K-5 MENTOR TEACHERS’ JOURNEYS TOWARD REFORM-ORIENTED SCIENCE
WITHIN A PROFESSIONAL DEVELOPMENT SCHOOL CONTEXT

A Dissertation in
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by

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ABSTRACT

Reform-oriented science teaching with a specific focus on evidence and explanation provides a student-centered learning environment which encourages children to question, seek answers to those questions, experience phenomena, share ideas, and develop explanations of science concepts based on evidence. One of the ways schools have risen to meet the challenge of ever-increasing demands for success in science and all other curricular areas has been in the development of professional development schools (PDSs). Dedicated to the simultaneous renewal of schools and teacher education programs, the structure of a PDS plays a significant role in the change process.

The purpose of this research study was to investigate the nature of change in mentor teachers' beliefs and pedagogical practices toward science teaching in the elementary school as conveyed through their own "stories of practice". The major research questions that guided the study were:

1) How do mentor teachers describe their science teaching practices and how have they changed as a result of participation in PDS?
   a. In what ways do PDS mentor teachers’ descriptions of practice reflect contemporary reform ideas and practices in science education?
   b. To what extent do their stories emphasize technical aspects of teaching versus epistemological changes in their thinking and knowledge?
   c. How is student learning in science reflected in teachers’ stories of practice?

2) What is the relationship between the levels and types of involvement in PDS to change in thinking about and practices of teaching science?

3) What is the depth of commitment that mentors convey about changes in science teaching practices?
Using case study design, the research explored the ways experienced teachers, working within the context of a PDS community, described changes in the ways they think about and teach science. The connection to the issue of change in teaching practices grew out of interest in understanding the relationship between mentor teachers’ engagement in PDS activities and their thinking about classroom practice.

The main focus of this research study was on change in science teaching within the context of a professional development school. PDS literature and current literature on the learning and teaching of science in grades K-8 provided a theoretical orientation to guide the research. Additionally, literature on the process of change in schools helped to narrow the focus of the study while using a lens of situated learning provided additional insight.

Analysis of the interview data generated seven assertions that captured the nature of the change process of mentor teachers. Science-specific professional development as well as strong support and encouragement within an active community of learners played significant roles in the transformation of mentor teachers from traditional or activity-based science teachers into educators who use reform-oriented methods and a lens of evidence and explanation to guide their science teaching. Mentor teachers acknowledged an increase in student interest and excitement toward science as a result of these changes in science teaching practices. In addition, data revealed that mentor teachers remained committed to their changed practice after several years. By examining the change process of mentor teachers in a PDS environment, findings from this study are discussed based on implications regarding the factors that contribute to and affect change as reform-oriented practices are implemented in science, a curricular area that is often neglected by elementary teachers.
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CHAPTER 1: INTRODUCTION

1.1 The Challenge of Change in Science Education

Teachers are society’s most valuable resource for improving science education and the most important agents of change in education (NRC, 2008). In their practitioner-based science education text, Michaels, Shouse, and Schweingruber indicate that the newest research in science education points teachers toward classroom practices that differ substantially from what occurs in most science classrooms today. Conceptions of child development held thirty or forty years ago suggest that children could only think concretely, not abstractly and historically focused on what children could not do rather than on what they could do (NRC, 2007). Contemporary research on children’s learning provides compelling evidence that children can do much more than we previously thought and are not the concrete and/or simplistic thinkers that we once believed them to be. Research evidence now shows that children’s thinking is surprisingly sophisticated and they “can use a wide range of reasoning processes that form the underpinnings of scientific thinking” (p. 335).

In contradiction to what is believed about learning by young children, researchers in science education generally agree on one central finding: “Our institutions of formal education do not help students to learn science with understanding” (Anderson, 2007, p. 5). Science is usually presented as a rigid body of facts, theories and rules to be memorized and practiced, rather than a way of knowing about natural phenomena (van Driel, Beijaard, & Verloop, 2001). The United States has been engaged in science reform for nearly five decades and current thinking about science education encourages K-8 teachers to embrace “different ways of thinking
about science, different ways of thinking about students, and different ways of thinking about science education” (NRC, 2008, p. 3).

Thinking differently about science education has the potential to yield the result of a change in practice. However, Duschl, Schweinguber, & Shouse (NRC, 2007) state: “After fifteen years of focused standards-based reform, improvements in U.S. science education are modest at best” (p. 11). In 2003, the Trends in International Mathematics and Science Study (TIMSS) reported that U.S. fourth grade students exceeded the international average in science, outperforming their peers in sixteen of the twenty-four countries. Initially, this may sound hopeful, yet it should also be noted that no measurable changes were detected in the average scores between when the tests were administered in 1995 and again in 2003. When this second statement is considered, the news about outperforming students in other countries does not seem as stimulating. In fact, the average fourth grade student score dropped by six points over this eight year time span while the scores of three of the four countries outperforming U.S. children rose by an average of thirty points. Again in 2007, although the average score for U.S. fourth-grade students was 539 (above the 500 worldwide average), this number still remained below the 542-point average from 1995. In 2007, fifteen percent of our nation’s fourth graders reached the TIMSS advanced international benchmark, putting them in the number four spot worldwide. For a country that has engaged in science education reform for five decades and spends nearly $425 billion dollars per year on public elementary and secondary schools, these results seem modest at best.

In response, the focus should shift to looking at how these students are being taught. What do reform efforts look like in the classroom and how are students being taught science? Results of the 1999 TIMSS Video Study of eighth grade science teachers revealed that science
lessons in the United States were characterized by a variety of activities that may have engaged students in doing science work, but with less focus on connecting these activities to the development of science content ideas. The report highlighted that U.S. eighth grade science lessons kept students busy on a variety of activities such as independent practical activities (hands-on labs), independent seatwork activities (reading, writing, small group discussion) and whole class discussions. In addition, although students were exposed to challenging content and various forms of evidence, it was reported that these activities were often disconnected from the science content or the big ideas in science.

This information is in contrast to contemporary trends in reform-oriented science teaching practices. Science education trends have called for an emphasis on supporting learning through inquiry (AAAS, 1990; AAAS, 1993; NRC, 1996; NRC, 2000). Current literature in science education supports the knowledge that teaching should reflect the development of ideas with the support of evidence in the form of first-hand data and phenomena. Using inquiry-based strategies with a focus on giving priority to evidence to propose explanations based on evidence is the foundation for such reform. Elementary science should be aimed at helping students “know, use, and interpret scientific explanations of the natural world; generate and evaluate scientific evidence and explanations; understand the nature and development of scientific knowledge; and participate productively in scientific practices and discourse” (NRC, 2007, p. 2).

According to recent research (NRC, 2011), it is claimed that K-12 science education in the United States “fails to achieve these outcomes, in part because it is not organized systematically across multiple years of school, emphasizes discrete facts with a focus on breadth over depth, and does not provide students with engaging opportunities to experience how science is actually done” (p. ES-1). This new framework for K-12 science education highlights the
power of “integrating understanding the ideas of science with engagement in the practices of science” (p. viii). The conceptual framework is designed to build students’ proficiency in and appreciation for science over multiple years of school while implementing teaching and learning practices that are rooted in reform.

Some research (Abell, Anderson & Chezem, 2000; Gagnon & Abell, 2008) has examined whether or not it is reasonable to expect students at the elementary level to be able to engage in scientific inquiry, to understand the processes of giving priority to evidence, and to grasp the concept of using evidence to support and justify explanations. Gagnon and Abell (2008) have asserted that it is possible and is a reasonable expectation in elementary science classrooms. However, in order for students to be successful at building evidence-based explanations, teachers must know how to do this, also. Therefore, if an emphasis on evidence-based explanations in science is necessary for promoting inquiry, and the research says that it is reasonable that elementary students can engage in this type of learning, then why is it not happening?

Making changes in practice that reflect these current reform ideas is a challenge. These changes require time and resources that are often unavailable to elementary teachers and as a result trickles down to becoming unavailable to students. Goodlad (1994) clarified this point when he described that in order to have better schools, we need better teachers. Additionally, student’s performance in American schools cannot be expected to improve without the quality of teaching significantly improving (Holmes Group, 1986). This poses a great challenge to the science education community in order to provide the best possible science education not only for children, but also for their teachers.

1.2 The Potential of PDSs to Affect Change
One of the ways that schools have risen to meet the challenge of a changing society and the ever-increasing demands placed on teachers to meet the needs of their students has been in the development of professional development schools (PDSs). PDSs are collaborative partnerships that have been created between universities and P-12 schools/districts with a focus on inquiry, research, and educational reform. These partnerships are dedicated to the simultaneous renewal of schools and teacher education programs (Goodlad, 1990). According to the National Council for Accreditation of Teacher Education (NCATE, 2001), schools and universities engaged in this relationship work together, using the process of inquiry to identify and address the diverse learning needs of students. PDS partners engage in inquiry:

- to identify and meet students’ learning needs;
- to effect candidate learning; and
- to determine their professional development agenda (p. 4).

Students in P-12 schools are increasingly expected to know more, have better skills, and show deeper understanding of content (NCATE, 2001). One approach to meeting this challenge has been through standards-based reform efforts and school restructuring. Additionally, educators have undertaken numerous reforms in professional preparation of both pre-service and in-service teachers. However, what is often missing is an alignment between these two strategies (NCATE, 2001). PDSs provide the potential to bridge the gap between these two areas of reform through the development of a partnership in which members work together to connect research to practice with the goal for all to benefit from the relationship that is created between them.

In 2001, Teitel talked about the “leap of faith” that was associated with the benefits of PDSs and complained about the lack of careful documentation of their impact. He was concerned that without good documentation of this impact on both pre-service teachers and
experienced educators, PDSs would wither away. In recent years, there has been a dramatic increase in PDS research. Zeichner (2007) points out that there has been an increase in research conducted on the effects of PDSs on aspects of teacher quality, student learning, and institutional change. This research base includes a large proportion of inquiries of studying methods involved with pre-service teacher candidates (interns) involved in PDSs.

NCATE (2001) points out that “attention to teacher quality is critical” (p. 2). Research is abundant in the literature in the content areas of reading/language arts, mathematics and social studies, however, little research has been done on the impact that PDSs have made on science teaching practices. For the research that has been conducted in science, much has focused on the impact of PDSs on pre-service teachers in middle and secondary science classrooms (Scharmann, 2007) with little attention being reported on practicing elementary teachers in science education. Little is known about the impact that PDSs have had on change in the science teaching practices of in-service elementary teachers.

What we do know about PDSs and their effects on teachers is growing. As Kroll, Bowyer, Rutherford, and Hauben (1997) reported, dedicated classroom teachers are essential components of effective PDSs. PDS teachers not only work with their own students in the classroom, but they also mentor pre-service teachers and often take classes and conduct action research in their classrooms while working with university faculty. Regardless of the increased workload on these teachers, they do appear to be satisfied with their decision to take on active roles in the PDS community and benefit from the arrangement. This implication on the inherent nature of PDS teachers and their willingness to embrace change is encouraging and was a benchmark for this research study.
In the area of science education, a large portion of the PDS studies to date have focused on pre-service teachers or in-service teachers at the middle school or secondary school level. To date, there have been no published studies to specifically assess the impact that PDSs have had on the science teaching practices of elementary teachers. If the goal for the science education community is for widespread change toward reform-oriented science teaching at the elementary classroom level, such as implementing practices that reflect the importance of giving priority to evidence in science and the relationship between evidence and explanation, then the potential of PDSs and their effect on improving classroom practices in this realm is motivating.

