* = 0.771	***r* = 0.38** ***p* = 0.019***	*r* = 0.27 *p* = 0.565	*r* = -0.38 *p* = 0.397

$^{\bullet}p < 0.2$, $^{*}p < 0.05$, $^{**}p < 0.01$

Comparisons Among Specific *Fundamental Abilities of Inquiry*. Overall, participants with the seven *highest* PSTE scores referenced more of the six specific *Fundamental Abilities of Inquiry* (Table 4.8) than did participants with the seven *lowest* PSTE scores (Table 4.9). Of those abilities that were referenced, however, most correlated across areas of *perceived* science teaching for both groups. Regardless of PSTE, for those inquiry abilities that were mentioned during interviews, there was general agreement between a majority of the inquiry abilities teachers said they believed should ideally be included in science teaching and the abilities they described using in their own classrooms in general and during the observed lesson (Tables 4.8 and 4.9).

Table 4.8. Abilities of Inquiry Correlating Across Beliefs for Participants with the Highest Seven PSTE Scores

Inquiry Ability	**Perceived Ideal vs. Perceived General**	**Perceived Ideal vs. Perceived Observed**	**Perceived General vs. Perceived Observed**
Students ask questions	$r = 0.43$ $p = 0.332$	$r = -0.18$ $p = 0.707$	$r = 0.30$ $p = 0.508$
Students plan investigations	$r = -0.17$ $p = .721$	---[a]	---[a]
Students gather data	$r = 0.26$ $p = 0.576$	$r = 0.30$ $p = 0.513$	**$r = 0.71$** **$p = 0.074^{\bullet}$**
Students formulate explanations	**$r = 0.93$** **$p = 0.003$****	---[a]	---[a]
Students communicate ideas	**$r = 0.64$** **$p = 0.119^{\bullet}$**	**$r = 0.71$** **$p = 0.075^{\bullet}$**	**$r = 0.86$** **$p = 0.013$***
Students make predictions	**$r = 1.00$** **$p < 0.001$****	**$r = 1.00$** **$p < 0.001$****	**$r = 1.00$** **$p < 0.001$****

$^{\bullet}p < 0.2$, *$p < 0.05$, **$p < 0.01$

[a]This ability was not mentioned for perceived observed science teaching.

Table 4.9. Abilities of Inquiry Correlating Across Beliefs for Participants with the Lowest Seven PSTE Scores.

Inquiry Ability	Perceived Ideal vs. Perceived General	Perceived Ideal vs. Perceived Observed	Perceived General vs. Perceived Observed
Students ask questions	***r* = 0.64** **p = 0.124˙**	*r* = 0.09 *p* = 0.846	*r* = 0.19 *p* = 0.677
Students plan investigations	---[a]	---[a]	---[a]
Students gather data	---[b]	---[b]	***r* = 0.94** ***p* = 0.001****
Students formulate explanations	---[b]	---[b]	***r* = 1.00** ***p* < 0.001****
Students communicate ideas	---[b]	---[b]	*r* = -0.37 *p* = 0.418
Students make predictions	---[a]	---[a]	---[a]

˙$p < 0.2$, *$p < 0.05$, **$p < 0.01$
[a]This ability was not mentioned during interviews.
[b]This ability was not mentioned for perceived ideal science teaching during interviews.

On the other hand, there were important differences between the high and low PSTE groups in how *beliefs* of these teachers regarding specific inquiry abilities correlated with the abilities that were *actually observed* during the lesson. For the seven teachers with the highest PSTE scores, the only inquiry ability for which beliefs correlated with actual observed practice at a close-to-significant level was *Students Plan Investigations*; $r(5) = 0.65$, $p = 0.117$ (Perceived Ideal versus Observed). That is, among the teachers with the highest PSTE scores, those who made more references to having students plan investigations as part of ideal science teaching, were more likely to actually have students plan components of investigations during the observed lessons.

Among teachers with the seven lowest PSTE scores, beliefs correlated negatively at a significant or close-to-significant level for two *Fundamental Abilities of Inquiry*: *Students Ask Questions* [$r(5) = -0.65$, $p = 0.117$, Perceived Ideal versus

Observed] and *Students Communicate Ideas* [$r(5) = -0.80$, $p = 0.031$, Perceived General versus Observed]. In other words, among teachers with the lowest PSTE scores, it seems that those who made more references to encouraging students to ask questions as part of their descriptions of ideal science teaching, or who made more references to having students communicate their ideas as part of their descriptions of their general science teaching practices, were *less* likely to be actually observed doing these things in their classrooms.

4.2.3 Scientific Content and Interdisciplinary Connections

Another important component of reformed science teaching cited in the literature is that teachers take the scientific content in a lesson and make it meaningful for students by connecting it to the real world, students' lives, related scientific content, and/or other academic disciplines (NRC, 1996; Sawada & Pilburn, 2000). Past research studies suggest a link between science teaching self-efficacy and this component of reformed teaching; teachers with higher science teaching self-efficacy have been reported to do a better job connecting and attending to students' prior knowledge and experiences along with tying the content to the real world and other content areas (Haney et al., 2002; Riggs, Enochs, & Posnanski, 1998).

In the case of the study presented here, within all three categories of teachers' beliefs (ideal, general personal, and observed personal), teachers with higher PSTE scores did appear to make more references to connecting scientific content to students' lives, the real world, related scientific content, and/or other academic disciplines such as mathematics, literacy, or art. However, they were no more likely than teachers with lower levels of self-efficacy to be *actually observed* making these connections during their lessons. To elaborate, even though participating teachers with higher science teaching self-efficacy *claimed* to incorporate more relevant connections with scientific content during their lessons, they were not *observed* to actually do this more often in their classrooms. In addition, while there appeared to be a general consistency among beliefs regarding content and interdisciplinary connections, there was no apparent consistency between perceived and actual observed teaching practices (Table 4.10).

Table 4.10. Relationships Among Perceived and Observed *Content Connections*.

	All Teachers (N = 38)	**Teachers with Lowest 7 PSTE Scores**	**Teachers with Highest 7 PSTE Scores**
***Perceived* Science Teaching**			
Ideal vs. General	**r = 0.51, p = 0.001****	r = -0.13, p = 0.789	**r = 0.75, p = 0.054•**
General vs. Observed	**r = 0.59, p < 0.001****	r = 0.41, p = 0.360	r = 0.29, p = 0.538
Ideal vs. Observed	**r = 0.37, p = 0.021***	**r = -0.73, p = 0.062•**	**r = 0.74, p = 0.057•**
***Perceived* vs. *Observed* Science Teaching**			
Perc. Observed vs. Obs. (% of Total Lesson Time)	r = 0.15, p = 0.383	r = 0.29, p = 0.535	r = 0.22, p = 0.634
Perc. Observed vs. Obs. with Discussion (% of Total Discussion Time)	r = -0.08, p = 0.648	r = -0.44, p = 0.325	r = 0.36, p = 0.433
Perc. Observed vs. Obs. with Activities (% of Total Activity Time)	r = 0.10, p = 0.280	r = 0.14, p = 0.762	r = 0.12, p = 0.794

•p < 0.1, *p < 0.05, **p < 0.01

4.2.4 External Influences

Related research literature has suggested that teachers with lower science teaching self-efficacy feel a greater influence of external factors on their ability to teach science effectively, and thus cite these factors more often as influencing their teaching practices and impacting whether or not a science lesson was successful (Carleton, Fitch, & Krockover, 2008; Ramey-Gassert et al., 1996; Rubeck, 1990). On the other hand, teachers with higher self-efficacy levels have been shown to be more likely to take responsibility for both the successes and failures of a lesson (Czerniak & Schriver, 1994). This is important, since it has been suggested that teachers with lower self-efficacy are more likely to give up trying to teach science effectively due to factors outside of the teacher's control and perceived as being insurmountable, while those with higher self-efficacy feel more empowered to create an environment for effective science learning through their own actions.

While the former claim did not entirely hold true for the teachers participating in my study, the latter did appear to manifest itself among participants. Although the teachers participating in this study who had higher PSTE scores referenced somewhat fewer (but not significantly so) external influences when describing their general teaching, they cited just as many when describing their observed lesson as those with lower PSTE levels. However, when describing the success of their observed lesson[16], those teachers with higher PSTE levels were more likely to reflect on the pros and cons

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[16] Refer to section 4.1.3 for a description of the factors that participants referenced when describing their perceived success of the observed lessons.

of their lesson as they related to their own role in making the lesson a success. For example, those with higher PSTE scores said things during their interviews such as:

> "I wish I had more knowledge about the polymer, about the crystal itself, and maybe historically why and how it was developed. For those specific kids they probably could have used that information. So I felt good about it, but there's always something you can do better."

> "There was a little period of time where I though it lagged a bit, but when I pulled out the thermometers off it ran, which is what I was looking for. So I might have gone a little too long at that point in time, but they were still talking to each other and I don't like to stop it when they're talking to each other."

> "It was also successful because I created a fun learning environment where all the students were engaged."

This indicates that, for teachers participating in the current study, those with higher science teaching self-efficacy do feel more power to impact the effectiveness of their science lessons through their own actions, although overall they do not appear to feel less constraint from factors outside of their control.

4.2.5 Student Enjoyment Versus Learning

Another reason that has often been cited for why science teaching self-efficacy is important when preparing effective elementary science teachers is that teachers with higher self-efficacy tend to put more emphasis in their lessons on students' learning and understanding of the scientific content rather than on students simply having fun (Czerniak & Schriver, 1994; Riggs et al., 1998). In addition, teachers with higher self-efficacy have been reported to hold fewer scientific misconceptions (Schoon & Boone, 1998), have greater knowledge about scientific concepts (Angle & Moseley, 2009; Desouza, Boone, & Yilmaz, 2004; Hechter, 2011; Ramey-Gassert et al., 1996), and are more likely to present accurate scientific content to their students (Haney et al., 2002).

Therefore, teachers with higher PSTE levels should do a better job effectively teaching accurate science content to students.

The data presented in this dissertation, however, suggest that this positive correlation between science teaching self-efficacy and the promotion of students' learning of accurate scientific concepts did not hold true among the 38 elementary teachers. For example, participants with higher self-efficacy made just as many references to promoting student learning when describing how they perceived ideal science teaching and their own science teaching practices. In addition, teachers with higher PSTE actually made more references to the goal of having students enjoy science and were more likely to talk about students' apparent enjoyment when describing their perceived success of the observed lesson. Perhaps most importantly though, during the observed lessons, teachers with both high and low science teaching self-efficacy were just as likely to promote misconceptions about the scientific concepts by giving students information that was scientifically incorrect. For example, teachers with relatively high PSTE scores (53 and 54) were observed to tell their students during their lessons that the moon produces its own light, palm trees do not exist in the desert, and the goal of science is to prove scientific facts.

4.3 Chapter Summary

Other research studies have reported that teachers with higher science teaching self-efficacy appear to incorporate (or *say* they incorporate) a wide variety of favorable teaching practices in their science classrooms that their lower-efficacy colleagues do not, including:

- encouraging greater student autonomy or control over their science learning (Czerniak & Schriver, 1994; Enochs et al., 1995);
- being more likely to choose activities in which students are expected to use higher-level thinking skills (Czerniak & Schriver, 1994);
- doing a better job promoting student-student interactions and student collaboration (Enochs et al., 1995; Haney et al., 2002);
- incorporating more hands-on (Enochs et al., 1995; Marshal et al., 2009; Ramey-Gassert et al., 1996) and inquiry-based (Bhattacharyya et al., 2009; Haney et al., 2002; Lakshmanan et al., 2011; Marshall et al., 2009; Nolan et al., 2011) activities;
- attending more effectively to students' prior knowledge and experiences and connecting scientific content to the real world and other content areas (Haney et al., 2002; Riggs et al., 1998);
- putting greater emphasis on students' learning and understanding of accurate scientific content rather than simply just having fun (Czerniak & Schriver, 1994; Haney et al., 2002; Riggs et al., 1998);
- feeling less constrained by external factors on their ability to teach science effectively (Carleton et al., 2008; Ramey-Gassert et al., 1996; Rubeck, 1990); and
- taking responsibility for the successes and failures of a science lesson (Czerniak & Schriver, 1994).

Regarding the above, many of these factors seemed to manifest themselves in individuals with higher PSTE levels for the inservice elementary teachers participating in my study when *describing* their beliefs about how they teach science. The data presented in this chapter suggests that the teachers in this sample with higher science teaching self-efficacy were more likely to report to (a) allow students to have greater control over their own science learning in general and during the observed lesson; (b) incorporate more connections between scientific content and other academic disciplines such as mathematics or literacy in general and during the observed lesson; (c) put a greater emphasis on developing student thinking in general (but not during the observed lesson); (d) feel less constrained in their ability to effectively teach science by factors that are outside of their control in general (but not during the observed lesson); and (e) take responsibility for their perceived successes and failures of the observed lesson.

However, even more importantly than what teachers *say* they do is what they are actually observed *doing* in their classrooms. In the case of the teachers participating in this study, it appears that teachers with higher PSTE scores were more likely than their colleagues with lower PSTE scores to encourage their students to have control or autonomy over their own science learning, including giving students more opportunities to plan aspects of scientific investigations and to communicate and collaborate with their fellow students. However, while teachers with higher self-efficacy were observed to spend more time engaged in individual, small-group, and whole-class activities, they were *not* more likely to incorporate more *Fundamental Abilities of Inquiry* as described in *Inquiry and the National Science Education Standards* (NRC, 2000), excluding allowing students to plan investigations. Participating teachers with higher PSTE scores did also *not* appear to overall (a) do a better job of connecting scientific content to students lives, the real world, and/or other academic disciplines; (b) provide more opportunities for students to use higher-level thinking skills; or (c) promote fewer scientific misconceptions, during the observed science lesson.

Overall, therefore, the results presented in this chapter indicate that, while a few of the purported benefits of higher science teaching self-efficacy seem to hold true for this diverse nationwide sample, not all carried over to observations of the teachers' science classroom practices. This should give us pause when making blanket assumptions regarding the overall benefits of increasing science teaching self-efficacy for elementary teachers and when considering the mechanisms behind the association between efficacy beliefs and practice. That is, it appears that not all teachers with elevated efficacy beliefs incorporate all of the aspects of reformed science teaching that we would hope. Results also suggest that the relationships between science teaching self-efficacy and science teaching behaviors are complex, and not as straightforward as they are sometimes assumed to be. The next chapter addresses some of these complexities by describing a few of the specific relationships that exist between science teaching self-efficacy beliefs and science teaching classroom practices for eight case profile teachers within the study sample.

CHAPTER 5: RESULTS FOR CASE PROFILE TEACHERS

As indicated by the results presented in Chapter 4, the relationships between science teaching self-efficacy and reformed science teaching practices are complex. Chapter 5 serves to explore some of these complexities that may not be immediately apparent from the overall coded or survey data presented in the previous chapter. In order to accomplish this, the interviews and observations of eight case profile teachers were examined and described in greater depth.

The first section of this chapter describes the characteristics of these eight teachers, including an explanation as to why they were chosen. Next, the major themes that emerged among the eight case profile teachers regarding their science teaching self-efficacy and classroom practices are discussed. Within the third section of this chapter, I provide a discussion of what was learned from the case profile teachers as related to relevant research literature. Finally, the last section summarizes the chapter and outlines possible implications of the results.

5.1 Characteristics of Case Profile Teachers

In order to examine some of the possible complex relationships among science teaching self-efficacy, beliefs about science teaching, and actual science teaching practices, eight teacher case profiles were examined by utilizing detailed field notes and transcriptions from the teachers' observations and interviews. These eight teachers were chosen from among the total 38 teachers based upon the agreement or non-agreement between their level of self-efficacy and the amount of reform actually observed during their science lessons; two of the teachers had high *Personal Science Teaching Efficacy* (PSTE)[17] scores and high Reformed Teacher Observation Protocol (RTOP)[18] scores, two had low PSTE scores and low RTOP scores, and the remaining four had mixed scores[19]. Besides these two scores, the eight teachers were of mixed gender, taught a variety of grade levels at diverse school settings, and varied in their amount of experience with science content and teaching. The specifics of these case profiles can be found in Table 5.1.

5.2 Themes Among Case Profiles

In examination of the eight teacher case profiles, several key themes related to teacher beliefs interacting with self-efficacy and science teaching behaviors emerged: (a) their meaning of "hands-on"; (b) level of classroom control; (c) ongoing university faculty support; (d) beliefs about provided curriculum; and (e) availability of resources. These themes, which I discus in the following narrative, help to explain some of the differences in the manifestation of high or low reform-levels in observed teaching with such disparate levels of self-efficacy. Because not all of these themes were relevant to all eight of the case profile teachers, only those teachers for which each theme was pervasive are included in the following discussion.

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[17] PSTE scores were measured using the Science Teaching Efficacy and Beliefs Instrument (STEBI-A), found in Appendix D and described in section 3.2.2.
[18] Refer to Appendix B and section 3.2.2 for further information regarding the RTOP.
[19] See Figures 3.1 and 4.1 for relative distributions of PSTE and RTOP scores.

Table 5.1. Characteristics of Case Profile Teachers.

Teachers	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**
Score Designation	High PSTE / High RTOP		Low PSTE / High RTOP		High PSTE / Low RTOP		Low PSTE / Low RTOP	
PSTE*	58	63	21	25	55	54	17	22
RTOP**	81	82	84	84	48	40	37	29
Gender	Female	Female	Female	Male	Female	Female	Female	Male
Type of School	Private	Public	Public	Public	Public	Private	Public	Public
Grade Level	2^{nd} Grade	3^{rd} Grade	2^{nd} Grade	6^{th} Grade	$4^{th}/5^{th}$ Combo	3^{rd} Grade	6^{th} Grade	4^{th} Grade
Total Years Taught	3	1	21	4	11	3	1	4
Years Taught at Current Grade	3	1	16	2	1	3	1	1
Science Background	Several undergraduate science courses for preservice teachers	Extensive	Few undergraduate science courses (did not remember)	Extensive	None	Few undergraduate science courses	Four undergraduate science courses for preservice teachers	Four required science courses as an undergraduate
Science Education Background	One science teaching methods course	Extensive (Currently earning her M.S. degree in science education)	None	Extensive (Has an M.S. in education with a focus on science)	None	One science methods course	Two elementary science education courses	One science methods course
Professional Development	Some	Extensive	Some	Extensive	None	Some	Some	None

* Maximum possible score for PSTE is 65, as measured by the STEBI-A.

** Maximum possible score for the RTOP is 100.

5.2.1 The Meaning of "Hands-on"

Among the overall group of 38 teachers, as discussed in Chapter 4, those individuals with higher PSTE scores were found to be just as likely as those with lower scores to describe the best ways to teach science, as well as the ways they generally teach science in their own classrooms, as being "hands-on." However, there was no correlation found for the study's 38 teachers between their *descriptions* of the observed lessons as being "hands-on" and the *actual* amount of inquiry, nor the amount of time spent engaged in activities (as opposed to whole-class discussion, direct instruction, and/or managerial tasks), observed during the lessons. Furthermore, teachers with the highest seven PSTE scores, who described their observed lesson as being "hands-on," were actually observed to incorporate fewer fundamental abilities of inquiry[20] into their lessons. This indicates that the teachers participating in this study do not necessarily have an equivalent understanding of what "hands-on" science means, nor do they all equate this term with inquiry-based instruction. In examining the eight case profile teachers' specific beliefs about what the term "hands-on" means, we can explore some specific examples of how these beliefs relate back to self-efficacy and the behaviors these teachers exhibited during their science lessons.

As was the case with the overall sample of participants, all eight case profile teachers expressed "hands-on" to be the best way to teach science at the elementary level. However, the teachers varied greatly in their description of what the term "hands-on" means to them and, in turn, the ways that "hands-on teaching" was manifested in

[20] The six fundamental abilities of inquiry, as outlined in *Inquiry and the National Science Education Standards* (NRC, 2000) are described in Appendix E.

their observed lessons. In addition, teachers' beliefs about the meaning of "hands-on" seemed to impact not only the ways that they taught the observed science lessons, but also the beliefs about their own efficacy as teachers of science.

The two teachers who had low RTOP scores and high PSTE scores (T5 and T6) both felt that they were teaching science the way that it should be taught, in a "hands-on" manner. However, observations and interviews revealed that both of these teachers had images of effective activity-based science teaching that were very different from a reformed inquiry-oriented view of science teaching. T6, for example, described working with computers and having her students answer simple questions on the SMART Board as "hands-on" and "interactive." Since she was confident in her ability to integrate technology into her science lessons due to her participation in professional development workshops, she felt that she was teaching science effectively, both in her general teaching and during the lesson we observed. Her actual observed lesson, however, showed that her activities involved no complex student thought or interaction, nor did she incorporate any of the fundamental abilities of inquiry as described in *Inquiry and the National Science Education Standards* (National Research Council [NRC], 2000). In addition, T6 actually perpetuated misconceptions about the science content during her lesson to her students, repeating multiple times that the moon is a luminous object and creates its own light. (She seemed confused by and chose to ignore the fact that the SMART Board did not register this as a correct answer.) Similarly, T5 described her lesson in which her fourth and fifth graders blew bubbles as "hands-on," the kind of activity that she "should really be doing all the time for science" (*Interview Transcript for T5*). Although her students did use their hands to conduct an activity in her observed lesson, little student thought or reflection in connecting the activity to the science content was apparent. In the cases of both T5 and T6, beliefs about effective science teaching, although they did not match a reformed inquiry-oriented view of science teaching, served to bolster these teachers' perceived self-efficacy while effectively decreasing the level of reform in their actual observed teaching practices.