1.3 Why Study Elementary Science?

Science classrooms, school environments, and teaching practices have remained essentially unchanged for over fifty years (Duschl & Osborne, 2002). Elementary teachers, as generalists, tend to shy away from teaching science in their classrooms for a multitude of reasons: feeling of inadequacy in science content knowledge; lack of time and/or resources to adequately teach science; lack of support from administration; and/or poor preparation in science teaching methods courses. As a result, most elementary teachers teach science the way that they were taught in high school and even college, through textbook reading and hands-on activities that are unconnected to science ideas. The teacher, not the student, often continues to be at the center of educational practice. Rarely is elementary science expanded beyond this notion of “facts and crafts” (J. Kur, personal communication, May 20, 2005).

There are several factors that could explain this, ranging from an increased focus on reading and mathematics for performance on standardized tests (NRC, 2011) to a general disinterest in or intimidation by science content (Appleton, 2006). Regardless of the explanations that are often used for not teaching science in elementary schools, it remains that
most children love science. It has been found that students in the early elementary grades are often deeply attracted to topics that are related to the natural and designed worlds, interests that provide a foundation for learning science (NRC, 2011, p. 11-4). Many children come to school with an inquisitive nature that, if teachers are not prepared or do not feel confident enough to teach science using an inquiry stance (NRC, 2000), may be stifled at an early age.

Herein lies a dilemma. Most elementary teachers are not sufficiently prepared to teach science subject matter, nor do they have the confidence or skills necessary to teach science (Tilgner, 1990). Unfortunately, science is a content area in which professional development aimed at improving teacher practice is underserved. As reported by Buczynski and Hansen (2010), the teachers who are most in need of professional development are those who do not have ready access to professional development opportunities to support their learning and practice.

The challenge to science educators is to provide opportunities to allow teachers to foster their students’ inquisitiveness by preparing them to engage their students in inquiries that are interesting and important to them. Rethinking pedagogy and embracing the model of teaching science as inquiry and teaching science through inquiry is essential to meeting reform goals. It is imperative that reform-oriented science teaching practices are modeled through in-depth professional development opportunities, beginning as early in their education as possible in order to facilitate conceptual understanding and scientific literacy (AAAS, 1993).

Reform-oriented science teaching is rooted in the practice of teaching science as outlined in the National Science Education Standards (1996) and described in-depth in the NSES Inquiry Standards (2000). Student-centered inquiry learning environments focus on engaging students in seeking answers to questions, experiencing phenomena, sharing ideas, and developing
explanations of science embedded in the everyday world. Reform-oriented science teaching describes a collection of instructional practices that are designed to engage students as active participants in their own learning and to enhance the development of complex cognitive skills and processes.

The Committee on Science and Mathematics Teacher Preparation emphasized the critical importance of the teachers’ role in student achievement and learning in both science and math. In their report, the committee affirmed: “As noted in the extensive body of evidence cited throughout this report, research is confirming that good teaching does matter” (NRC, 2001, p.4). Knowing this, improving teachers’ knowledge, skills and dispositions through professional development is a critical step in improving student achievement. Effective teacher professional development in science is critical for the continued advancement of student learning in science. Using a lens of reform-oriented science teaching practices that reflect evidence and explanation building in the classroom is the next generation of reform and pushes prior expectations for teaching science to new heights. Teachers not only need to have a solid understanding of student learning in science, but they should also have a deeper understanding of their own views of the nature of science in order to transform pedagogical practices effectively. Factors such as subject matter understanding and pedagogical orientations critically influence the quality of teaching (McDiarmid, Ball, & Anderson, 1989). Career-long professional development is necessary to meet these expectations and to challenge teachers’ thinking and practice beyond textbook reading and craft-like activities in science. This poses a very real challenge for schools and for teachers.

Research and development in science education has progressed substantially since the first National Science Foundation (NSF) curriculum efforts of the 1960s (NRC, 2007). Current
science education literature places an increased focus on the importance of the use of evidence and explanation in children’s learning of science and of using methods of inquiry in order to meet the needs of this type of learning (NRC, 1996; NRC 2000; NRC, 2011). However, Duschl and colleagues (NRC, 2007) point out that there is still a long way to go in the process of improving science education, despite the recurrent efforts in curriculum and standards-based reform movements. One of the factors, they assert, that may help to explain the limited impact of these reform efforts focuses on “insufficient teacher preparation and professional development” (p. 17). This research study addresses not only this issue, but also ties together the pieces of teacher growth, teacher change, and teacher development as a result of unique experiences within the professional development school context.

1.4 Purpose of the Study

Teachers grow tired of professional development opportunities that are constantly delivered by an administrator or higher authority that they are expected to implement (Courson, 2001). Through the implementation of professional development school partnerships, collegiality is renewed and the school is often seen as a center of educational renewal (Osguthorpe, Harris, Harris, & Black, 1995) where the school is changed from within. By using contemporary perspectives on teacher learning and reform practices in science education, this research is grounded in the literature of change and was designed to gain an understanding of what elementary teachers find to be most meaningful in contributing to their learning and teaching practice as it relates to science in the elementary classroom.

Knowing that change is both difficult and challenging, the purpose of this research was to investigate how teachers in one school district have changed not only the way that they teach
On a survey distributed throughout the local PDS community and used as the initial basis for this research study, mentor teachers reported high levels of change in thinking and/or practice in the area of science education as a result of their PDS involvement. These survey results were the initial motivation for this research. If mentor teachers reported significant change in their thinking and practice in science, what did this change look like and was it more consistent with current reform in science education? What kinds of PDS engagement contributed to teachers’ changes in practice and in thinking?

These questions were important in the assessment of this reported change to determine if the criteria that Sparks and Hirsch (2000) mentioned in the following quotation played a role in the change process of these teachers. They stated:

The lack of high-quality professional development for teachers explains much of the failure of past school reforms. In the absence of substantial professional development, many teachers naturally gravitate to the methods they remember from their own years as students. Studies show only about half of teachers use new instructional strategies aligned with high standards and specifically developed to lead all students to achieve. States cannot improve schools through mandating high standards and tough tests unless they give teachers the tools, support, and training to help them change their practice (p. 42).

Therefore, the purpose of this research study was to investigate the nature of change in PDS mentor teachers’ thinking and pedagogical practices toward science education in the elementary school as conveyed through their “stories of practice.” The research explored the ways experienced teachers, working within the context of a professional development school community, described changes in the way they think about and teach science.

The major research questions that guided this study were:

1) How do mentor teachers describe their science teaching practices and how have they
changed as a result of participation in PDS?

a. In what ways do PDS mentor teachers’ descriptions of practice reflect contemporary reform ideas and practices in science education?

b. To what extent do their stories emphasize technical aspects of teaching versus epistemological changes in their thinking and knowledge?

c. How is student learning in science reflected in teachers’ stories of practice?

2) What is the relationship between the levels and types of involvement in PDS to change in thinking about and practices of teaching science?

3) What is the depth of commitment that mentors convey about changes in science teaching practices?

Question one provided a brief description or background on each of the participants in the study based on teachers’ self-reports of their change. The sub-questions analyzed each participant’s story of practice in order to identify ways in which each teacher changed (or did not change) toward a view of reform-oriented science teaching. Question two revealed the extent to which there was any relationship between how teachers were involved in the professional development school setting (e.g. serving on committees, working with interns) and how they came to view their science teaching through the change process. Finally, Question three examined teachers’ reported changes in order to determine how deeply committed the participants were to their transformed science teaching practices.

1.5 Overview of the Dissertation

Recent professional literature is replete with discussions about the effectiveness of school-university partnerships in teacher change (Hoffman, Reed, & Rosenbluth, 1997). Additionally, there is a growing body of literature that is focused on change by secondary school teachers in the discipline of science within professional development schools (Scharmann, 2007). However, the literature is scarce in the focused area of changed science teaching practices by
elementary teachers. The purpose of this research study was to understand the process of change experienced by these mentor teachers in order to begin to fill this void in the literature.

A review of the relevant literature as it applies to the design and framework of this study is found in Chapter Two. Chapter Three provides an in-depth description of the unique PDS context of this research study and includes a description of the overall science initiative within the context of this PDS. Chapter Four outlines the research method of the study, including a description of the data collection and analysis. Chapter Five contains the description of each of the eleven study participants and tells each participant’s story of practice and story of change. In Chapter Six, assertions resulting from the data analysis are developed and organized around the research questions that drove this study. Chapter Seven provides lessons learned through this research process and offers research implications and recommendations for future research for the educational community.
CHAPTER 2: REVIEW OF THE RELATED LITERATURE

2.1 Overview

The purpose of this study was to investigate the nature of change in PDS mentor teachers’ beliefs and pedagogical practices toward science education in the elementary school as conveyed through their “stories of practice.” The research explored the ways experienced teachers, working within the context of a professional development school community, described their self-reported change in the way they think about and teach science. The background of this study focused on the review of two major bodies of literature. First, an overview of the science education reform movement in elementary schools with emphasis on how these reform efforts are progressing in elementary schools across the country is documented. Secondly, a review of professional development school studies is provided to establish the conceptual understanding of this model of school/university collaboration and to inform professional development issues in science education. Additionally, influences of teacher change literature and teacher learning through social constructs are discussed throughout the chapter.

In the 2007 National Research Council publication, *Taking Science to School*, Duschl, Schweingruber and Shouse made two claims about supporting quality science instruction. First, they claimed that student learning of science “depends on teachers having adequate knowledge of science” (NRC, 2007, p. 296). They discussed how elementary teachers have limited knowledge of science as well as minimal opportunities to learn science. Due to inadequate undergraduate coursework in science and the focus of that introductory coursework being broad and fact-based in presentation and learning style, elementary teachers either follow that same teaching model in their own classrooms, or attempt to do the opposite by making science “fun” through an activity-mania approach (Moscovici & Nelson, 1998).
Secondly, Duschl and colleagues claimed that in order for elementary teachers to teach science as practice, they need “sustained science-specific professional development in preparation and while in service” (NRC, 2007, p. 296). In other words, teachers need their own opportunities to learn about science and how to teach science as practice. Teaching science as practice reflects an approach to science in which students engage in aspects of scientific practice such as developing scientific explanations and models, participating in scientific argumentation, and designing and conducting scientific investigations, all of which should be embedded within a meaningful problem-based approach. To move toward instruction that is consistent with the research base on such reform methods in science education, teachers need opportunities to learn within the context of schools as well as within professional development programs. “Professional development that supports student learning is rooted in the science that teachers teach and includes opportunities to learn about science, about current research on how children learn science, and about how to teach science” (p. 296).

These two claims regarding the knowledge and practice of teachers play a leading role in the current development of science teaching and learning in elementary classrooms. Therefore, in order to support quality science learning experiences in the school curriculum, mechanisms for quality science instruction must be in place and teachers should implement best practices for teaching science.