On the other end of the spectrum, all four teachers with high RTOP scores (T1, T2, T3, and T4) described "hands-on" science in a more inquiry-based context that much more closely aligned with current national science education guidelines (Huffman, Thomas, & Lawrenz, 2008; NRC, 1996, 2000). In addition, their observed lessons incorporated a majority of the fundamental abilities of inquiry and included multiple lesson segments in which students were encouraged to use higher-level thinking skills and to collaborate with one another. For example, in their observed lessons and in their own descriptions of the ways science should be taught at the elementary level, these four teachers stated that students should be given the opportunity to discuss scientific topics among themselves, make and test predictions, and investigate the answers to their own questions. Statements included:

> "I think [the best way to teach science in elementary classrooms is] hands-on. When I was student teaching in the public schools, they loved it when you brought in the stuff, if they could feel it and experiment with it, whether it was a fossil or balls and ramps. [...] Give them that freedom of asking their questions and experimenting with it, and then draw it into the lesson. [...] They can try it and if it fails, why? Have them talk about why they think it wouldn't work and what they did see." (*Interview Transcript for T1*)

> "I'm trying to do more hands-on activities like today. I introduced it and modeled it. Then they went and explored the questions that they wanted to answer, to see what happens. They wrote down their data. We came back

> together, we gathered the data, and we discussed it." (*Interview Transcript for T3*)

> "[The best way to teach science] is hands-on. It's inquiry. [...] I'm going to go back to when the student has the question, let them go with the question and let them figure out the answer. [...] Like you saw today, I'm teaching the kids to argue and to discuss and to disagree with each other. And if they disagree they've got to be able to stand up and say, 'This is why I disagree,' and project their reasons and be able to accept when somebody else says, 'Well, I don't think that works. I think it works this way.' And [me] kind of stepping out of the circle and letting them come up with the answer." (*Interview Transcript for T2*)

Through the examination of the interviews with T1, T2, T3, and T4, the differing levels in self-efficacy among them seemed to be primarily due to personal reflection of the effectiveness of their ability to use inquiry in their classrooms; although all four teachers with high RTOP scores had views of effective science teaching that coincided with those of a reformed inquiry-oriented approach, the two teachers with low PSTE scores seemed to be much more concerned as to whether or not they were implementing inquiry in their classrooms effectively. T3 and T4 (high RTOP scores and low PSTE scores) stated that their biggest barrier in planning and teaching science was finding the best ways to effectively implement inquiry-based instruction in their classrooms while appropriately assessing student learning and understanding. On the other hand, T1 and T2 (high RTOP scores and high PSTE scores) were confident in their ability to incorporate inquiry into their science lessons, and so had high perceived self-efficacy for teaching science.

The two teachers with low RTOP scores and low PSTE scores (T7 and T8) were mixed in their description of "hands-on" science teaching. T7 had a view that was similar to T5 and T6, describing her observed teaching strategy as "hands-on note-taking" in which her sixth grade students silently copied notes into "foldables" that she directed them to make out of construction paper. She believed that this strategy was demonstrative of good teaching practices since the students were "using their hands to learn about science" (*Interview Transcript for T7*). In the case of T7, therefore, her lower self-efficacy seemed to be due to her concern that she was overall not teaching science effectively in her classroom, rather than during the specific lesson we observed. On the other hand, T8's description of ideal science teaching was much more closely aligned with the ideas of teachers with high RTOP scores, incorporating many of the fundamental abilities of inquiry. However, due to his lack of classroom control and his desire to keep his students quiet and orderly, T8 expressed a helplessness to enact his beliefs about effective science teaching in his own classroom, resulting in low confidence in his ability to effectively teach science and low levels of reform in his observed science teaching.

5.2.2 Classroom Control

The eight case profile teachers also varied in the level of concern they expressed over classroom management and controlling the behavior of their students. The two case profile teachers with low RTOP scores and low PSTE scores (T7 and T8) seemed to be very concerned with keeping tight control of their classrooms. T7, for example, spent a great deal of time during her observed lesson correcting student behavior and keeping students quiet. Even more extremely, T8 was very uncomfortable with his inability to "control students' excitement in science" (*Interview Transcript for T8*). He spent the majority of his lesson unsuccessfully trying to keep his students quiet and orderly. Due to his lack of classroom control during science activities, T8 seemed to feel little confidence in his or his students' ability to engage in inquiry-oriented activities in the classroom, although he expressed that ideally this would be the best way to teach science. Consequently he much preferred that his students be engaged in activities such as silent reading, where the students could more easily be kept quiet. ["It's so nice and quiet. Reading time is so much better than science time." (*RTOP Notes for T8*)]

All four teachers with high RTOP scores (T1, T2, T3, and T4), on the other hand, regardless of PSTE scores, seemed to be more concerned about the learning needs of their students and not as concerned about "messiness" or behavioral issues. These teachers were not only more comfortable with the noise level and the amount of student movement involved in inquiry-based science teaching, but also seemed more comfortable overall with handing over a greater amount of control to the students during the observed lessons and in their science classrooms in general[21]. For example, while describing their observed lessons, these teachers stated:

> "I knew that they were probably gaining so much from experimenting with the ramps themselves and from their interaction and talking. So it didn't bother me if the noise level rose or if it took longer than I expected. The students let me know what they need and I try to listen." (*Interview Transcript for T3*)

> "We talked about it first. […] I tried to just have a conversation about it to get their ideas out there so I had an idea about what they already knew. Then I introduced what we were going to be doing, and we did the experiment with the three bottles, having *them* mix, having *them* give me the predictions before we mixed. I did that so they would be comfortable with making a prediction and not worrying if it was right or wrong. 'What

[21] See Chapter 4 for a more detailed discussion of the theme of *Student Control* as it pertains to the overall 38 teachers.

> do *you* think?' Just using those phrases. […] But really letting them know that science is about observing. 'What do *you* notice?' 'Does it agree with what your prediction or hypothesis was?'" (*Interview Transcript for T1*)

The two case profile teachers with low RTOP scores and high PSTE scores (T5 and T6) were mixed in their focus on classroom management. T5 seemed comfortable with student-student interaction, although this interaction was ultimately orchestrated by the teacher and focused primarily on social skills rather than science content. In the view of this teacher, it seemed that as long as the students were communicating in some way, regardless of whether or not that communication was about the scientific content of the lesson, she was confident that she was being an effective teacher of science. For example, she stated:

> "No matter what, whether they understood that they were all circles or not really wasn't [the goal]. What I wanted with that was the interaction that went on outside and the excitement that went on out there. So I was happy with it just based on that." (*Interview Transcript for T5*)

In contrast, T6 kept things quiet and orderly during her observed lesson, discouraging student talking unless she called upon them. Based on T6's interview, because part of her vision of being an effective science teacher was keeping tight control over her classroom, she had high self-efficacy for her ability to effectively teach science, even though there was little to no student interaction in her science class.

5.2.3 Ongoing University Faculty Support

During their interviews, all four teachers with high RTOP scores (T1, T2, T3, and T4) described the ongoing support they received from local university faculty through coursework, professional development, and/or personal contact. One difference that existed between the two teachers out of the group with high PSTE scores and the two with low PSTE scores is the extent to which university faculty members served as mentors to them. That is, both teachers with high RTOP scores coupled with high PSTE scores (T1 and T2) had ongoing personal relationships with local university faculty members who provided them with encouragement and support. This seemed to not only boost these teachers' beliefs in their own ability to teach science, but also provided them with continuing resources and guidance to help them teach science more effectively. For the two teachers who had high RTOP scores but low PSTE scores (T3 and T4), university faculty had provided the resources and support to teach science but not at a high level of personal encouragement. It therefore seems as though, in part, support from university faculty influenced not only the level of reform observed for the eight case profile teachers, but also to some extent their levels of perceived self-efficacy for teaching science.

5.2.4 Beliefs about Provided Curriculum

Several of the case profile teachers differed in their attitudes toward, beliefs about, and use of science curricular materials provided (or not provided) by their school districts. Teachers' varying attitudes seemed to impact their confidence in their ability to teach science and, to some extent, the strategies they used to teach science in their classrooms. For example, in some instances teachers felt that district-mandated kits positively influenced their ability to teach science, although this was not evident in observations of their science lessons.

In one specific example, T7, who had low RTOP and PSTE scores, felt limited by the fact that she did not have the district-provided activity kits for science that the lower grades at her school did, kits that she felt were important to enact effective science teaching practices. Because of this, she felt that she lacked materials and guidance that would be helpful for her to teach science effectively. T5, who had low RTOP and high PSTE scores, seemed to feel empowered by the curricular materials she was given despite the fact that she had virtually no formal background or training in science content or science teaching. She felt that these materials gave her direction by telling her what she should be teaching, thereby boosting her confidence even though her observed lesson revealed low levels of reform. As she stated during her interview:

> "I read what I have to do and then I do it […] I'm pretty confident about what the pacing guide tells me, to direct me to teach. I'm going to have left that to the experts to decide that." (*Interview Transcript for T5*)

In contrast, teachers with high RTOP scores who used district-mandated kits or other curricular materials treated these materials in a different way. Instead of seeing these materials as something that needed to be followed exactly, these teachers seemed to treat them more as suggested guidelines. T2, for example, who had high RTOP and PSTE scores, used district-mandated kits, but it was not the driving force of her science instruction. Instead, she seemed comfortable adapting the curriculum and taking the pieces that best served her instructional goals, incorporating aspects of scientific inquiry into her lesson and encouraging a high level of student thought and reflection whenever possible.

5.2.5 Availability of Resources

The case profile teachers also differed in their reaction to the availability of non-curricular science instructional materials in their classroom, which seemed to influence both their science teaching self-efficacy and their science teaching practices. Both T1 and T6, for example, worked at private schools with extensive resources, especially in the area of technology. Both of these teachers also described the presence of materials for science class, particularly the availability of a SMART Board in the classroom, as being a contributor to their perceived ability to successfully teach science. However, while both teachers had high confidence in their ability to teach science, they differed greatly in the reform level of their observed teaching.

Based on observations, the difference in the reform level between these two teachers seems to be partially due to differences in their background knowledge regarding science and science education. As an undergraduate major in elementary science and mathematics, T1 had a good understanding of scientific concepts and science education. This understanding was apparent in the way in which she effectively utilized resources available in her classroom to support students' learning of scientific concepts. During her observed lesson, for example, she used her SMART Board as an effective tool to support the lesson's inquiry-based activity in which her students simulated the water pollution recently impacting a nearby river. T6, on the other hand, centered the majority of her lesson on PowerPoint slides and pre-made SMART Board activities during which she called on individual students to answer low-level questions. Throughout the lesson, T6 did not stray from the provided SMART Board materials. She did not expand upon them, could not answer students' questions about the concepts (indeed, she discouraged questions), and unfortunately perpetuated student misconceptions. However, because T6 seemed to believe that by simply using technological resources she was teaching science in an effective "hands-on" way, although she had little background in science or science education, she was confident that she had taught the observed lesson effectively.

5.3 Discussion

As revealed by the interviews and observations of eight case profile teachers, the relationship between science teaching self-efficacy and practice is not only much more complex than a simple quantitative correlation, but seems to be mediated by a variety of factors including other beliefs teachers hold. For example, case profile teachers differed in their beliefs about what it means for a science lesson to be "hands-on" and about the role of district-provided curriculum and other non-curricular resources in effective science lessons. Elementary teachers' beliefs regarding what effective science instruction means can have a large impact on self-efficacy beliefs, and thus have an unintended impact on reformed science teaching behaviors, especially if these beliefs do not coincide with those identified by science education researchers (Bhattacharyya, Volk, & Lumpe, 2009; Haney, Lumpe, Czerniak, & Egan, 2002) or if a mismatch exists between how teachers *believe* they are teaching and how they are *actually* teaching (Wheatley, 2005; Roehrig, Turner, Grove, Schneider, & Liu, 2009). For example, the case profile teachers in this study, who had high levels of confidence in their abilities to teach science but low levels of reform in their observed teaching, believe that effective science teaching involves activities in which students simply "use their hands" in some way and a classroom in which the teacher has tight control of his or her students. Since these teachers' self-efficacy beliefs were based upon a different image of effective science teaching than that of proponents of reformed science teaching, the fact that the teachers had high confidence in their own abilities to teach science well was not transformed into teaching in a reformed inquiry-oriented manner.

In addition, as observed in other studies (Czerniak & Schriver, 1994; Kind, 2009; Settlage, Southerland, Smith, & Ceglie, 2009), because case profile teachers with high PSTE scores and low RTOP scores (T5 and T6) believed they were using teaching practices that were consistent with effective science instruction, they seemed to feel little need to critically reflect upon their teaching practices; effectively, they seemed to think that if they are *already* effective science teachers, then there is really no need to look for ways to make their science lessons more effective. Wheatley (2002) claimed that this is one of the dangers of focusing too narrowly on the elevation of teacher efficacy beliefs; if teachers have no doubts regarding their teaching efficacy, then they will not experience a perturbation, leading them to feel no need to reform their teaching practices even if reformation would improve student learning. This contrasts greatly with case profile teachers who had high reform level in their observed lessons but low self-efficacy levels (T3 and T4). These two teachers seemed to actually be hyper-reflective, critical concerning almost all aspects of their lessons and particularly focused upon whether or not they were effectively implementing inquiry-based teaching strategies (their vision of effective science teaching) to promote student learning.

Teachers with varying levels of self-efficacy and reform in their science teaching also seemed to differ in their judgment of the skills required to be an effective science teacher. This, in turn, impacted their own perceived efficacy as a science teacher. Bandura (1997) claimed that, "Evaluation of one's self-diagnostic skills requires not only self-knowledge of capabilities but also understanding of the types of skills needed for different activities" (p. 115). Thus, teachers may over- or under-estimate their own efficacy based on the self-perceived importance of their skill set. For example, T5 did not have any formal background in science nor science education; she did not take any science content or methods courses and had not participated in any professional development for improving her science teaching. In her eyes, however, these were not important criteria for her to be an effective science teacher. Instead, T5 indicated a high confidence in her ability to teach science due to her assurance of the effectiveness of the district-provided science curriculum and in her self-perceived ability to meet the specific needs of her students. In contrast, T3 also had very little formal science content or science education background, but saw this as a detriment to her ability to teach science well. Consequently, T3 lacked confidence in her ability to effectively teach science to her students, although her observed science lesson demonstrated a high level of reformed inquiry-oriented teaching. In the case of T3, her self-perceived lack of content knowledge, while decreasing her self-efficacy, also seemed to contribute to the effectiveness of her teaching practices; because she perceived a deficiency in her own background knowledge, she felt the need to critically reflect on the effectiveness of her own science teaching and seek out aid from others such as in professional development.

5.4 Chapter Summary

Based on the data presented in this and the previous chapter, due to the variety of factors involved it is difficult to characterize or predict the relationships between self-efficacy beliefs and the reform level of individuals' science teaching practices. In other words, just because teachers have higher science teaching self-efficacy, describe their lessons as being "hands on," and/or have an excessive amount of resources at their disposal, it does not mean that these teachers will automatically teach science effectively in their classrooms. Relationships among self-efficacy, beliefs about teaching practices, and actual teaching practices are complex. As revealed in this study, several themes, such as those regarding teachers' specific conceptions of "hands-on" versus "inquiry" and the role of technological and various curricular resources in the classroom, may have a major impact on the relationships between self-efficacy and reformed science teaching for particular teachers. Thus, emerging themes such as these warrant closer examination in future studies as they relate to self-efficacy, beliefs about science teaching, and actual effective science teaching behaviors. A discussion of such possible future directions in research, as well as other considerations when interpreting the data generated by this study, is presented in the next chapter.

Chapter 5, in part, is currently being prepared for submission for publication of the material as it may appear in Research Based Undergraduate Science Teaching: Investigating Reform in Classrooms, 2012, Lardy, Corinne H.; Mason, Cheryl L. The dissertation author was the primary investigator and author of this material.

CHAPTER 6: DISCUSSION

This dissertation has examined some of the important relationships existing within and among Personal Science Teaching Efficacy (PSTE), beliefs about science teaching, and observed science teaching practices for a diverse, nationwide group of inservice elementary teachers. The goal of this final chapter is to summarize and discuss the overall findings of the research study as they pertain to current and future studies in the field of science teacher education.

This chapter begins with a summary of the key results presented in Chapters 4 and 5. Next, I describe some of the potential implications of these results as they pertain to the current research literature regarding science teaching efficacy beliefs. In the third section, potential limitations of the study when interpreting the generalizability of the results are considered and discussed. I then describe some potentially beneficial areas for future research regarding the relationships between elementary teachers' science teaching self-efficacy beliefs and classroom practices. Finally, in the last section overall concluding remarks for this dissertation are presented.

6.1 Summary of Results

Based on coded interview transcripts and observational field notes coupled with quantitative surveys for all 38 teachers participating in this study, there do appear to be some important associations between participating elementary teachers' science teaching self-efficacy levels and their *beliefs about* ideal and their own science teaching practices. For example, participating teachers with higher PSTE scores were more likely to report, as part of their beliefs about ideal and their own personal science teaching (both generally and during the observed lesson), that effective elementary science instruction incorporates (a) opportunities for students to have control and/or responsibility over their own learning; and (b) connections between scientific content and the real world, students' lives, related scientific concepts, and/or other academic disciplines such as mathematics or literacy. Additionally, those participants with higher PSTE scores were more likely to take responsibility for the successes and failures of their observed science lessons.

However, not all of the participants' beliefs were aligned across the three categories of *perceived* science teaching (ideal, general personal, and observed personal). For example, teachers with higher PSTE levels seemed to put less emphasis on classroom management and referred to more of the fundamental abilities of inquiry (National Research Council [NRC], 2000) when describing *ideal* science teaching, but *not* their *own* science teaching practices (general or observed). Those participants with higher self-efficacy also generally put a greater emphasis on developing student thinking and felt less constrained by factors outside of their control in their ability to effectively teach science in their classrooms in *general*, but *not* during the *observed* lesson. In addition, *no* correlations were found between PSTE scores and teachers' references to the following when describing their beliefs about ideal or personal science teaching: (a) utilizing elements of direct instruction such as lecturing and memorization; (b) giving students opportunities to communicate with one another; (c) integrating multiple approaches that address the diverse learning needs of their students; and (d) focusing on students' learning of the scientific concepts.

Many of the above relationships between teachers' science teaching self-efficacy level and their *beliefs* about science teaching are in line with those asserted by previous research[22]. However, even more critical than teachers' *beliefs* about their instructional practices, is what they are actually *observed* doing in their classrooms. In the case of my study, some potential connections were found between PSTE and actual observed reformed science teaching practices. For example, participating teachers with higher PSTE scores were generally more likely than those with lower PSTE scores to actually be observed encouraging their students to have control and/or responsibility over their own learning by giving students more opportunities to (a) control the focus and direction of lesson segments; (b) plan aspects of scientific investigations; (c) share their ideas about scientific concepts; and (d) communicate and collaborate with their fellow students. In addition, teachers with higher PSTE scores were observed to spend a greater percentage of their lessons engaged in small group, individual, or whole-class activities (as opposed to whole-class discussion, direct instruction, or managerial tasks). However, during their observed science lessons, participants with higher self-efficacy, as compared to colleagues with lower self-efficacy, did *not* (a) incorporate more fundamental abilities of inquiry, excluding giving students the opportunity to plan aspects of investigations; (b) provide more opportunities for students to use higher-level thinking skills; (c) make more relevant connections between scientific content and students' interests, the real world, and/or other academic disciplines; or (d) promote fewer misconceptions about the scientific content being taught. Therefore, although there were a few aspects of reformed inquiry-oriented science teaching that were

[22] See section 4.3 for a list of these assertions.

apparent in the observed lessons of participants with higher PSTE scores, there are many others that were not.

In addition to results from the total group of 38 teachers, the interview transcripts and observation field notes for eight case profile teachers with varying levels of PSTE and reform observed during their science lessons[23] were examined and described in greater depth. The results for case profile teachers shed additional light on some of the complexities among self-efficacy, beliefs about effective science teaching, and actual observed reformed science teaching practices. This is especially true for teachers who had a mismatch between their levels of self-efficacy and observed levels of reform (i.e. high PSTE and low RTOP scores; low PSTE and high RTOP scores). These eight teachers, for example, differed in their beliefs about what it means for a lesson to be “hands-on” and about the role of science instructional materials, which impacted both their perceived science teaching efficacy and the level of reform observed during their science lessons. For instance, the two teachers who had *high* self-efficacy but who were observed teaching at a *low* level of reform were both very confident in their abilities to effectively teach science, although they were not observed to teach in a reformed, inquiry-oriented manner. This high level of self-efficacy seemed to partially be due to their beliefs that they were teaching science in an effective “hands-on” way by simply using district-provided resources such as SMART boards and/or curriculum guides, regardless of their lack of scientific knowledge. Because of their elevated confidence, these teachers did not see the need to reflect upon and/or reform

[23] Case profile teachers’ level of reform observed during their science lessons was measured using the *Reformed Teaching Observation Protocol* (RTOP). For more information on this instrument, see section 3.2.2 and Appendix B.

their teaching practices. On the other hand, those case profile teachers with *low* PSTE scores, but who were observed teaching science at a *high* level of reform, had beliefs about "hands-on" science that were much more inquiry-based. These teachers, however, had much greater concern about their ability to effectively implement reformed inquiry-based instruction in their classrooms, partially due to their perceived lack of scientific knowledge. Therefore, although they were observed to teach in a highly reformed way, these two teachers had low confidence in their ability to teach science, expressing that they still had much more to learn before they believed themselves to be truly effective teachers of science. In the case of these two teachers, their low levels of self-efficacy did not seem to inhibit their abilities to teach science effectively; instead, a low sense of self-efficacy actually made them more reflective about their own science teaching practices, and seemed to instill in them a desire to keep working to make their science lessons more effective.

6.2 Implications

In recent years, there has been a popular argument in the field of science education that science teacher educators should make a concerted effort to increase the science teaching self-efficacy of preservice and inservice elementary teachers (e.g. Brand & Wilkins, 2007; Nolan et al., 2011; Young & Kellogg, 1993). The rational behind this argument is that elementary teachers with higher self-efficacy for teaching science will actually be more effective teachers of science. Many researchers seem to have taken this argument to heart and have moved away from researching the relationships between science teaching efficacy beliefs and classroom behaviors, assuming that these relationships are already well correlated. Consequently, much of the most recent research regarding efficacy beliefs has focused primarily on the mechanisms for increasing science teaching self-efficacy for inservice and preservice elementary teachers, rather than examining how self-efficacy relates back to teachers' actual science teaching behaviors (e.g. Batiza et al., 2011; Bayraktar, 2011; Cantrell, Cantrell, & Patch, 2011; Cartwright & Smith, 2011; Deniz, Orgil, & Carroll, 2011; Gunning & Mensah, 2011; Hechter, 2011; Kazempour, 2011; Matkins et al., 2011; Rethlefsen & Park, 2011).