2.2 The Science Education Reform Movement

In the 1950s and 1960s, the United States saw its first major push to reform teaching practices in classrooms across the country. The initial stimulus to these efforts was the 1957 launching of the earth-orbiting satellite, Sputnik, by the Russians. The U.S. response to this was to commit money and resources to the development of exemplary science programs in our
schools. Such programs became known as “Alphabet Soup” programs as a result of the acronyms that accompanied them (e.g., Science Curriculum Improvement Study (SCIS), Elementary Science Study (ESS), Science – A Process Approach (S-APA)). These programs were widely used in school districts across the country. The spirit of this new approach to learning science was hands-on and aimed at providing students with early exposure to authentic science experiences (NRC, 2007).

Many of these programs continued to be used in U.S. schools throughout the 1960s, 1970s, and 1980s. Curriculum developers at the time hoped that exposure to science through these hands-on and investigative approaches would contribute to a greater public understanding of science as well as attract talented students to advanced study in science. As Duschl and colleagues (NRC, 2007) reported, these curricula were driven more so by theories of teaching and less so by theories of learning. In other words, although the curricula were engaging students in hands-on activities with the anticipation of interacting with phenomena like scientists, they were not truly allowing for student-driven learning or ideas in the learning process. As a result, by the mid-1980s, many schools had given up on these programs and therefore returned to textbook-driven teaching practices.

In 1983, the report *A Nation at Risk* by the National Commission on Excellence in Education, offered a less than desirable assessment of K-12 education in the United States. Although selective attention was given to the formative years spent in elementary schools, the report posited that U.S. students were far behind students in Japan and other industrialized nations in both science and mathematics (National Commission on Excellence in Education, 1983). Specifically, time spent on subjects such as biology, chemistry, physics, and geography
was about three times that spent by even the most science-oriented U.S. students, was required by all students, and started as early as sixth grade.

The results of these findings eventually led to the emergence of standards-based reform efforts in science education. Project 2061 set the stage for this movement with its publication of two pivotal documents, *Science for All Americans* (AAAS, 1990) and *Benchmarks for Science Literacy* (AAAS, 1993). These documents helped to determine what all U.S. students should know and be able to do in science in the twenty-first century. The National Research Council organized a panel of experts in the field to develop national standards for science education. In 1996, the *National Science Education Standards* were published, followed in 2000 by a more focused look at scientific inquiry in schools in *Inquiry and the National Science Education Standards; A Guide for Teaching and Learning*.

More recently, the National Research Council appointed a committee of experts in science education, science, and engineering to create new standards in K-12 science education by developing a framework to guide K-12 science education. This most recent document, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* is based on a growing body of research on teaching and learning in science in an effort to define foundational knowledge and skills for K-12 science and engineering (NRC, 2011). The creation of these standards was not meant to replace existing national documents, but rather to build upon the foundation of these standards in order to revitalize science education.

The new framework builds upon the strong foundation of inquiry science practices that have been the focus of reform efforts since the 1990s. The framework emphasizes the value of integrating “the ideas of science with engagement in the practices of science and is designed to build students’ proficiency and appreciation for science over multiple years of school” (NRC,
By developing a framework that is focused on content knowledge and scientific practices, science education moves toward a more coherent vision. Teaching and learning that reflect such scientific practices as explanation building, evidence gathering, questioning, and scientific discourse, and a curriculum design that is focused on a limited set of core ideas is intended to help students develop a true understanding of science concepts over time.

2.2.1 Goals of Contemporary Reform Movement in Science Education

Based on contemporary reform in science education, the question can be asked, “What is science and why should we teach it?” Over the years, expectations of what it means to be competent in doing science and understanding science have broadened (NRC, 2007) and there is a new and growing body of research on learning and teaching in science that can inform these new or modified goals for science education.

Goals for contemporary reform in science education are broad and envelop a grand scope of elements within the scientific enterprise. First and foremost, guiding contemporary reform is the underlying premise that children learn science by engaging in scientific practices. To elaborate further, this means that children engage in scientific discourse and practices that are focused around big ideas in science. Students own and engage in aspects of scientific practice that are modeled after expert practice. Student-designed questions lead to investigations wherein they explore phenomena and answers questions by gathering evidence to help them build a strong knowledge base, and are then able to formulate explanations based on that evidence to describe their experiences and their learning (Abell, Anderson & Chezem, 2000; Folsom, Hunt, Cavicchio, Schoenemann, & D’Amato, 2007; Gagnon & Abell, 2008; Zembal-Saul, 2009). This view of science as evidence-based explanation building is reflective of what it means to really do science. Just as scientists encounter patterns in the world and construct theories to explain them
(Gagnon & Abell, 2008), children come to school with a multitude of experiences that stem from their natural inquisitiveness and attempt to make sense of the world around them. Science is not only learned in the school classroom, but is embedded in the everyday experiences of children. Reform-oriented science teaching is reflective of this condition and provides opportunities for students to engage in authentic experiences in the classroom and apply that knowledge elsewhere.

According to the National Science Education Standards (1996), the goals for school science are to educate students who are able to;

- Experience the richness and excitement of knowing about and understanding the natural world;
- Use appropriate scientific processes and principles in making personal decisions;
- Engage intelligently in public discourse and debate about matters of scientific and technological concern; and
- Increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers. (p. 13)

To support these goals, recently, Duschl and colleagues (NRC, 2007) developed four strands of scientific proficiency that support a strong foundation for reform in science education. They assert that students who are proficient in science:

- Know, use and interpret scientific explanations of the natural world;
- Generate and evaluate scientific evidence and explanations;
- Understand the nature and development of scientific knowledge; and
- Participate productively in scientific practices and discourse. (p. 36)
These four strands suggest that “learning science involves learning a system of thought, discourse, and practice – all in an interconnected and social context – to accomplish the goal of working with and understanding scientific ideas” (NRC, 2011). This science-as-practice perspective calls upon the knowledge that science learning takes place in a social context and attends to the combination of each of the strands of proficiency. This perspective also supports the goals for science education that reinforce students’ abilities to generate and evaluate explanations from evidence and the understanding that learning is a process, not a product.

By taking a science-as-practice approach to teaching and learning, these goals for reform can be achieved. By approaching problems from both a disciplinary perspective as well as a personally situated perspective (NRC, 2007), students engage in aspects of scientific practice. This is “a crucial shift away from typical K-8 science instruction” (p. 255). In order to support these goals for learning in a manner that is both effective and meaningful, not only must classrooms provide learning opportunities that attend to the four strands of scientific proficiency, but teachers must also be afforded the occasion to learn, practice, and reflect on implementation of these methods through sustained professional development opportunities.

2.2.2 Professional Development as it Relates to Reform in Science Education

Professional development can be described as the process of achieving professional competence through learning to improve student success (Speck & Knipe, 2001). “Professional development programs have the goal of facilitating changes toward more effective teacher practices that ultimately are intended to improve students’ science learning” (Hewson, 2007, p. 1189). Learners of all ages, including adults, are more motivated when they can see the usefulness of what they are learning (Bransford, Brown & Cocking, 2000). Many aspects of learning are consistent among both children and adults (Bransford et al., 2000). According to
Knowles (1975), instruction for adults should focus more closely on the process and less on the content being taught. Relating this to professional development in elementary science, current research asserts that instruction in science education should focus equally on subject matter preparation and pedagogical knowledge (Bransford et al., 2000; Loughran, Mulhall, & Berry, 2004; Shulman, 1987; vanDriel, Verloop, & Vos, 1998).

Teacher professional development refers to classes and less formal activities that teachers participate in to increase their knowledge and skills (National Academy of Sciences, 2003). Learning is required to support change in educational practice and the kinds and types of professional development structures in the field of education are as diverse as the teachers who are engaged in them. Professional development and becoming an effective science teacher, as described in the National Science Education Standards (1996), is:

...a continuous process that stretches from pre-service experiences in undergraduate years to the end of a professional career. Science has a rapidly changing knowledge base and expanding relevance to societal issues, and teachers will need ongoing opportunities to build their understanding and ability. Teachers also must have opportunities to develop understanding of how students with diverse interests, abilities, and experiences make sense of scientific ideas and what a teacher does to support and guide all students. And teachers require the opportunity to study and engage in research on science teaching and learning, and to share with colleagues what they have learned. (pp. 55-56)

Professional development is a central feature of nearly all reform efforts in education, yet professional development efforts are frequently described as being ineffective. Teacher lore suggests that traditional in-service teacher training has little impact on teaching practices in general. A report on results from a national survey of teachers’ views about the effectiveness of various professional development opportunities found that in-service training ranked last out of fourteen possible opportunities for learning and were considered by teachers to be the least
effective (Smylie, 1989). What teachers ranked as most important was direct classroom experience.

The most common professional development opportunities for teachers are characterized by traditional structures such as in-service workshops, graduate courses, or conferences conducted by experts in a particular field of study (Lieberman, 1995). Much of the educational establishment has been set up to accept these quick fixes as the standard for professional development. Especially in science, these strategies have been shown to be ineffective (Guskey & Sparks, 2000; Loucks-Horsley, Love, Stiles, Mundrey, & Hewson, 2003; Luft, 2001; Wee, Shepardson, Fast, & Harbor, 2007).

Ineffective professional development has the potential to do more harm than good and experienced teachers often question the importance and relevance of such professional development in their careers. Ineffective professional development programs for teachers affirm these principles because they are structured in such a way as to reflect that they are: 1) not learner-centered, 2) not knowledge-centered, 3) not assessment centered, and 4) not community centered (Bransford et al., 2000).

In the nineties, Garet, Porter, Desimone, Birman and Yoon (2001) reported that literature emerged on effective examples of professional development, teacher learning, and teacher change. Even exemplary professional development programs found it difficult to maintain support for teachers (Carey & Frechtling, 1997), to encourage sustained discourse, or to even offer time outside of the classroom for the teachers to interact. Therefore, those who develop learning opportunities for teachers should focus on the richness, the relevance, and the means for teachers to learn within the context of their own school environment (Darling-Hammond & McLaughlin, 1995).
What is known about effective professional development for science education based on years of research and practice (Loucks-Horsley, Hewson, Love, & Stiles, 1998; Loucks-Horsley et al., 2003) is that “quick-fix” types of opportunities and short-term workshops do not effectively support the long-term learning of teachers who engage in them. Learning is a process in which learners construct their own knowledge, a process that teachers need to do for themselves rather than one that is done to them by others (Borko, 2004; Loucks-Horsley et al., 1998). Peers, Diezmann, and Watters (2003) reported that adequate time is required to both understand an innovation and to reflect on and make changes to teaching practice. Directly related to this, providing quality professional development is necessary to ensure teacher growth and development in science education. There is a need to provide systematic and ongoing professional development that positively impacts student outcomes. Researchers continue to build the body of evidence that defends this idea to provide school districts with the knowledge to develop and provide a set of mutually reinforcing conditions that would need to be considered, understood, and built over time (Lieberman, 1995).

Speck and Knipe (2001) address “Conditions of Professional Development” (p. 91) as considerations to meet the needs for highly qualified professional development. Questions about time, trust, collaboration, incentives, recognition, resources, leadership, and policy issues arise when teachers view professional development plans and opportunities. Additionally, the National Science Education Standards (1996) recognized the importance of these concerns among teachers and envisioned the professional development standards embedded within the NSES as experiences relevant to their status as professionals, requiring substantive changes in professional development practices at all levels (NRC, 1996). Bransford et al. (2000) report that
successful teacher professional development involves activities that are “extended over time and encourage the development of teachers’ learning communities” (p. 204).