My argument, however, supported by the results of my dissertation, is that the relationships between science teaching self-efficacy and effective science teaching practices are not as well established as many researchers seem to assume. Much of the current data upon which this assumption rests are based on self-reported accounts from preservice and inservice teachers (e.g. Desouza, Boone, & Yilmaz, 2004; Enochs, Sharmann, & Riggs, 1995; Haney, Lumpe, Czerniak, & Egan, 2002; Marshall, Horton, Ego, & Switzer, 2009; Nolan et al., 2011; Ramey-Gassert, Shroyer, & Staver, 1996) and/or from classroom observations for a very limited number of teachers (Bhattacharyya, Volk, & Lumpe, 2009; Haney et al., 2002; Khourey-Bowers & Simonis, 2004; Nolan et al., 2009; Ramey-Gassert et al., 1996). In contrast, my dissertation has demonstrated that, among a larger, more diverse, nationwide group of inservice elementary teachers, individuals with higher science teaching self-efficacy did not necessarily incorporate all of the reformed science teaching strategies supported by educational researchers into their actual lessons. Indeed, as is indicated by the descriptions of the case profile teachers, there are some teachers with higher levels of science teaching self-efficacy who actually teach in a *less* reformed way, due to conflicting areas of belief that sometimes lead to a lack of personal reflection. The results of this study therefore indicate a continuing need for researchers to examine the actual mechanisms connecting self-efficacy and practice, rather than automatically assuming a positive correlation between the two.

In addition, this study highlights the importance of the use of interviews and observations in self-efficacy research and the caution to not rely solely on quantitative instruments and/or self-reported data. The interviews and observations utilized in my dissertation study provided much more detailed and valuable information regarding teachers' beliefs and practices than any survey by itself would. In particular, the inclusion of observations of teachers' actual science teaching practices, as opposed to self-reported measures alone, was critical to this research; it is clear from the results of my dissertation that teachers' *beliefs* about science instruction do not always agree with their actual *behaviors* in the classroom. It is therefore critical that we as teacher education researchers base, at least in part, our conclusions about the associations between science teaching self-efficacy and reformed inquiry-oriented science instruction on *actual* observational data. If, as the case often has been, the association between the two continues to be grounded primarily in self-reported data, inaccurate assumptions regarding the power of simply increasing elementary teachers' self-efficacy levels will continue to be made with a seeming failure to recognize the complexity of the issue. Further research, including longitudinal studies with multiple interviews and observations, which focuses on the relationships that exist between self-efficacy beliefs and teaching practices is needed.

6.3 Study Limitations and Considerations

This dissertation provides us with many new ideas to think about when reconsidering the assumption of a simple positive correlation between science teaching self-efficacy and effective science teaching practices. However, there are a few limitations of this study to bear in mind when considering the generalizabilty of the results. Because of these potential limitations, it is important for me to stress that the results of this dissertation are not necessarily generalizable to the rest of the total population of elementary teachers in the United States, but only serve to raise some important questions for future research and discussion.

Many of the past studies that have examined the relationships between science teaching self-efficacy and *actual* observed classroom behaviors have focused on small groups of subjects from within homogenous populations (Bhattacharyya et al., 2009; Haney et al., 2002; Khourey-Bowers & Simonis, 2004; Nolan et al., 2009; Ramey-Gassert et al., 1996). The generalizability of the results of these past studies to the greater population of elementary teachers in the United Stated is, therefore, uncertain. I tried to overcome this limitation in my dissertation, to some extent, by increasing the number of teacher participants and pulling from a much broader nationwide sample of teachers with a wide variety of backgrounds and experiences. However, although the sample size utilized here is much larger than the vast majority of past studies examining the relationships between science teaching efficacy beliefs and actual classroom behaviors, it is still relatively small. (Though, anecdotally, it is interesting to mention that accounts of NSEUS project staff, including myself, seem to indicate that many of the results represented in the current sample of 38 teachers appeared to carry over into the larger group of over 100 teachers participating in the NSEUS project.)

In addition, the extensive diversity of the group of teachers contributing data to my dissertation, while more accurately representing the larger population of inservice elementary teachers in the United States, comes with its own set of complications. Because the teachers were so diverse in a variety of characteristics (e.g. years of teaching experience, grade level currently teaching, amount of professional development, and number of science content and science education university courses taken), there are a multitude of factors that may have influenced the relationships found between self-efficacy beliefs and observed practices. For example, perhaps teachers with more extensive content knowledge or a greater number of years of teaching experience simply teach in a more reformed manner regardless of their levels of self-efficacy. In addition, demographic factors of teachers such as gender (Bursal, 2010; Evans & Tribble, 1986; Gencer & Cakiroglu, 2007; Kiviet & Mji, 2003; Mulholland, Dorman, & Odgers, 2004), age (Angle & Moseley, 2009; Kind, 2009; Perkins, 2007), amount of university science coursework and professional development (Andersen, Dragsted, Evans, & Sorensen, 2007; Angle & Moseley, 2009; Bhattacharyya et al., 2009; Bursal, 2010; Khourey-Bowers & Simonis, 2004; Ramey-Gassert et al., 1996; Rubeck, 1990), and years of science teaching experience (Angle & Moseley, 2009; Nolan et al., 2009; Rubeck, 1990) have all been demonstrated to influence science teaching self-efficacy beliefs. Although I tried to minimize these potential interactions, at least to some extent, by confirming that none of the participant characteristics significantly correlated with PSTE scores or RTOP sub-scores, this probably does not tell the whole story. When each individual teacher characteristic is examined, for example, the sample size is effectively reduced even further; for instance, within my sample of 38 teachers, only three taught first grade and only five had been teaching at their current grade level for ten or more years. It would be beneficial therefore for future studies to utilize much larger sample sizes, including more teachers within categories of the particular characteristics in question such as specific grade levels currently teaching or number of years of teaching experience. Likewise, while out of the scope of my dissertation, it would be valuable to examine in greater depth how the particular characteristics of the teachers in this study, and those in larger sample sizes, appear to mediate the relationships between self-efficacy and practice.

Another limitation is that the data collected for this study essentially represents only a single snapshot of the beliefs and practices of each participating teacher; a snapshot that may not be accurate for all of the teachers. It is possible, for example, that single observations of each teacher were not representative of the teachers' normal science teaching practices, although I attempted to account for this by asking each teacher whether or not the observed lesson was typical for the ways in which they teach science. Another possibility is that PSTE scores as measured by the STEBI-A are not representative of teachers' overall level of self-efficacy for teaching science. Bandura (1997) argued that self-efficacy is a context-dependent construct. Indeed, studies have demonstrated that the science teaching efficacy beliefs of one teacher may change depending upon the particular group of students he or she is teaching (Angle & Moseley, 2009; Ramey-Gassert et al., 1996; Raudenbush, Rowan, & Cheong, 1992) and the science content or academic level being taught (Kind, 2009; Perkins, 2007). In addition, a few studies have reported that preservice elementary teachers' responses to the STEBI survey changed when it was administered multiple times, and/or when they were asked about their response choices during interviews (Cartwright & Smith, 2011; Hechter, 2011; Perkins, 2007). Anecdotally, NSEUS project staff members have also noticed that in the case of some elementary teachers, science teaching self-efficacy beliefs may vary at different times of the school year; some teachers appear to have elevated or lowered levels of self-efficacy at the end of the school year, for example, depending on their perceptions of what transpired during that year. The teachers who participated in my dissertation study may therefore be more or less confident teaching science overall than is represented by the single STEBI-A survey they filled out. For these reasons, it would be fruitful, in future studies, to measure self-efficacy multiple times for each teacher and in a variety of ways, not only with quantitative survey instruments such as the STEBI, but also with qualitative measures such as interviews. It would also be beneficial to examine the longitudinal relationships existing between science teaching self-efficacy and actual observed classroom practices for inservice elementary teachers.

6.4 Future Research

Aside from the above recommendations, results of this dissertation point to a few areas that may be productive and worthwhile to examine further in future studies as they relate to self-efficacy beliefs. These areas, in no particular order, include elementary teachers'

- understandings of the concepts of "hands-on" as compared to "inquiry";

- perceptions of the role of technology and/or other district-provided science materials in the classroom as they relate to effective science instruction; and
- beliefs about what it means for students to “learn” and/or “understand” science, and for them to “have fun” while doing so.

In addition, while not directly connected to the results of this dissertation, there are other potential areas of future research that would be interesting to examine as they relate to teachers’ self-efficacy beliefs and science teaching practices, such as elementary teachers’

- design of the classroom context, including their use of visual materials; and
- ethnicities, as well as the relative diversity of the student populations whom they serve.

In the following paragraphs I elaborate on each of the areas listed above and identify some guidelines for future research within each of them.

One area that seems to warrant closer examination is the ways in which teachers understand “hands-on” and “inquiry,” and how these understandings relate to their self-efficacy beliefs and observed science instruction. A majority of the teachers in this study, regardless of self-efficacy level, used the term “hands-on” when describing how they believe science should be taught and how they teach science in their own classrooms. However, very few of them articulated what they meant by this phrase. It is clear from examining the ways that teachers referenced the fundamental abilities of inquiry in their interviews and the ways that these abilities manifested in the observed lesson, that not all teachers associated aspects of inquiry with “hands-on” instruction. Unfortunately, while several of the participating teachers were asked directly during their interviews what they meant by the term “hands-on,” many were not; at the time that data were collected, the probing of teachers’ beliefs about this term was not an established part of the protocol. Therefore, it would be beneficial for future studies to examine in greater depth elementary teachers’ understandings of the concept of “hands-on science teaching” as it relates to their self-efficacy beliefs and to their actual science teaching practices, by utilizing interview questions specifically designed to probe these beliefs.

Another area that would be valuable to examine in greater detail is elementary teachers’ beliefs about the use of technological resources and other district-provided materials during science lessons, as they relate to their science teaching self-efficacy and actual observed science teaching practices. School districts across the United States are incorporating more technological devices and ready-made science curriculum kits into the elementary science classroom. Indeed, over the last four years of collecting data for the NSEUS project, my colleagues and I have observed more and more technological resources, such as computer projectors, document cameras, and SMART boards, along with other district-generated science curriculum materials appearing in elementary classrooms across the country. This movement seems to be primarily based on the argument that, in effect, if teachers are provided with better resources with which to teach science, they will be more effective teachers of science. Based on our observations, however, elementary teachers’ vary dramatically in their effective use of these resources. As suggested by the results of my dissertation, some of this relative effectiveness may be due to beliefs about the use of technology as an effective tool for “hands-on” science instruction as they relate to self-efficacy. For example, some teachers appear to have elevated science teaching self-efficacy due to their access to technology, although they do not have a large amount of knowledge regarding science or science teaching. For these teachers, if they are simply using technology, regardless of *how* it is used, they feel confident that they are teaching science in a hands-on, effective manner. Similarly, some teachers seem to have complete confidence in the science curriculum materials provided by their districts; as long as they follow the curriculum guidelines, it doesn't matter if they themselves do not understand the scientific concepts that the materials are designed to teach. In these cases, the availability of such resources may serve to artificially increase some teachers' self-efficacy beliefs, leading them to feel no need to reflect upon or improve their science teaching. It would thus be beneficial, especially for those seeking to effectively incorporate such instructional materials into elementary classrooms, to examine in greater depth the relationships between teachers' beliefs about the materials, their self-efficacy beliefs, and how such materials are actually utilized in their science classrooms.

The third area that would be interesting to explore in greater depth is that of elementary teachers' usage of the terms "learning," "understanding," and "having fun" when describing students' roles in the science classrooms, particularly as these terms relate to their self-efficacy beliefs. Contrary to past research (Czerniak & Schriver, 1994; Riggs, Enochs, & Posnanski, 1998), in my dissertation study those teachers having higher levels of science teaching self-efficacy did not seem to place greater emphasis on their students' learning and/or understanding of scientific concepts, or less emphasis on student enjoyment, than those participants with lower self-efficacy.

However, one fact that is important to remember when interpreting these results is that they are based on the number of references teachers made during their interviews to *Student Learning* (e.g. “students learn,” “students understand,” “students get it”) and *Student Enjoyment* (e.g. “students have fun,” “students enjoy themselves,” “students are excited”). Because participants were not always directly asked during their interviews what they meant by these terms, nor did all of them give specific descriptions of their meaning, it may be that not all teachers used these terms in the same way. That is, for example, while teachers with higher PSTE scores did not reference *Student Learning* when describing science teaching any more times than those with lower PSTE scores, it does not mean that they don’t have a different understanding of “learning” or that they didn’t use this term in a different way. While such examination of participating teachers’ varying usage of these terms is out of the immediate scope of my dissertation study, it would be something that would be interesting to more closely examine within the data set and/or with additional groups of teachers in the future.

Another area of participants’ science teaching practices that was not explored in this study, but would of interest to do so in the future, is the examination of elementary teachers’ designs of the classroom context in comparison to their self-efficacy beliefs. During observations, my NSEUS colleagues and I noticed a wide variety of ways teachers had arranged their classroom environments. For example, some had students’ desks grouped together in pods, while others had them arranged in rows or in a horseshoe shape. Likewise, some teachers had a multitude of science-related materials on the walls and around the room (e.g. students’ projects, posters, live animals, and/or ongoing experiments), while others displayed primarily mathematics- and/or literacy-related resources. The ethos that teachers provide in their classrooms determines, in part, the effective facilitation of reformed inquiry-based instruction. It also indicates the extent to which a teacher promotes a positive attitude and sense of importance toward science in their classroom; for example, if only literacy- and no science-related materials are displayed throughout a teacher's classroom, that teacher is, in effect, sending a message regarding their beliefs about the relative importance of these two academic areas. Therefore, it would be beneficial to examine whether teachers with varying PSTE scores differed in their design of the classroom context, and whether this context aligned with the teachers' objectives for and beliefs about teaching science.

Finally, although it was not possible to accomplish in my dissertation, it would also be of interest to make comparisons between science teaching self-efficacy and classroom practices among those teachers with varying ethnicities themselves, as well as those who teach diverse versus primarily homogeneous groups of students. Several studies have demonstrated that the same teacher may have different levels of science teaching self-efficacy for different groups of students, depending upon the perceived academic abilities (Angle & Moseley, 2009; Ramey-Gassert et al., 1996; Raudenbush et al., 1992) or ethnicities (Wagler, 2009) of those students. Therefore, composition of student population, and the perceptions that teachers hold regarding that population, may also influence the relationships between self-efficacy and practice. Although I did not examine these aspects as a part of my dissertation, in would be productive and worthwhile to do so in future studies. In addition, data regarding this information for many of the teachers who participated in the larger NSEUS project is available for future analysis.

6.5 Concluding Remarks

While there do appear to be some overall advantages to increasing elementary teachers' science teaching self-efficacy, the situation is much more complex than it is sometimes portrayed in the literature. In other words, by simply increasing elementary teachers' levels of science teaching efficacy beliefs, there is no guarantee that they will actually teach science in a more reformed, inquiry-based manner. The results of my dissertation should, therefore, give science teacher education researchers pause when making blanket assumptions about the benefits of increasing elementary teachers' self-efficacy. If we truly want to improve elementary science education, instead of focusing all of our efforts on researching the mechanisms behind the *development* of self-efficacy, it would be beneficial to turn some of our attention back to the influences of self-efficacy beliefs on teachers' *actual* science teaching practices. Only with this information can we make accurate and informed decisions about how to develop effective elementary teachers of science and successfully improve science education at the elementary level.

APPENDIX A:

Participant Characteristics

CHARACTERISTIC	PERCENTAGE OF PARTICIPANTS (N = 38)	
Gender		
Female	84.2%	
Male	15.8%	
Location		
California	23.7%	
Alaska	15.8%	
West Virginia	13.2%	
Texas	15.8%	
Massachusetts	10.5%	
Minnesota	10.5%	
New Hampshire	5.3%	
Ohio	2.6%	
Wisconsin	2.6%	
School Type		
Public	78.9%	
Private	15.8%	
Charter	5.3%	
Teacher Ethnicity		
Caucasian	92.1%	
Asian	5.3%	
African American	2.6%	
Grade Level Currently Teaching		
Kindergarten	10.5%	
First	7.9%	
Second	13.2%	
Third	10.5%	
Fourth	13.2%	
Fifth	13.2%	
Sixth	13.2%	
Seventh	2.6%	
Eighth	2.6%	
Mixed Grades	13.2%	
Teacher Type		
Generalist	63.2%	
Science Specialist	36.8%	
Number of Years Taught	Total	At Current Grade
1	18.4%	28.9%
2-3	21.1%	31.6%
4-5	13.2%	13.2%
6-10	18.4%	21.1%
11-15	18.4%	7.9%
16-20	5.3%	7.9%
>20	7.9%	---

CHARACTERISTIC	**PERCENTAGE OF PARTICIPANTS (*N* = 38)**	
Number of Courses Taken	Science Content	Science Education
0	5.3%	34.2%
1	7.9%	39.5%
2	10.5%	10.5%
3	26.3%	13.2%
4	15.8%	---
5	5.3%	---
6	2.6%	---
>6	26.3%	2.6%
Amount of Professional Development Related to Science		
None	36.9%	
Some	13.1%	
Extensive	50.0%	

APPENDIX B:

Observation Protocol

RTOP
Reformed Teaching Observation Protocol
(Sawada et al., 2002)

I. BACKGROUND INFORMATION

Instructor/Teacher Code # ________________

Location of class ____
(district, school, room)

Lesson Observed ________________________ Year/Grade Level __________

Observer ________________________ Date of Observation __________

Start time ________________________ End time __________________

II. CONTEXTUAL BACKGROUND ACTIVITIES

In the space provided below please give a **brief description of the lesson observed**, the **classroom setting** (spaces, seating arrangements, etc), **and learning climate** in which the lesson took place (cooperative groups, teacher & student attitudes toward learning, classroom management strategies used, etc), and **any relevant details about the students** (number, gender, ethnicity), **teacher, building climate, administrative constraints, and other factors not covered in the RTOP** that you think are important for RTOP and other qualitative analysis that will lead to completion of the final report for the site visit.. Use diagrams and more pages if they seem appropriate and are needed.

Record salient events observed here that you will use in completing RTOP.

Time	Description of Events
	Lesson Begins

Record salient events observed here that you will use in completing RTOP.

Time	Description of Events
	Lesson Ends

III. LESSON DESIGN AND IMPLEMENTATION

		Never Occurred		Very Descriptive		
1)	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0	1	2	3	4
2)	The lesson was designed to engage students as members of a learning community.	0	1	2	3	4
3)	In this lesson, student exploration preceded formal presentation.	0	1	2	3	4
4)	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	0	1	2	3	4
5)	The focus and direction of the lesson was often determined by ideas originating with students.	0	1	2	3	4

IV. CONTENT

Propositional Knowledge

6)	The lesson involved fundamental concepts of the subject.	0	1	2	3	4
7)	The lesson promoted strongly coherent conceptual understanding.	0	1	2	3	4
8)	The teacher had a solid grasp of the subject matter content inherent in the lesson.	0	1	2	3	4
9)	Elements of abstraction (i.e., symbolic representation, theory building) were encouraged when it was important to do so.	0	1	2	3	4
10)	Connections with other content disciplines and/or real world phenomena were explored and valued.	0	1	2	3	4

Procedural Knowledge

11)	Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	0	1	2	3	4
12)	Students made predictions, estimations and/or hypotheses and devised means for testing them.	0	1	2	3	4
13)	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0	1	2	3	4
14)	Students were reflective about their learning.	0	1	2	3	4
15)	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	0	1	2	3	4

V. CLASSROOM CULTURE

		Never Occurred				Very Descriptive
	Communicative Interactions					
16)	Students were involved in the communication of their ideas to others using a variety of means and media.	0	1	2	3	4
17)	The teacher's questions triggered divergent modes of thinking.	0	1	2	3	4
18)	There was a high proportion of student talk and a significant amount of it occurred between and among students.	0	1	2	3	4
19)	Student questions and comments often determined the focus and direction of classroom discourse.	0	1	2	3	4
20)	`There was a climate of respect for what others had to say	0	1	2	3	4
	Student/Teacher Relationships					
21)	Active participation of students was encouraged and valued.	0	1	2	3	4
22)	Students were encouraged to generate conjectures, alternative solutions strategies, and ways of interpreting evidence.	0	1	2	3	4
23)	In general the teacher was patient with students.	0	1	2	3	4
24)	The teacher acted as a resource person, working to support and enhance student negotiations.	0	1	2	3	4
25)	The metaphor "teacher as listener" was very characteristic of this classroom.	0	1	2	3	4

Additional comments you may wish to make about this lesson.

APPENDIX C:

Interview Protocol

NSEUS Elementary Teacher Interview Questions

Below are the interview questions asked of elementary teachers for the purpose of collecting data for the NSEUS project. All questions that prompted subjects to provide responses related to their science teaching beliefs and practices were utilized for analysis in my dissertation study.

Background: (Co-Pa)

1) How long have you been teaching? What grade levels and number of years at each level have you taught? Have you been involved in any specialized teaching (i.e. as a departmentalized science teacher, etc.)?
2) Have you participated in professional development for improving your science teaching? Describe the extent of your professional development.
3) What university level science courses have you taken?
4) Have you taken any university level science education courses (i.e. teaching methods or content courses for education majors)? How many? What courses?

Science Courses taken at the University:

5) How would you define science or the nature of science? Has your definition of science and the scientific process changed over time due to a single university course or set of courses? If so, in what ways?
6) Has your understanding of science content (i.e. the main ideas or concepts) changed as a result of a single university course or set of courses? If so, in what ways?
7) Has your understanding of science teaching (i.e. pedagogy, methods, implementing curriculum) and the ways in which you teach science changed as a result of a single university course or set of courses? If so, in what ways?
8) Which instructional strategies (activities, assignments, etc.) did you experience as most beneficial to your learning science at the university?
9) **What science content areas do you feel most (least) prepared to teach? Why?**

Teaching Science at the Elementary School Level:

10) What science content areas are most/least important to teach at the elementary level in general? Why? What science content areas are most/least important in your teaching at the elementary level? Why?
11) What do you feel is the most effective way to teach science in elementary classrooms? Why? Do you feel as though this is the way that you teach science in your classroom? Why or why not?
12) What barriers have you had to overcome in planning and teaching science?
13) How interested do your students seem to be in science?
14) What should your students take away from science in your class this year? (What are your goals in teaching science to your students this year?)
15) What is some of the important information that you would advise future teachers to take from their university science courses? What is the least important information to take away?