Expert teachers already know the structure of the knowledge in their discipline (Bransford et al., 2000). They have a firm grasp of both the subject matter and the pedagogical considerations for teaching science to their students. However, how do elementary teachers, who may not be experts in teaching science as a discipline, learn to teach science in exemplary ways? Duschl, Schweingruber, and Shouse (NRC, 2007) claim “student learning of science depends on teachers having adequate knowledge of science” (p. 296). Evidence supports that elementary teachers have limited knowledge of science as well as having limited opportunities to learn science. We also know that elementary school teachers struggle with teaching science, and particularly inquiry-based science (Zembal-Saul, Blumenfeld, & Krajcik, 2000).

Importantly, research supports the effectiveness of aligning instruction with problem solving and inquiry as the central strategies for teaching (and learning) science (Llewellyn, 2002; Martens, 1992; NRC, 1996; NRC, 2000; Windshitl, 2004). According to the National Science Education Standards (1996), scientific inquiry can be defined as,

\[
\text{[T]he diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work...the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (p. 23)}
\]

Therefore, in order to teach science through inquiry, one must learn science through inquiry. Through professional development opportunities, teachers must engage in scientific inquiry in order to learn its meaning, its value, and how to use it to help students learn. In doing such, communities of teachers are formed that support the development of knowledge and effective practice by teachers (NRC, 2000). However, simply involving teachers in scientific inquiry experiences may not be enough to support understanding and implementation of inquiry into
teachers’ classrooms (Windschitl, 2004). It takes a considerable amount of time to learn how to teach science in an exemplary manner (Speck & Knipe, 2001). Additionally, teachers need to have support and involvement in communities of practice within the school environment (NRC, 2000) as well as additional significant science experiences (Windschitl, 2004) in order to learn how to teach science in an exemplary manner. Knowledge is constructed through a process of change that is often difficult and time consuming, but if the process is supported, it can be fruitful. As Loucks-Horsley and colleagues (1998) confirm,

There can be change when new ideas fit naturally with existing ideas and added to them; when a learner creates a new idea out of existing knowledge; when new ideas extend and challenge existing knowledge, leading to its minor modification or wholesale restructuring; and when the learner sees that new ideas are powerful but irreconcilable with existing knowledge, which leads to the rejection of the existing knowledge. (p. 29)

Therefore, professional development for elementary teachers, especially in the content areas of science and technology, must be substantial. Only if professional development is embedded in the philosophy, leadership, and organizational structure of schools can a culture of change and growth thrive (Loucks-Horsley et al., 1998).

2.2.3 Inquiry-Based Science and Reform-Oriented Teaching Methods

What is inquiry-based science? Reform documents such as the National Science Education Standards (1996) promote inquiry as the central strategy for teaching and learning science. For students of science, inquiry refers to the abilities they should develop to be able to design and conduct scientific investigations and the understanding they should gain about the nature of scientific inquiry (NRC, 2000, p. xv). Abilities to do scientific inquiry include identifying and posing questions, designing and conducting investigations, gathering evidence, analyzing data, constructing and using models, building explanations, and communicating findings. Understandings students should gain include knowledge of how scientists conduct
their work and concepts related to the nature of science (Keys & Bryan, 2001). Additionally, as students move away from traditional or process-based approaches, they should be able to participate in the evaluation of scientific knowledge.

What then is “teaching through inquiry” and when and how should it be done? For teachers in the classroom, inquiry-based science refers to the teaching and learning strategies that enable scientific concepts to be mastered through investigations (NRC, 2000). In order to enact these goals for science education in the classroom, teachers must be equipped with teaching methods that allow for successful implementation. The *NSES* (1996) provided a comprehensive view of science teaching which applied to many teaching strategies, including inquiry, that make up an effective teacher’s repertoire (NRC, 2000). Although inquiry was not the only strategy for teaching science, it was a central part of these standards. Unfortunately, these teaching standards as originally designed were very broad. Therefore, the following table was created to propose a working definition that “distinguishes inquiry-based teaching and learning from inquiry in a general sense and from inquiry as practiced by scientists” (p. 24) and to assist in the development and implementation of inquiry strategies into science teaching practices.

<table>
<thead>
<tr>
<th>Essential Feature</th>
<th>Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Learner engages in scientifically oriented questions</td>
<td>Learner poses a question</td>
</tr>
<tr>
<td></td>
<td>Learner selects among questions, poses new questions</td>
</tr>
<tr>
<td></td>
<td>Learner sharpens or clarifies question provided by teacher, materials, or other source</td>
</tr>
<tr>
<td></td>
<td>Learner engages in question provided by teacher, materials, or other source</td>
</tr>
<tr>
<td>2. Learner gives priority to evidence in responding to questions</td>
<td>Learner determines what constitutes evidence and collects it</td>
</tr>
<tr>
<td></td>
<td>Learner directed to collect certain data</td>
</tr>
<tr>
<td></td>
<td>Learner given data and asked to analyze</td>
</tr>
<tr>
<td></td>
<td>Learner given data and old how to analyze</td>
</tr>
<tr>
<td>3. Learner formulates explanations from evidence</td>
<td>Learner formulates explanation after summarizing evidence</td>
</tr>
<tr>
<td></td>
<td>Learner guided in process of formulating explanations from evidence</td>
</tr>
<tr>
<td></td>
<td>Learner given possible ways to use evidence to formulate explanation</td>
</tr>
<tr>
<td></td>
<td>Learner provided with evidence</td>
</tr>
<tr>
<td>4. Learner connects explanations to scientific knowledge</td>
<td>Learner independently examines other resources and forms the links to</td>
</tr>
<tr>
<td></td>
<td>Learner directed toward areas and sources of scientific knowledge</td>
</tr>
<tr>
<td></td>
<td>Learner given possible connections</td>
</tr>
</tbody>
</table>
5. Learner communicates and justifies explanations

<table>
<thead>
<tr>
<th>Learner forms reasonable and logical argument to communicate explanations</th>
<th>Learner coached in development of communication</th>
<th>Learner provided broad guidelines to sharpen communication</th>
<th>Learner given steps and procedures for communication</th>
</tr>
</thead>
</table>

| More | Amount of Learner Self-Direction |
| Less | Amount of Direction from Teacher or Material | Less | More |

Table 2.1 Essential Features of Classroom Inquiry (NRC, 2000, p. 29)

Emphasis on formulating questions, gathering and interpreting evidence, and constructing explanations based on evidence and experience is central to inquiry-based science teaching and reform in science education and is also the basis for the use of reform-oriented science teaching methods. These methods are defined by a teaching philosophy that supports inquiry learning as represented in the above table and include teaching strategies that are employed as a result. There are no specific prescriptions for how to conduct inquiry in the classroom and no list of methods that must be employed. However, as research on effective inquiry-based instruction is evaluated, several approaches such as in-depth questioning, using discourse both between and among students about scientific ideas, modeling scientific inquiry, and focusing on evidence to form explanations of phenomena are essential. Therefore, there is no one specific method for teachers to adopt to become “inquiry-based teachers of science.” They must scaffold their teaching using elements of instruction that frame science as practice (NRC, 2007).

2.3 Professional Development School Literature

The professional development school movement formally became a part of the educational setting approximately twenty years ago. A professional development school is not a physical entity in the form of a single school building as one traditionally envisions a school to be. PDSs are innovative collaborations that are formed through partnerships between professional education programs (universities) and PreK-12 schools (Teitel, 2003). The reality of

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a professional development school is the combination of many places and many people that all work together with one specific goal - to promote student learning. They exist as partnerships, collaborations, and unions of the many people that dedicate a substantial portion of their time and resources. The goal of promoting student learning is strived for by improving schools, preparing new teachers in better ways, supporting the growth and the development of all educators (e.g., classroom teachers, university faculty, administrators, parents) and using inquiry and research to establish what works well and what does not (Teitel, 2003). Following is a review of the literature as it relates to history of the PDS movement, goals of PDS, and teacher learning situated within PDSs.

2.3.1 Historical Perspectives of PDSs

The concept of professional development schools grew out of a response to the challenge of the report, *A Nation at Risk* (NCEE, 1983). This report was monumental in that it not only was it a wake-up call to the American people as to the state of our nations’ schools, but it also offered recommendations that seemed to be both logical and feasible. These recommendations were proposed with the intent to improve the education of our children in order to better prepare them for the twenty-first century in areas of content and citizenship, and were aimed at improving the training of our nation’s teachers in order to better equip them for these changes. Moreover, it was recognized that to do this, teaching needed to rise to the level of what society would consider a true profession. Its intentions, however harsh at the time, were admirable.

Many reform efforts were proposed and organized as a result of this report. Reform movement agendas put forward by the National Education Association, the American Federation of Teachers, the National Network for Educational Renewal, and other grass roots initiatives all
called for the restructuring of our schools and universities in an effort to transform America’s future in education (Teitel, 2000).

It is important to note that decades before the 1983 report, many universities and progressive communities educated their children through what became known as “lab schools”. Educator and researcher John Dewey has been credited with promoting these schools in an era where educating to the masses was dominant in most public schools. The fundamental beliefs and foundations of these lab schools were utilized as the building blocks for constructing what would in the future become known as professional development schools.

The Holmes Group (1986, 1990, 1995) is often credited with giving professional development schools their start, using these lab schools as well as the teaching hospital as a model for designing the concept of PDSs. The Holmes Group, named after a 19th century Harvard education leader who devoted his professional life to changing the way teachers were prepared, initially formed as a small group of education deans who responded to the challenge of *A Nation At Risk* by proposing an agenda to improve both schools and the teaching profession. This group from higher education (a consortium of ninety-six research universities with professional education programs) received funding from numerous foundations and became focused on changing these trends in education. They wanted to make schools of education *matter* in the profession and to provide a framework that, when implemented properly, would support a genuine profession of education. The concept that they envisioned would eventually become known as professional development schools (PDSs) and are a collaborative effort between universities and public schools “for the development of the teaching profession” (Holmes Group, 1990, p. 1).

**2.3.2 Goals of the Professional Development School Movement**
In addition to the Holmes Group, the professional development school movement has been promoted by many organizations including the American Federation of Teachers, the National Educational Association, and the National Network for Educational Renewal (Teitel, 2003). Although there are differences in the emphasis and focus of PDS advocates, a strong union around the following four goals exists:

1. Improvement of student learning
2. Preparation of educators
3. Professional development of educators
4. Research and inquiry into improving practice (p. 6)

From their inception nearly twenty years ago, educators intended professional development schools to “develop new visions of teaching and prepare practitioners who can implement these visions” (Holmes Group, 1990, p. 6). The National Council for Accreditation of Teacher Education (NCATE), the nation’s leading accrediting agency of teacher preparation programs, has developed PDS standards to guide and direct schools of education interested in the implementation of professional development school collaborations (Blair, 2001; NCATE, 2001). Approximately thirty percent of the 525 colleges and universities accredited by NCATE report being involved in PDS partnerships (Levine, 2002) with new schools joining each year and redesigning their programs around the PDS concept. These changes in the education programs at many universities add to the growing body of literature to support the implementation of PDS partnerships between teacher education programs and P-12 schools.

More recently, the National Association of Professional Development Schools (NAPDS) has put forward nine “fundamental qualities” that represent practical goals for PDS work. These nine essentials are:
A comprehensive mission that is broader in its outreach and scope than the mission of any partner that furthers the education profession and its responsibility to advance equity within schools and, by potential extension, the broader community;

2. A school-university culture committed to the preparation of future educators that embraces their active engagement in the school community;

3. Ongoing and reciprocal professional development for all participants guided by need;

4. A shared commitment to innovative and reflective practice by all participants;

5. Engagement in and public sharing of the results of deliberate investigations of practice by respective participants;

6. An articulation agreement developed by the respective participants delineating the roles and responsibilities of all involved;

7. A structure that allows all participants a forum for ongoing governance, reflection, and collaboration;

8. Work by college/university faculty and P-12 faculty in formal roles across institutional settings; and

9. Dedicated and shared resources and formal rewards and recognition structures (NAPDS, 2008, p. 3)

These nine fundamental qualities are intended to serve as a guide for teacher educators in their efforts to define, develop and implement their PDS work with pre-service and in-service teachers. A recent study (Maier & Bump, 2011) used these nine goals as guideposts to assess their teacher education program in order to validate effectiveness based on these common qualities. They
determined that these nine goals allow educators to more clearly “define, effectively plan for, and begin the implementation of a PDS” (p. 41).

**2.3.3 Learning Theory and the PDS**

Constructivism has been a focus of science education since the 1980s. Constructivist theories suggest that individuals build their understandings through the active construction of meaning based on their prior knowledge and experiences (von Glasersfeld, 1987, 1989). Knowledge is not transferred from one individual to another, but rather individuals construct knowledge as they attempt to make sense of their experiences. More specifically, a social constructivist model of teaching and learning (Vygotsky, 1978) believes that teachers construct knowledge for one another as learning is socially mediated. This model presumes that learning is facilitated by social interactions with others within the culture.

Lave (1988) argues that learning as it normally occurs is a function of the activity, context and the culture in which it occurs. Learning within a community of practice (Lave & Wenger, 1990) is based on the premise that it embodies an identity defined by a shared domain of interest. Based on this understanding, within a community of practice, people share a common concern or passion for something they do and as a result learn how to do it better as they interact on a regular basis. As such, learning is through practice and participation, or what was named *situated* learning. Newcomers to a community tend to get involved slowly, on the periphery through a concept Lave and Wenger (1990) called legitimate peripheral participation.

In more recent research, learning as social participation (Wenger, McDermott & Snyder, 2002; Wenger, 1998) reinforced the notion of communities of practice as creating and supporting the interactions and environment necessary to share ideas and guide their learning. PDS environments offer a variety of opportunities for teachers to engage in such communities.
Situated learning theory reinforces the cognitive learning that takes place by completing tasks in authentic situations (Brown et al., 1989). Eick, Ware and Williams (2003) reported that much of the knowledge for teaching could not be learned out of context and later applied in classrooms. Putnam and Borko (2000) took this notion of situated learning a step further and not only recognized cognition as being situated, but also social and distributed. The term *situative* refers to “a set of theoretical perspectives and lines of research with roots in various disciplines…[in which] theorists conceptualize learning as changes in participation in socially organized activities, and individuals’ use of knowledge as an aspect of their participation in social practices” (Borko, 2004, p. 5). Tying back to Lave and Wenger (1990), learning should not be viewed in such simple terms as the transmission of abstract knowledge from one individual to another. Rather, learning is a social process whereby knowledge is co-constructed, situated within a specific context, and embedded within a particular physical and social environment.

Often referred to as “a lonely profession” (Fullan & Hargreaves, 1996), teachers historically have been confined to their classrooms and forced to do much of their learning on their own. However brief, minor or unassuming, teacher-to-teacher interactions throughout the school day play an important role in the social system of schools and teacher learning. From a situative perspective, teacher learning or learning to teach “is usefully understood as a process of increasing participation in the practice of teaching and through this participation, a process of becoming knowledgeable in and about teaching” (Adler, 2000, p. 37). Social interaction is a critical component of situated learning, and the environment of a PDS fosters meaningful teacher-to-teacher interactions.
PDS partnerships impact and influence communities of practice in ways that affirm and support learning. Teacher education conducted within these centers of pedagogy (Goodlad, 1990), where the art and science of teaching is the subject of continuous inquiry and research, is essential to the well being of teacher education.

2.4 Connection between PDS and Reform-Oriented Science Teaching

How can school-university partnerships support science teacher learning? “Professional development activities need to be clearly and appropriately connected to teachers’ work in the context of the school” (NRC, 1996, p. 5). Through PDSs, teachers work within a community of learners in which one major function is to focus on professional growth and development. The context of the school-university partnership is comprehensive and offers opportunity and flexibility that may not be readily present in a traditional elementary school setting. Professional development activities tied to PDS partnerships allow teachers, interns, and university faculty to work together on teaching and learning issues that expand their knowledge and abilities (Speck & Knipe, 2001). PDS partnerships have the potential to play an enriching role for both the school and the university systematically, including in science. Experienced teachers and university faculty inform practice in a reciprocal manner, sharing university research and classroom practice. In other words, putting theory into practice and practice into theory.

The conditions under which teachers gain a sense of professional accomplishment and integrity in their professional development include collaborative working arrangements and restructured roles and responsibilities (Grimmett & Neufeld, 1994). The professional development school environment fosters this among teachers, affording them opportunities to work as partners both across the hallways and across the district. These factors contribute to the
more specific task of elementary teacher development in the area of science even when it is known that this is the curricular area that intimidate many elementary teachers the most.

The constructivist learning theory suggests that the learner “develops a way of knowing or understanding new concepts based on prior knowledge. Knowledge is not simply transmitted from one knower to another” (Bell, 2002, p. 8). The PDS model exemplifies this constructivist tenet to learning both in teacher preparation and teacher professional development. Teachers have the opportunity to connect theory and practice through their interactions with students in the classroom, as well as with pre-service interns, colleagues and university faculty. These experiences contribute to their professional growth as reflective practitioners and affords them opportunities to engage with other teachers to learn what works under what circumstances to develop effective teaching practices (Loucks-Horsley et al., 2003). These elements play a critical role in the development and growth of elementary teachers as confident teachers of science.

A major commitment of PDS partnerships is to build the kinds of conditions that make it possible for teachers to grow and develop by providing continuous opportunities for inquiry into their own practice, in all areas of the curriculum. However difficult the challenge, research shows that in-service teachers are reporting changes in their practice, their learning, and their beliefs (Hoffman et al., 1997). For these experienced teachers, much of the growth and impact of PDSs is often a result of the new roles that they play as part of this school culture (Teitel, 2003). Experienced teachers are the key to educational renewal within PDSs. By continuous inquiry into their own practice, (e.g. through classroom interns, PDS courses, inquiry teams) experienced teachers develop and grow as professionals in the field. As Teitel (2003) states, for experienced teachers:
…professional development follows from a great expansion of roles, a stretching in new teaching methods, and a broader conceptualization of the role and definition of teachers…it requires teachers to crystallize what they know and articulate it to novices, but it also has other farther-reaching effects. (pp. 130-131)

The implementation of a PDS is a large enterprise for schools to employ and should not be entered into haphazardly. As Olson (1989) reported, some of the supporters of PDSs worry that asking schools to simultaneously prepare new teachers, reinvigorate teaching veterans, engage in research, and undertake widespread school improvement efforts may be asking too much. It is therefore important to document the impact of PDS partnerships on experienced teachers in such a way that all aspects of PDS are acknowledged in order to capture as many aspects of the changes that are being made as possible. Literature defends the idea that more school districts will need to develop and provide a set of mutually reinforcing conditions that must be considered, understood, and built over time (Grimmett & Neufeld, 1994) in order to meet the needs of its students and teachers effectively, and PDSs offer an environment to support these conditions.

2.5 Contributions to the Literature from This Study

Change is ongoing in the education community. It is evident in the reform movements of schools and educational institutions, in the development of curriculum, in the changing focus of classroom environments and in the renewed vision of school environments. Change is also evident in the movement from teacher-centered to student-centered ideals and in the strategies that are used in classrooms. Changes are evident in the theories behind how specific disciplines are best taught, from reading to mathematics to science. The top-down process of change is not imagined; in many cases it is historically how change occurs in schools. However, if change is viewed as a process and not an event, as explained by Hall and Hord (2006), then this study
contributes to the body of literature that supports the notion of change as “a process through which people and organizations move as they gradually come to understand and become skilled and competent in the use of new ways” (p. 4).

Current research in science education points to the difficulties that elementary teachers have in enacting effective inquiry-based practices in science (Appleton, 2007; Appleton, 2008). However, recent research (Marshall, Horton, Igo & Switzer, 2009; Sahin, Isiksal, & Ertepınar 2010) posits that teachers at the elementary level advocate for the use of inquiry-based instructional strategies in science despite these difficulties. Rather, problematic aspects of elementary science teaching have been attributed to teachers’ (a) limited subject matter knowledge; (b) anxiety about the subject matter that often stems from negative prior experiences as science learners; (c) limited materials and resources for teaching science; and (d) pressure to focus on reading and math to the exclusion of science in the elementary grades (Appleton, 2006). This research contributes to the literature base by describing what works for teachers in an elementary PDS as they navigate their way through the change process in teaching science. Results point to the connection between meaningful implementation of inquiry-based practices and the factors that played a significant role in the process from former practice to current practice.

Additionally, the PDS initiative is a program designed to support simultaneous renewal and improve education for students, prospective teachers and experienced teachers. As Blair reported (2001), since the late 1980s, researchers have been studying professional development schools and writing about their benefits. Much of the current research on PDS reform efforts focuses on the development of pre-service teaching candidates in a professional development school setting (Bell, 2002; Gimbert, 2001; Paese, 2003; Snow-Gerono, Dana & Silva, 2001,
Zembal-Saul, 2009) by pointing out benefits and pitfalls of teaching and learning inquiry science in this context. However, there are a growing number of qualitative research studies that focus on the impact of PDS on in-service teachers (Badiali et al. 2011; Bell, 2002; Francis, 2004; Scharmann, 2007; Silva, 2002). These studies point out that the nature of the professional development school model provides an environment in which unique and innovative decisions advance systemic reform and suggest that effective science learning experiences have long-term effects on how elementary teachers perceive and teach science. Bell (2002) asserts that partnerships between universities and school districts can substantially enrich and continue education for in-service teachers. This study contributes to the body of literature for in-service teachers by describing factors of this partnership that contributed to and supported change for each participant.

Some of the early research in this PDS tended to use phenomenological inquiries and studies of school culture to attempt to capture the experiences of in-service teachers and the impact that PDS has had on their beliefs and practice (Henning, 2002; Snow-Gerono, 2003). Through this research study, development of methods to document the influence and impact of PDSs (both on student learning and teacher learning) and for the collection of evidence of such impact (in the ways in which they were intended to influence education) was constructed and reported.