Science Lesson: (Co-Pa) (*Note to the interviewer: If the interview is conducted* <u>*prior*</u> *to the lesson observed, please modify the questions below accordingly*)

16) What were the main ideas or concepts of this class session or lesson? What <u>specifically</u> did you intend your students to learn about these main ideas or concepts?
17) Describe how you taught these main ideas or concepts, and explain why you chose to use these strategies.
18) How typical is this lesson for this class? If this is not typical, please describe a typical science class session in your class.
19) Why is it important for students to know the main ideas or concepts taught during this class session?
20) How confident do you feel teaching about these concepts? Why? What did you anticipate will be some difficulties and/or limitations connected with teaching these ideas or concepts?
21) What knowledge about students' thinking and/or learning influences how you taught the main ideas or concepts?
22) How did (will) you assess students' understanding of, or confusion about, these ideas? How confident are you that the students understood these concepts at the end of the lesson? Why?
23) Overall, how successful do you think the lesson was today? Why?

APPENDIX D:

Science Teaching Efficacy Belief Instrument – Form A (STEBI-A)

Science Teaching Efficacy Belief Instrument – Form A
(STEBI-A)

Note: Only those items used to measure teachers' Personal Science Teaching Efficacy (PSTE), as indicated in bold, were utilized for this study.

Instructions: Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA = Strongly Agree
A = Agree
UN = Uncertain
D = Disagree
SD = Strongly Disagree

1. When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	SA A UN D SD
2. I am continually finding better ways to teach science.	**SA A UN D SD**
3. Even when I try very hard, I don't teach science as well as I do most subjects.	**SA A UN D SD**
4. When the science grades of students improve, it is most often due to their teacher having found a more effective teaching approach.	SA A UN D SD
5. I know the steps necessary to teach science concepts effectively.	**SA A UN D SD**
6. I am not very effective in monitoring science experiments.	**SA A UN D SD**
7. If students are underachieving in science, it is most likely due to ineffective science teaching.	SA A UN D SD
8. I generally teach science ineffectively.	**SA A UN D SD**
9. The inadequacy of a student's science background can be overcome by good teaching.	SA A UN D SD
10. The low science achievement of some students cannot generally be blamed on their teachers.	SA A UN D SD
11. When a low achieving child progresses in science, it is usually due to extra attention given by the teacher.	SA A UN D SD
12. I understand science concepts well enough to be effective in teaching elementary science.	**SA A UN D SD**
13. Increased effort in science teaching produces little change in some students' achievement.	SA A UN D SD
14. The teacher is generally responsible for the achievement of students in science.	SA A UN D SD

15. Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	SA A UN D SD
16. If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.	SA A UN D SD
17. I find it difficult to explain to students why science experiments work.	SA A UN D SD
18. I am typically able to answer students' questions in science.	**SA A UN D SD**
19. I wonder if I have the necessary skills to teach science.	**SA A UN D SD**
20. Effectiveness in science teaching has little influence on the achievement of students with low motivation.	SA A UN D SD
21. Given a choice, I would not invite the principal to evaluate my science teaching.	**SA A UN D SD**
22. When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.	**SA A UN D SD**
23. When teaching science, I usually welcome student questions.	**SA A UN D SD**
24. I do not know what to do to turn students on to science.	**SA A UN D SD**
25. Even teachers with good science teaching abilities cannot help some kids learn science.	SA A UN D SD

Enochs & Riggs (1990)

APPENDIX E:

Coding Scheme

The following coding scheme was designed to use interview and observation data to answer the main research questions:

1) How do teachers with varying levels of science teaching self-efficacy compare in the ways that
   a. they describe how science *should* ideally be taught in elementary classrooms and their reasons for this? (Interviews)
   b. they describe how they teach science in general in their own classroom and their reasons? (Interviews)
   c. they describe how they taught science in the observed lesson and their reasons? (Interviews)
   d. we observed them teaching science during a lesson? (Observations)

2) In what ways are these teachers' descriptions of ideal science teaching (1a), their descriptions of their own science teaching (1b and 1c), and their observed science teaching practices (1d) aligned?

In the following coding tables, **codes for <u>interviews</u> are in <u>bold</u>**, otherwise the default codes are for observations (in regular text). They were kept together in the tables to show how the two fit together, and so how some comparisons were facilitated in the analysis between interview sections and observations. In addition, all observation codes were applied separately to the categories of (1) Perceived *ideal* science teaching, (2) Perceived *general* personal science teaching, and (3) Perceived *observed* personal science teaching. For example, during her interview a participant may have referenced the code "Student Control" when talking about how science should ideally be taught, how she describes the manner in which she generally teaches science in her class, and how she thinks she taught during the observed science lesson. In this case, three different codes would apply to these aspects of her interview.

Codes have emerged from (1) interview and observational data, (2) research literature regarding the relationships between teaching self-efficacy and teacher classroom behaviors, and (3) literature regarding the critical characteristics of reformed inquiry-oriented science teaching. The third column on the tables ("Reasons for Inclusion") indicates where the particular code came from and why it was decided to include that particular code. In the case of the second table, "Fundamental Abilities of Inquiry," all of these characteristics came from the *National Science Education Standards* (National Research Council [NRC], 2000) regarding the critical components of inquiry in the elementary science classroom.

<u>Tables for Coding Schemes:</u>

1) General Lesson Segment Characteristics:

Characteristic	Description	Examples	Reason(s) for Inclusion
1. Format: ***What is the overall format of this lesson segment?***			
1a. Group Activity	Students work in small groups to complete a task.	Group lab activities; Group projects	This characteristic provides a way of categorizing the basic structure of each lesson component. By looking at the different components used in a lesson, we can see the breakdown of the types of instructional formats that each teacher used in their observed lesson. Research suggests that teachers with high teaching self-efficacy spend more time in small-group instruction (Gibson & Dembo, 1984), less time in direct instructional activities, and more time having their students engaged in hands-on activities (Ramey-Gassert et al., 1996) than do teachers with low levels of self-efficacy.
1b. Individual Activity	Students work independently to complete a task.	Students complete worksheets independently; Independent practice	
1c. Whole-Class Activity	**Teacher guides students to complete an activity or task together as a class.**	Class works together to create something such as a dichotomous key; Teacher leads the class to do a lab activity all together; Teacher leads the class to fill in a chart together	
1d. Whole-Class Discussion	Teacher facilitates class in a discussion about a scientific concept or activity. The nature of the segment is that the teacher and students are talking about the concept.	Teacher has students share/brainstorm ideas about a particular concept	
1e. Direct Instruction **(1e.) Interview Code: Direct Instruction**	Teacher focuses on providing the students information. Students take on a passive role and student participation is minimal. **Teachers talk about how elements of direct instruction are a part of ideal or personal science teaching.**	Lecture; Note-taking; Textbook reading; PowerPoint presentation; Drill for memorization; Teacher models how to do a particular task **"I'm a firm believer that there always needs to be some memorization."** **"I usually follow-up with a short lecture."**	

1f. Managerial **(1f.) Interview Code: Managerial**	Teacher focuses on managing the flow of the lesson and/or directing behavior of students. **Teachers describe ideal or personal science teaching as including aspects of classroom management.**	Teacher gives instructions; Teacher hands out papers; Teacher reviews safety rules **"Teachers need to be well organized for science."** **"I grouped the students based on who I know can get along."**	
2. Control: ***Who has primary control over the focus and direction of this lesson segment?***			
2a. Student **(2a.) Interview Code: Student Control**	The students have primary control over the focus and direction of this lesson segment. Teacher provides guidance, but does not direct students' actions. **Teacher says that part of ideal or their own science teaching is giving students autonomy/control over their learning.**	Teacher allows students to investigate the answers to their own questions; Teacher allows students to discuss/explore a new idea brought up by one of the students **"Students should be given freedom to explore their own questions and conduct own investigations."** **"The best is when students discover things for themselves."**	In reformed science teaching, greater control of the lesson is given to the students; students take on active rather than passive roles in their learning (Huffman et al., 2008; NRC, 1996). Research has shown that teachers with higher science teaching self-efficacy encourage greater student autonomy in their lessons (Czerniak & Shriver, 1994; Enochs et al., 1995).
2b. Teacher-Student	Teacher and students share control over the focus and direction of this lesson segment. Teacher still determines the focus, but is guided by some input from the students.	Teacher encourages some student-student interaction, asks open-ended questions, and/or explores student ideas related to the lesson topic	
2c. Teacher	Teacher has primary control over the focus and direction of the lesson segment.	Students listen to teacher without much if any input; Teacher asks questions, but calls on students directly and is looking for specific answers; Students complete a "cookbook" activity provided by the teacher	

3. Student Thinking: ***What level of student thought is necessary for this lesson segment?***			
3a. High	Students' thinking level corresponds to Bloom's taxonomy* levels 4 (Analysis), 5 (Synthesis), and/or 6 (Evaluation).	Students actively reflect on a concept or idea; Students critically solve problems and/or evaluate ideas	The development of students' critical thinking skills is an important component of reformed science teaching (Huffman et al., 2008). Research indicates that elementary teachers with higher science teaching self-efficacy levels are more likely to choose activities where students are expected to use higher-level thinking and problem solving skills (Czerniak & Shriver, 1994).
3b. Medium	Students' thinking level corresponds to Bloom's taxonomy* levels 2 (Comprehension) and/or 3 (Application).	Students describe concepts; Students connect concepts to a new example or use information in a new situation	
3c. Low	Students' thinking level corresponds to Bloom's taxonomy* level 1 (Knowledge) or student thinking is not evident.	Students passively receive information from the teacher; Students recall factual information	
(3d.) Interview Code: Student Thinking	**Teachers talk about how developing their students' thinking is a part of their ideal or personal science teaching.**	**"Don't just give them the answers. Make them really think about it."** **"I ask my students why. I try to make them think."**	

*Revised Bloom's taxonomy (Huitt, 2004)

2) **Fundamental abilities of inquiry*** demonstrated in the lesson:

Characteristic	Description	Examples
FAI1. Students ask scientifically oriented questions **Interview Code: Students' Questions**	Teacher encourages students to ask questions that are "scientifically oriented" (NRC, 2000, p. 25), related to the scientific content of the lesson.	Students ask questions "about objects, organisms, and events in the environment" (NRC, 2000, p. 19); Students determine questions to be answered using scientific investigations.
FAI2. Students plan/design an investigation **Interview Code: Students Plan Investigations**	Teacher prompts students to develop their own ways to answer a scientific question and/or to test a prediction/hypothesis. Students may develop the entire procedure or one or more components of the procedure.	Students design an experiment to answer a question or test a prediction/hypothesis; Students are given a general procedure for an investigation, but choose what materials they will test; Students are asked how they might go about answering a particular question.
FAI3. Students gather data/evidence **Interview Code: Students Gather Data**	Teacher prompts students to gather data/evidence related to a scientific question.	Students "employ simple equipment and tools to gather data and extend the senses" (NRC, 2000, p. 19); Students "use appropriate tools and techniques to gather data" (NRC, 2000, p. 19).
FAI4. Students use data/evidence to formulate explanations **Interview Code: Students Formulate Explanations**	Teacher prompts students to use data/evidence to formulate explanations for scientific concepts observed in class or otherwise.	Students use data from an experiment conducted in class to explain the class' results; Students explain how they think something works or why something is the way it is based upon their prior knowledge.
FAI5. Students communicate investigations/procedures and explanations **Interview Code: Students Communicate Ideas**	Teacher encourages students to share results/procedures of an investigation/activity and/or explanations of/ideas about the scientific concepts.	Students create graphs or other written representations demonstrating results and/or conclusions of an investigation; Students verbally explain their results/explanations to other members of the class and/or the teacher.
FAI6. Students make predictions/hypotheses** **Interview Code: Students Make Predictions**	Teacher prompts students to make predictions about what will or might happen based on prior knowledge and/or data.	Students predict what will happen if a variable is changed based on data; Students predict what might happen based on their prior knowledge.

* Based upon the "fundamental abilities necessary to do scientific inquiry" for grades K-4 and 5-8 as listed in the *National Science Education Standards* (NRC, 2000, p. 19). This portion of the coding scheme is designed to determine which abilities are fostered/promoted by any parts of the observed lesson and/or the perceived ideal or personal teaching practices of the teachers.

**This characteristic is not specified as a separate "fundamental ability" by the NRC (2000), but is instead combined within the others. It was separated in the analysis for this study based on the interviews with and observations of the participants.

3) **Other characteristics** demonstrated in the lesson and/or in teachers' interviews:

Characteristic	Description	Examples	Reason(s) for Inclusion
OC1. Student-Student Communication **Interview Code: Student-Student Communication**	Teacher encourages/promotes communication and collaboration *between students* about scientific concepts. **Teachers talk about student-student communication and/or interaction as being a part of ideal or personal science teaching.**	Pair-share; Students work together in small groups to discuss a scientific concept/question **"It's very important to always have students share their ideas"** **"I like to have students explain things to each other."**	Not simply student communication, but students communicating *with each other* about scientific ideas is an important component of reformed science teaching (NRC, 1996; Sawada & Pilburn, 2000). Research suggests that teachers with higher science teaching self-efficacy do a better job promoting student-student interactions and student collaboration in the science classroom (Enochs et al., 1995; Haney et al, 2002).
OC2. Content Connection **Interview Code: Content Connection**	Teacher connects the content of the lesson to the real world, students' prior knowledge, related science content, and/or students' interests. **Teachers discuss connecting the science content to the real world/lives of the students and/or making the content relevant for the students.**	Teacher connects the topic of water pollution to the pollution of a local river; Teacher uses a skateboarding example to explain a concept in physics **"If it's not relevant to their lives you're going to lose them."** **"I always try to connect the content to the real world."**	This characteristic has been cited as an important component of reformed science teaching (NRC, 1996; Sawada & Pilburn, 2000). Teachers with higher science teaching self-efficacy have been reported to do a better job connecting and attending to students' prior knowledge and experiences and tying the content to the real world and other content areas (Haney et al., 2002; Riggs et al., 1998). In addition, participants in this study frequently cited this characteristic in their interviews.
OC3. Misconceptions	Teacher promotes information that is scientifically incorrect. (An exception is made when teachers explains in their interview why they did this on purpose.)	Teacher gives incorrect information; Teacher does not challenge and/or agrees to an idea that is incorrect and/or a misconception.	An important component of effective science teaching is for teachers to promote student learning of accurate scientific information and to not promote students' misconceptions. Research suggests that teachers with higher levels of science teaching self-efficacy have fewer scientific misconceptions (Schoon & Boone, 1998) and have greater knowledge about scientific concepts (Angle & Moseley, 2009; Desouza et al., 2004; Ramey-Gassert et al., 1996).

Characteristic	Description	Examples	Reason(s) for Inclusion
OC4. Interdisciplinary **Interview Code: Interdisciplinary**	Teacher connects the science content with another discipline such as literacy or mathematics. **Teachers say that part of ideal and/or personal science teaching is connecting the science content with other disciplines such as mathematics or literacy.**	Teacher has students use mathematics to analyze data; Students sing a song about the concept **Teachers say they incorporate other disciplines into science and/or vice versa; Teachers talk about using interdisciplinary units**	Research suggests that teachers with higher levels of science teaching self-efficacy are more likely than low self-efficacy teachers to present science content in an interdisciplinary way (Haney et al., 2002).
OC5. Interview Code: Student Enjoyment	**Teachers say that a part of ideal and/or their own science teaching practices involves students having fun/enjoying science and/or science-related activities.**	**Teachers did/do something because they want students to have fun; Promoting student excitement about science; Students enjoy what they're doing in science**	Studies have suggested that teachers with higher science teaching self-efficacy levels are focused more on the goal of student learning than on student enjoyment of science (Czerniak & Schriver, 1994). Participants in this study also frequently mentioned student enjoyment of science in their interviews as a reason for their actions.
OC6. Interview Code: Student Learning	**Teachers say that part of ideal and/or their own science teaching practices involves promoting student learning and/or understanding of scientific concepts.**	**Teachers did/do something because they want students to learn/understand concepts; Wanting students to really "get the concepts"**	Studies have suggested that teachers with higher science teaching efficacy levels are focused more on the goal of student learning than student enjoyment of science (Czerniak & Schriver, 1994). Participants in this study also frequently mentioned aspects of student learning and/or understanding of scientific concepts in their interviews as a reason for their actions.
OC7. Interview Code: External Influences	**Teachers say that effective ideal and/or their own science teaching is influenced by external influences (factors outside of their control).**	**Teachers feel that their science teaching practices are influenced by external factors such as time, materials, standardized exam scores, parental involvement, number of students, etc.**	Studies have suggested that teachers with lower science teaching self-efficacy feel a greater influence of external factors on their ability to teach science effectively (Carleton et al., 2008; Ramey-Gassert et al., 1996; Rubeck, 1990), and thus cite these factors more often as influencing their teaching practices.

Characteristic	Description	Examples	Reason(s) for Inclusion
OC8. Interview Code: Multiple Approaches	**Teachers say that part of ideal and/or personal science teaching is to use many different approaches – particularly to hit the learning needs of diverse students**	**Teachers say that they teach science in a variety of ("all different") ways; They say they use/used a lot of different strategies**	This factor came up in interviews for both personal and ideal science teaching. It was of interest to look at the actual multitude of approaches in the observed science lessons of teachers who described this factor as a part of their science teaching.
OC9. Interview Code: Hands-on	**Teachers say that they should (or do) use hands-on activities as part of their science teaching practices.**	**Teachers talk about the importance of using "hands-on" activities; activities where students are actively doing and/or manipulating something; students use their hands to experience something in science**	Research has shown that teachers with higher levels of science teaching self-efficacy claim that they do more hands-on activities in their science lessons (Enochs et al., 1995; Ramey-Gassert et al., 1996). The phrase "hands-on" came up frequently in interviews. It was very interesting to compare teachers who said "hands-on" versus talking about any of the specific abilities of inquiry.

APPENDIX F:

Example Observation Coding Matrices

Observation Code for: Teacher A **Length of Lesson: 50 min**

Segment #	Segment Length	General Segment Characteristics			Inquiry Abilities	Other Characteristics	Notes
		1	2	3			
1	4 min	1d	2b	3b	FAI4, FAI5	OC1, OC2	Teacher tells students to pair-share about water conservation for 1 minute. Teacher asks students to share with the class what they talked about. (She calls on individual students.) Teacher encourages students to explain what they are thinking. Teacher asks students to share ideas about what we can do to conserve water. She connects the information to the desert region in which the students live.
2	2 min	1d	2b	3b	FAI4, FAI5	OC2	Teacher has students share what they think we need in order to plant corn. (Calls on students.) Teacher encourages students to share their experiences with planting things.
3	6 min	1d, 1e	2b	3b	FAI4, FAI5, FAI6	OC1, OC2, OC4	In unison, class reads text on easel ("Technology to the Rescue") about a new technology to conserve water. Teacher goes through the text and thinks aloud (modeling reading strategies). Teacher calls on students to share ideas. • What does absorb mean? • What can I learn from this part? • Why would this be important? One pound of crystals can absorb 43 gallons of water. o Teacher has students pair-share about this question. • What happens when water comes down as rain? Where does it go? • What would happen if these crystals were there?

Segment #	Segment Length	General Segment Characteristics			Inquiry Abilities	Other Characteristics	Notes
		1	2	3			
4	5 min	1f	2c	3c	---	OC2	Teacher introduces the activity. She talks about how these crystals are available for everyone to buy at Home Depot. She gives instructions and safety rules.
5	20 min	1c	2b	3b	FAI3, FAI4, FAI5, FAI6	OC1, OC2	Whole Class lab activity: Class describes observations of what happens to special crystals when water is added to them. Students make a circle around the room. They each receive a cup with some crystals in it. Teacher: Observe the physical characteristics of your crystals. What are physical characteristics? • Students are called on to share ideas (smell, feeling) • Teacher reminds students not to taste • Teacher: I want you to think of at least 4 physical characteristics to describe your crystals. • Teacher has students pair-share the physical characteristics they observe and then students share out loud. Teacher calls on students to predict what will happen when water is added. After each addition of water, students first share their observations with their neighbor, then with the class. Teacher always has students predict what will happen when more water is added and has them explain what they think is happening.
6	2 min	1d	2b	3a	FAI5	OC1, OC2	Teacher asks students to share their observations about how the crystals have changed from the beginning to now. She has the students pair-share about how this activity connects to water conservation and then share with the whole class.

Segment #	Segment Length	General Segment Characteristics			Inquiry Abilities	Other Characteristics	Notes
		1	2	3			
7	6 min	1d, 1e	2b	3c	FAI5	OC2	Students sit down on the carpet. Teacher reviews the activity and has students share some more observations. Teacher tells the students that over the next few weeks they will be growing corn in their crystals and making more observations.
8	5 min	1f	2c	3c	---	---	Students get their corn seeds and plant them in their cups.

Observation Code for: Teacher B **Length of Lesson: 30 min**

Segment #	Segment Length	General Segment Characteristics			Inquiry Abilities	Other Characteristics	Notes
		1	2	3			
1	5 min	1f	2c	3c	---	---	Teacher gives an overview of what the topic of the class will be.
2	7 min	1e	2b	3b	FAI4, FAI5	OC2	Teacher asks students what they already know about photosynthesis. She tries to have them explain what they mean and why they think that.
3	13 min	1e, 1f	2c	3c	---	---	Teacher writes notes on the overhead and students copy. Teacher spends a lot of time correcting student behavior and tells students to pay attention.
4	5 min	1e	2c	3c	---	---	Teacher orally quizzes students on information from the notes they just took. Only recall questions are asked.

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