Finally, the PDS concept is based on a school-university-community partnership that makes a difference in the lives of students, teachers, and parents that are involved. The concept is about both student learning and teacher learning. For a school-university partnership to effect lasting change, “a structure must be created in which all partners have equal status” (Osguthorpe et al., 1995, p 3). The nature and effectiveness of these collaborations is critical to the
development, implementation, and maintenance of PDS partnerships (Guadarrama, Ramsey, & Nath, 2008; Osguthorpe et al., 1995). PDS literature supports the importance of relationships in the growth and development of these partnerships (Tietel, 2001; Darling-Hammond, 2006; Darling-Hammond, 1996).

The impact of PDS initiatives and partnerships on individual schools and teachers is less clear, as reported by Damore & Kapustka (2007). It is important to identify ways that PDS partnerships create areas for growth and leadership within the teaching profession by restructuring current practice. Rethinking pedagogy and embracing the model of teaching science as inquiry and teaching science through inquiry is essential to meet the reform goals of science education. This research study contributes to the existing professional development school literature on mentor teachers and how PDS involvement influences changes in thinking and practice related to science teaching.
CHAPTER 3: PDS CONTEXT

THE PENN STATE UNIVERSITY – STATE COLLEGE AREA SCHOOL DISTRICT
PROFESSIONAL DEVELOPMENT SCHOOL COLLABORATIVE

3.1 Overview of the School District – Elementary Schools

Situated in central Pennsylvania, the town of State College is a community that is dominated economically and demographically by the presence of the University Park campus of the Pennsylvania State University. As of the 2010 census, the borough population was 42,034 and roughly this same quantity of people live in the surrounding townships. The public school system draws its student population from a 150 square mile attendance area that encompasses the borough of State College and these surrounding townships for a total enrollment of approximately 7,000 with approximately 2,500 elementary students enrolled in the district’s ten elementary schools. The average per pupil ratio for classroom teachers is twenty-three to one at the elementary level.

The mission of the State College Area School District is “to prepare students for lifelong success through excellence in education” (http://www.scasd.org/page/615, retrieved 04/01/11). The district’s elementary schools focus on these six fundamentals:

- emphasizing respect for self and others;
- celebrating diversity;
- providing a nurturing environment with active parent involvement;
- holding children to high academic and behavioral standards;
- providing and elementary failsafe support program; and
- promoting excellence for all children.
The student population within the district is economically diverse, supporting students who come from affluent families as well as low-income neighborhoods. Demographically, many of the students are white and middle class with a small percentage of the student population being from foreign countries.

In general, elementary students within the State College Area schools tend to surpass state averages on state-mandated tests such as the Pennsylvania System of School Assessment (PSSA) tests in the areas of Reading, Mathematics, Science and Writing. For example, the following chart shows comparison results from the 2009 PSSA examinations at the fourth grade level:

<table>
<thead>
<tr>
<th>Grade 4</th>
<th>District Average</th>
<th>State Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics Proficiency</td>
<td>90</td>
<td>82</td>
</tr>
<tr>
<td>Reading Proficiency</td>
<td>86</td>
<td>72</td>
</tr>
<tr>
<td>Science Proficiency</td>
<td>91</td>
<td>83</td>
</tr>
<tr>
<td>Grade 5 Writing Proficiency</td>
<td>73</td>
<td>59</td>
</tr>
</tbody>
</table>

Table 3.1 PSSA Examination Comparison Results
Information retrieved from (http://www.seasd.org/page/616, retrieved 04/01/11)

In school year 2009-10, nine of the district’s ten elementary schools met the statewide annual yearly progress targets while one elementary school missed AYP by only one point.

The State College Area School District takes great pride in its students and its programs and offers a large variety of extracurricular activities in the arts, sciences, academics, governance, languages, athletics, and basic personal enjoyment and enrichment activities.

3.2 PSU College of Education
The Penn State College of Education serves approximately 2,700 undergraduate and 1,300 graduate students each year. The College prepares administrators, counselors, psychologists and researchers, as well as K-12 teachers in twenty-three different undergraduate teacher preparation areas leading to state certification at elementary and secondary levels across twenty campuses, including the University Park campus. All of the College of Education graduate programs that are ranked by the U.S. News & World Report appear at least in the top twenty, with six programs in the top ten. The College of Education is fully accredited by all pertinent agencies, including the National Council for Accreditation of Teacher Education (NCATE), the American Psychological Association (APA), the National Association of School Psychologists (NASP), the Council on Rehabilitation Education (CORE), and the Council for Accreditation of Counseling and Related Educational Programs (CACREP). In addition, all of the college’s professional education certification programs are approved by the Pennsylvania Department of Education.

The College is known nationally for its academic programs, educational research, and outreach and is involved in a number of initiatives that advance both education research and practice. For example, Penn State houses such academic programs as the Central Pennsylvania Holmes Partnership (PDS), Distance Education through PSU’s World Campus, the Humphrey Fellowship Program, and the American Indian Leadership Program to name a few. Additionally, it houses such research/outreach centers as the Center for the Study of Higher Education (CSHE), the Center for Science and the Schools (CSATS), the Mid-Atlantic Center for Mathematics Teaching and Learning (MAC-MTL), the Mid-Atlantic Regional Education Laboratory (REL Mid-Atlantic) and LifeLink PSU.
Penn State’s College of Education takes great pride in the many meaningful experiences that it offers to its students during their academic career. Five hundred and fifty student teachers are placed in schools each year throughout Pennsylvania and beyond and these students have high success rates on Praxis standardized tests for educators. Furthermore, ninety-eight percent of PSU College of Education students are employed in their field or in graduate school within one year of graduation (http://www.ed.psu.edu/educ/about-the-college, retrieved 04/13/11).

3.3 Historical Perspective of this School-University Partnership Development

Historically, partnerships between Penn State University and the local school district have existed since the 1800s. The earliest teachers of the late 1800s and early 1900s in the area taught public school for elementary children in the library room of the Old Main building on Penn State’s campus. Over the years, thousands of Penn State’s education students acquired many hours of their learning interactions with children within the public schools in State College through student teaching opportunities and basic classroom observations.

In 1994, the State College Area School District was approached by an innovative group of education professors from the university who were interested in implementing a type of partnership that had been taking members of the national educational community (Holmes Group, 1986) by storm – a Professional Development School partnership. Several years were spent prior to this formal partnership developing a relationship through small projects. The formal partnership was initiated with the intent to build a trusting partnership that together could improve teacher education for new teachers entering the profession, provide continuing professional development for school district teachers and Penn State teacher educators and most importantly, build strong classrooms for the district children. After many months of discussion and planning, the two institutions joined to form a partnership, The Pennsylvania State
University – State College Area School District Elementary Professional Development School. The collaboration between Penn State and the State College Area School District is formally called The Central Pennsylvania Holmes Partnership. The Holmes Partnership is a network of universities, schools, community agencies, and national professional organizations working to create high-quality professional development and significant school renewal to improve teaching and learning (Holmes, 1990). In order to symbolize the creation of this new network of roles and relationships, the traditional labels of student teacher, cooperating teacher, and university supervisor were changed to intern, mentor teacher, and professional development associate (PDA) respectively (Badiali, Nolan, Zembal-Saul & Manno, 2011).

According to the Holmes Group (1990), six general guiding principles exist for creating PDSs, and as such, these principles guided the formation of this partnership. They maintain that PDS sites must include a commitment to:

1. Teaching for understanding (rather than a factual recall) so that students learn for a lifetime
2. Organizing classrooms and schools as learning communities
3. Setting ambitious goals for everybody's children
4. Establishing an environment that supports continuing learning for all adults as well as children
5. Making reflection and inquiry the central feature of the school
6. Inventing a new organization (Holmes Group, 1990, p. 7)

With these goals in mind, Gimbert and Nolan (2003) described the beginning phases of development of the PSU-SCASD partnership:

The professional development school relationship…developed slowly over an
eight-year period. This partnership has emerged from a shared vision of university faculty and administrators and the school district’s principals and teachers. Members of this community believed that their collaborative efforts could yield better teacher preparation opportunities for pre-service teachers and enhanced learning environments for children. (p. 358)

During these first several years of building the program, interns, veteran teachers, administrators and university faculty worked together to develop and accomplish four goals. The goals that were conceptualized for this PDS partnership are known as the “Four Es.” These goals are described as the following:

(1) Enhance the educational experiences of all children
(2) Ensure high quality induction of new teachers into our profession
(3) Engage in furthering our own professional growth as teachers and teacher educators
(4) Educate the next generation of teacher educators.

The "Four Es" focused on the simultaneous renewal and professional development of the school and university-based faculty involved in the partnership. These goals have guided the actions and efforts of the partnership since its inception (http://www.ed.psu.edu/educ/pds, retrieved 04/13/11).

What originally began in 1998 in two elementary schools has expanded to include all ten elementary schools. The 2004-05 school year marked a milestone in the history of the PDS partnership when the Elementary Professional Development School Collaborative expanded to become a PDD – a Professional Development District. At that time, there were sixty-two interns placed across all ten elementary schools.

3.4 Structure of This PDS

While one component of the PDS, the undergraduate teaching internship, is focused primarily on the preparation of pre-service teachers (interns) to become "career professionals"
(Holmes Group, 1986), the PDS culture supports and celebrates the engagement of teachers and other PDS professionals within the educational community as well. Those in the PDS community construct knowledge through intentional, systematic inquiry and use that knowledge to continually reform, refine, and change the practice of teaching. The inquiry basis for the PDS internship contributes greatly to the interns' (and mentor teachers') development as critically reflective practitioners, and within the context of this research study, these relationships are significant.

The following detailed descriptions of the requirements and practices of undergraduate interns and mentor teachers within the PDS program are provided for the purpose of illustrating the unique structure and dedication of this professional development school.

3.4.1 Undergraduate Interns

This PDS offers undergraduate elementary education majors (called interns) a unique opportunity to pursue an intensive field-based alternative to traditional student teaching for completion of their teacher preparation program. Interns who are accepted into this program during their final two semesters of college work to complete thirty credits of coursework as they teach on-site in an elementary school throughout their senior year.

Entrance to the yearlong internship is competitive. Each intern candidate must submit a detailed application and successfully complete an in-depth interview with mentors and university teacher educators as part of the selection process. The candidate must express commitment to the following criteria in order to be considered for acceptance:

- willingness to follow the school district’s calendar for entire school year
- motivation toward learning and teaching
- demonstrate organizational skills
• complete a detailed philosophy of teaching
• demonstrate positive work habits
• ability to collaborate with other professionals

Once accepted into the program, work begins for the interns during the beginning of the fall semester. They begin the school year with their classroom of children, beginning on the school’s first teacher day in August, and continue in that same classroom through the end of the school year (even after they have graduated and have their degree in-hand) ending on the last teacher day in June. The yearlong internship is an intensive field-based program where learning to teach is accomplished through partnering with a mentor teacher and a university- or school-based educator, a professional development associate (PDA), for an entire school year. The work in the PDS environment is designed to “immerse the prospective teacher into the school’s culture, develop deeper understanding of student learning, and create a wider experience base from which the prospective teacher can draw when they enter the profession as a first-year teacher” (http://www.ed.psu.edu/educ/pds/general-information/introduction-to-the-penn-state-elementary-education-pds, retrieved 08/10/11). Most of the coursework that each intern takes concurrently with his/her classroom practice is taught on-site in the elementary schools and targets the connection of theory and practice. Interns typically spend four to five days a week at the PDS sites and teach alongside their mentor teacher while learning about their work with children in a public school classroom. The key outcome of the partnership is to have new teachers (graduates of the program) be well-positioned to problematize practices of teaching, systematically study those practices, and take action for change based on such study.

3.4.2 Mentor Teachers
Being a mentor teacher to an intern within this PDS looks very different from working with a traditional student teacher in a student-teaching setting. A mentor teacher sets goals at the beginning of the mentor/intern relationship to be willing to spend his or her time and expertise to guide the development of this new teacher over the course of ten months, not ten weeks. The role of the mentor is not to simply to critique observed teaching methods on sporadic lessons often prepared for unrelated purposes in the classroom, but rather to share knowledge and expertise together both formally and informally on daily interactions with children both in and out of the classroom setting. This professional development school model conceptualizes the mentor/intern relationship in this program to be that of co-teachers.

In addition to their role in the classroom setting and working with the intern, mentor teachers are also encouraged to use the knowledge that they have gained through their experiences to share with others and continue to grow professionally. For example, as a mentor teaches an intern, he/she reflects metacognitively about his/her practice and beliefs about teaching. This is an informal vehicle for both personal and professional development. As a result of this growth, one such opportunity he/she is encouraged to engage in a formal inquiry project during the mentor process in order to explore a topic or issue that they are interested in with the support of their intern, university faculty and other teaching colleagues. Engaging in teacher inquiry, also known as action research, within the classroom is one of the hallmarks of this PDS partnership.

In addition to engaging in teacher inquiry, mentor teachers are also encouraged to participate in several other forms of professional development opportunities that have been crafted specifically to meet the needs of teachers working within the school district and also more expressly for mentor teachers/teacher educators. One of these opportunities is the ability to
engage in coursework to earn graduate credits from Penn State for their work in the PDS setting. Another opportunity offered through the PDS is the chance to serve on course planning teams with the purpose of planning, delivering and evaluating the methods courses offered during the internship year. Mentor teachers can also participate in CIG (Conversation as Inquiry Groups) or other forms of collegial study groups that develop as a result of working closely with colleagues within the PDS.

These are just some of the options and opportunities that the PDS has afforded and strengthened as a result of its implementation within the school district. Mentor teachers are in a unique position to grow both personally and professionally in a safe, supportive and dynamic community.

### 3.4.3 Intern/Mentor Relationship

This Professional Development School model conceptualizes the mentor and intern as co-teachers, allowing the relationship to evolve over the course of the internship year. This relationship typically develops in three phases. During the first part of the year (typically August through December) the mentor is the guide and the intern is a tutor for the children. The mentor teacher typically takes the lead in planning and delivering daily instruction while the intern acts as a support teacher by carrying out planned lessons and working with individual students or small groups. Additionally, during this phase, interns are engaged in university methods courses and have opportunities to take the lead teaching role on some lessons designed in these methods courses.

During the second part of the year (typically January through March of the internship year) there is much more co-planning and co-teaching. By following this model and engaging in daily dialogue and observation, the intern gains critical insight into the mentors’ “personal
practical knowledge” of the teaching profession. In addition, s/he tries to gain an in-depth understanding of not only how the mentor teaches, but also why s/he teaches in certain ways, uses particular learning strategies or focuses on different methods of lesson sequencing or behavioral modification. In this phase, the mentor is often seen as the “coach” as the intern practices methods of implementing and reaching instructional goals.

Finally, during the third part of the year (typically April through June), the mentor offers support and guidance while the intern takes the lead in planning and implementing classroom instruction. Similar to the beginning of the year, the roles are flip-flopped and the mentor offers support through working with individuals or small groups of students while the intern leads instruction.

The yearlong internship offers a unique and challenging experience for interns and mentors alike. However, using the lens of co-teaching to guide daily practice allows growth not only for interns and mentors, but is a benefit for students who receive more individualized and small group instruction throughout the school year.

3.5 Focus on Adaptive Inquiry

A focus on teacher inquiry is a core feature of this PDS partnership, however, this focus is not an end in itself. The intention when establishing this PDS was “to create a community of practice in which all participants come to embrace an inquiry orientation toward teaching” (Badial et al., 2011, p. 324). Over the years, this notion of “inquiry orientation” has evolved to now reflect components of Cochran-Smith and Lytle’s (1999a) “inquiry as stance” position and Hammerness, Darling-Hammond and Bransford’s (2005) notion of “adaptive expertise.” According to Cochran-Smith and Lytle (1999a), they describe teachers and student teachers who adopt an inquiry stance as those who work “within inquiry communities to generate local
knowledge, envision and theorize their practice, and interpret and interrogate the theory and research of others” (p. 289), understanding that this work is both social and political. Joined with this concept, adaptive experts (Hammerness et al., 2005) are marked by a disposition to learn from others and to move beyond existing routines that necessarily require one to balance the dimensions of efficiency and innovation. As a result, the focus of this community of practitioners has been modified slightly to reflect a focus that encourages interns, mentor teachers, and PDAs to embrace an adaptive inquiry orientation toward their practice.

As synthesized in their report on affirmation and change within this PDS, Badiali and colleagues (2011) described the characteristics of teachers who possess an adaptive inquiry orientation toward teaching. An overview of those characteristics follows:

1. They approach teaching as a complex, problem-solving endeavor. This disposition leads them to view problems as opportunities and to raise important questions about their practice, student learning, the curriculum, and general practices of schooling;

2. They engage in teacher inquiry, either formally or informally, as a means of making sense of problems of practice. They systematically collect data and use evidence derived from those data to assess the impact of their practice on student learning;

3. They critically examine their own and others’ underlying beliefs and taken for granted assumptions about learners, practice, curriculum, schools, and schooling;

4. They seek professional development as a means of gaining access to cognitive tools that will enable them to inquire into problems of practice more fruitfully;

5. They see themselves as engaged, contributing members in communities of practice that may be either internal or external to the context in which they teach on a daily basis. They see knowledge as distributed across these communities. They seek
opportunities to connect their own inquiries with the knowledge of the larger community.

6. They exhibit a strong commitment to enact practices that are consistent with their own commitments to learning and with the evidence concerning the impact of their practice on learners, even when those practices are contrary to prevailing norms and practices with the school culture; and

7. They demonstrate a willingness to move beyond existing routines to transform their ideas and practices based on new insights gained from personal, practical, and professional knowledge. They are willing to live through the temporary lack of efficiency, caused by the disruption of familiar ways of acting, when they believe that alternative ways of thinking and acting will be more beneficial for learners (p. 325).

The concept that these characteristics are supported and adopted within the community of interns, mentor teachers, and PDAs is powerful and a strong function of this PDSs goal of developing a community of practitioners that is unique and effective for both teacher development and student learning.

3.6 Unique Experiences

Over the course of the twelve years that this partnership has been in place, graduates, mentors and others involved in the program have compiled a list that explores many of the unique opportunities that are experienced as a result of PDS participation. This list can be found on the PSU PDS website (www.ed.psu.edu/educ/pds) and consists of several of the following:

- A full year of teaching experience for interns before graduation;
- Daily feedback from school-based personnel as well as university-based teacher educators;
• Experience with technology (both interns and mentors) in a district with a strong focus on integration of technology as part of the strategic plan;
• Collaborative work in a non-competitive culture focused on best practices for children;
• Professional development seminars and in-service workshops developed by university and school-based teacher educators;
• Leadership opportunities within the district and through national organizations;
• Emphasis on developing an inquiry stance to teaching and the necessary support needed to be successful.

These unique experiences also make this a unique partnership, one in which teachers are working in an environment that both supports and upholds standards of excellence. Interns are guided through a program that supports their learning and gives them a more complete view of the teaching profession from aspects of the learning process that they would not receive from a traditional student teaching placement. Support and co-teaching opportunities with mentors, PDAs and other teaching professionals as well as detailed reflection and research into their own thinking and practice on a daily basis make this experience for interns incomparable to traditional programs. For teachers, their work is both strengthened and validated by interns and university faculty. Teachers are treated as professionals and are highly involved in the professional development of interns and themselves. University faculty are afforded the opportunity to be involved in the day-to-day routines of the teachers, the schools, and the children, which keeps them on the path of learning how to apply research into practice.

This PDS community is highly collaborative and is one in which an inquiry orientation to teaching is “nurtured, supported, and, in many ways, accepted among the members of the community” (Badiali et al., 2011, p. 337). Learning about the unique experiences that this PDS
finds to be both successful and unsuccessful contribute to it’s growth and development and can assist other PDS partnerships to assess aspects that they may or may not want to adopt into their own programs.

3.7 Awards and Recognition

To date, the Penn State – State College Elementary PDS has been recognized for several exemplary achievements. In 2009, it was recognized with the National Association for Professional Development Schools’ (NAPDS) Award for Exemplary Professional Development School Achievement. NAPDS is the premier national organization focused on PDSs. The award selection noted the partnership’s demonstration of exemplary use of scholarly research, inquiry and practice within the PDS community. This was the PDS partnership’s third national award from the NAPDS during its twelve year tenure. In addition to these three awards, the partnership has also been presented with the 2004 Nancy Zimpher Award by the Holmes Partnership to honor the outstanding school university partnership in the country, the 2002 Distinguished Program in Teacher Education by the Association of Teacher Educators, and the 2001 Northeastern Educational Research Association’s Outstanding Teacher Research Award.

3.8 Summary

In summary, in taking a brief look at the PDS program at Penn State University, the fifteen year Pennsylvania State University-State College Area School District Professional Development School Collaborative is the result of a Holmes Partnership commitment. From its informal beginnings in 1994 as a collaborative effort between a few university professors and two original elementary schools to what now includes numerous university faculty, school personnel, all ten of the elementary schools, and both middle schools in the district, the impact of this program on the State College Area School District is far-reaching. In fact, this partnership
has now extended beyond a PDS into a PDD (a Professional Development District) and in 2009 was recognized for the third time with the National Association for Professional Development Schools’ Award for Exemplary Professional Development School Achievement which recognized the strength of the collaboration between the school district and the university.

This PDS partnership was an ideal context for this study for several reasons. First, because of the growth of the program from a few schools to all of the schools in the district, this study was able to gather data from both teachers that were involved from the beginning and teachers that only recently became involved. This offered a unique perspective to determine if practices and features of the partnership were meaningful in the same ways to each person throughout her/his involvement. Secondly, because the partnership has been in place for several years, analysis of practices could be used to determine change over time to determine what practices and procedures are/were most effective in the successful growth of teachers in the partnership. Finally, this PDS served as an ideal context due to its unique structure of support at both the school district and university level. Unlike my experiences at another nearby university where there was no “buy in” by the university to fully support PDS partnerships financially, academically, or through sufficient workforce commitment, this PDS partnership strives to bridge these gaps effectively and is committed to achieving success.
CHAPTER 4: RESEARCH METHODS

4.1 Overview

Identifying and understanding the methodological approach that is used in a research study is both critical and necessary. How a researcher “shows their workings” is central to identifying how rigor has been maintained and makes the writing of the research a central element in achieving accountability (Holliday, 2002). This chapter addresses these issues by describing the qualitative methods used to characterize mentor teachers’ change in thinking and practice toward contemporary reform-oriented science education. In addition to a description of the conceptual framework that guided participant selection, data sources, data collection, and data analysis, a description of the research method proposes to justify why case study methodology is the most appropriate construct for supporting this inquiry.

The purpose of this research study was to investigate the nature of change in PDS mentor teachers’ thinking and pedagogical practices toward science education in the elementary school as conveyed through their “stories of practice.” The study explored the ways experienced teachers, working within the context of a Professional Development School community, described their changes in the way they think about and teach science.

The research addressed the following questions:

1) How do mentor teachers describe their science teaching practices and how have they changed as a result of participation in PDS?

   a. In what ways do PDS mentor teachers’ descriptions of practice reflect contemporary reform ideas and practices in science education?

   b. To what extent do their stories emphasize technical aspects of teaching versus epistemological changes in their thinking and knowledge?
c. How is student learning in science reflected in teachers’ stories of practice?

2) What is the relationship between the levels and types of involvement in PDS to change in thinking about and practices of teaching science?

3) What is the depth of commitment that mentors convey about changes in science teaching practices?

4.2 Philosophical and Historical Perspectives of Qualitative Research

Given the research questions that guided this study, a qualitative approach to research design was identified as being appropriate. Qualitative research begins with questions and its ultimate purpose is learning (Rossman & Rallis, 2003). It includes a broad range of research strategies and designs that have their roots in the research of the social sciences (Denzin & Lincoln, 2000; Hittleman & Simon, 2006; Rossman & Rallis, 2003). Qualitative research is “a way of knowing that assumes that the researcher gathers, organizes, and interprets information (usually in words or pictures) with his or her eyes and ears as a filter. It is a way of doing that often involves in-depth interviews and/or observations of humans in natural and social settings” (Lichtman, 2006, p. 23).

Qualitative research examines people, such as students, teachers and administrators, in natural contexts, interacting with other people and objects in their surroundings. Qualitative data is what happens in a particular social setting – in a particular place or amongst a particular group of people (Holliday, 2002). Knowing this, a qualitative research design is then particularly well suited for capturing how an individual comes to understand the complex dynamics of learning and professional growth over time (Francis, 2004). As Creswell (1998) states:

Qualitative research is an inquiry process of understanding based on distinct methodological traditions of inquiry that explore a social or human problem. The researcher builds a complex, holistic picture, analyzes words, reports detailed views of informants, and conducts the study in a natural setting. (p. 15)
The purposes of qualitative research are to describe, interpret, verify, evaluate and share knowledge about the phenomenon (Plante, Kiernan & Betts, 1994). These qualities, as well as others described above, make this research paradigm particularly well suited for this research study as these characteristics are aligned with the goals of the research questions. The purpose of this research is to gain an understanding of the nature of change in PDS mentor teachers’ thinking and pedagogical practices toward science education in the elementary school as conveyed through their “stories of practice.” Through detailed description and exploration, investigation and interpretation, the phenomena of this research are reported.

4.3 Research Design: Case Study

Two sets of interests are embedded within every well-crafted research purpose – one is substantive and the other is epistemic (Baptiste, 2004). Substantive interest points to the content of the information that is being studied or produced. In the case of this research study, the substantive interest is “the mentor teachers’ change in thinking and practice based on their stories of practice.” Epistemic interest focuses on particular types of interpretation. The epistemic interests of this research are “to describe” and “to investigate.”

Since the major interests of this research were exploratory in nature, exploratory research methods were identified as being the most appropriate choice for the study. This study was bounded within the context of a Professional Development School program that focused on the simultaneous renewal and professional development of the school and university-based faculty involved in the partnership. One of the major goals of the PDS program was for the participants to engage in furthering their own professional growth as teachers and teacher educators. This study sought to establish the constructs of this PDS program that have aided in the change
process of mentor teachers and to specifically understand the nature of the changes that have been made in the area of science education.

Creswell (1998) suggests that in a case study the researcher should focus on an event, process, or program for which we have no in-depth perspective. In this research study, the context, or program is the Penn State University – State College Area School District Professional Development School partnership. This context has been the focus of numerous research studies over the past ten years, however, most of the research has focused on pre-service teacher learning and development (Amond, 2008; Barreto-Espino, 2009; Gimbert, 2001) and there have been no in-depth studies that have related specifically to the change process of PDS mentor teachers in science education. The current study was defined within the parameters of a case study as defined by Merriam (1988) and Yin (2003) and is a single case study with multiple participants. The “case” being studied within this context is the phenomenon: the nature of change in PDS mentor teachers’ thinking and pedagogical practices toward science education in the elementary school as conveyed through their “stories of practice.”

Why choose a case study design for this research? Merriam (1988) asserts that a case study can “test a theory or build theory, incorporate random or purposive sampling, and include quantitative and qualitative data” (p. 2). She continues by stating that most case studies in education are qualitative and hypothesis generating. Patton (1990) builds on this assertion by maintaining that a case study design is useful when the objective of the study is to collect in-depth, comprehensive information about experiences. Conversely, a case study approach to studies in educational research has also been reported as being controversial, prejudicial, and a less desirable form of inquiry over recent years. Yin (2003) purports that there are four general arguments against using a case study approach: (1) lack of rigor; (2) confusion with case study
teaching; (3) little basis for scientific generalization; and (4) length of time and amount of material. Understanding that case study research could be controversial made it imperative that the researcher takes every step possible to ensure that the quality of the research made this the best choice for investigating the phenomenon.

Conducting this research in the form of a case study provided a format to help inform practice and to seek unexplored details of the context. Following the advice of Yin (2003) in his understanding of how to conduct proper case study research was critical. Case study was the best methodological approach for the research questions based to a great extent on his insight on the method. According to Yin (2003), “A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (p. 13). In the set of circumstances surrounding the design and implementation of this research study, the context of the research was highly pertinent to the phenomenon that was being studied because it was imperative to understand the contextual conditions of the study. However, because phenomenon and context are not always easily distinguishable in real-life situations, the technical aspects of data collection and analysis strategies must also be understood. Again, following Yin’s definition of case study, “the case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis” (pp.13-14). In other words, by choosing case study as the research strategy, the researcher has chosen an all-encompassing method – covering the logic of design, data collection techniques, and specific approaches to data analysis. Yin asserts that case study is not simply a
design feature or a data collection tactic; it is a comprehensive research strategy. As Merriam (1988) supports, case study research design permits the researcher and reader to understand how all parts work together to form a whole.

4.4 Trustworthiness of Research Design

A key goal of research in the social and behavioral sciences is the improvement of practice (Carnine, 1997). Basic research is valued because it is concerned with the development of knowledge, which can have far-reaching implications in the design or expansion of a theory or even the alteration of teaching practices. Therefore, trustworthiness of the study is necessary in order to establish credibility and to make the study reliable to the reader.

Lincoln and Guba (1985) have identified four constructs that should be addressed in any naturalistic inquiry to ensure trustworthiness in qualitative research: credibility, transferability, dependability, and confirmability. In addition to the processes that have been explained throughout the above description of the research process, these four constructs and how they are addressed in this research study are outlined below.

4.4.1 Credibility

Lincoln and Guba (1985) claim that “truth value” can be conveyed in a research study by establishing credibility through prolonged engagement, triangulation, and member checks. In this study, the researcher used these complementary strategies for the purpose of establishing credibility.

(1) Prolonged engagement: The duration of this research study was spread over a three-year period. The initial impact surveys were distributed and completed by mentor teachers in February 2005. Upon their return later that month, the surveys were reviewed and the research design was developed. Initial mentor teacher interviews
were conducted in May and June of 2005 and the data was analyzed over the following months. The findings from the original interviews were reported and published as a portion of a larger study conducted on the impact of the PDS. As a result of this first round of interviews, assertions were generated and the researcher wanted to follow-up with the original study participants to see if these assertions held true. Therefore, a second round of interviews was conducted in the spring of 2007, two years after the first interviews. This two-year cycle was not only important for the sake of the longitudinal nature of the study, but it was central to understanding the professional development of each teacher. In this school district, science units are taught on a two-year cycle. If the researcher had conducted the second interviews just one year later, the mentor teachers would not have had the opportunity to teach the science units that they had referred to in their original interviews again. However, by conducting the interviews on a two-year cycle, the mentor teachers were teaching the same science units that they had been teaching during the initial interviews. The two-interview protocol provided time for the participants to reflect on their experiences and to construct their stories in a meaningful manner. This strategy also allowed the researcher to “test” the assertions that had been generated after the first interviews.

(2) Triangulation: Triangulation is a vehicle for the conduct of a study that, when used appropriately, may produce valuable results. A major strength of case study data collection is the opportunity to use many different sources of evidence (Yin, 2003). Although participant interviews were used as the most prevalent source of data collection, additional sources were gathered and addressed in order to develop converging lines of inquiry (Yin, 2003). There were three main areas from which data
was collected: (a) Initial survey data from a PDS impact survey that was given to all mentor teachers in the district; (b) two sets of structured interviews conducted over a two-year time frame; and (c) relevant science classroom documents such as lesson plans, posters, examples of student work and science curriculum written by mentor teachers. All were used as evidence to support the events, or facts, of the case study.

(3) Member check: In member checks, the researcher solicits participants’ views of the credibility of the findings and interpretations (Creswell, 1998). Member checking provides an opportunity for study participants to understand and determine what the researcher intended to do throughout the study, allowing them the ability to correct errors and/or challenge what may be perceived as wrong interpretations. Upon completion of the interview transcription, each participant was sent a copy of his/her interview via both email and regular mail. This gave each participant the opportunity to make sure that what the researcher had recorded in the conversation was a fair representation of what he/she intended to say about the change in his/her science thinking and practice. Each participant was asked to send any changes or notations to me via email. No changes were reported as being necessary by any of the participants. Additionally, at the beginning of each of the second interviews, the researcher discussed her interpretation of each participant’s story of practice with him/her to ensure that she was representing the beliefs and practices of each mentor teacher appropriately.

4.4.2 Transferability

Transferability can be defined as the application of the findings of the study to other settings (Marshall & Rossman, 1989, 2010). Transferability in this study was examined on two
levels: transferability within the same school district to other school settings, and to other outside agencies (e.g., other professional development schools, other school districts). As Yin (2003) asserts, case studies are generalizable to theoretical propositions and not to populations or universes (p. 10). The assertions that have developed as a result of data analysis could be used to assist in the understanding and development of PDS practices in this partnership or in other partnerships.

4.4.3 Dependability

Dependability of a study refers to the act of showing that the findings of the study are consistent and could be repeated. The most common method used to establish dependability within a study is through an inquiry audit. This involves having a researcher not involved in the research process examine the process and product of the research study. Although an external audit was not formally conducted in this study, the processes of data collection, analysis, and synthesis and access to materials throughout the process was maintained by the researchers thesis co-chairs.

4.4.4 Confirmability

According to Guba and Lincoln (2005), confirmability is the extent to which the findings of a study are shaped by the respondents and not by researcher bias, motivation or interest. The researchers background and viewpoint has been declared in order to disclose bias. In addition to disclosing bias, a clear description of the research path that includes the research design and data collection decisions as well as the steps taken to manage, analyze and report data is included. Following is that information.

4.5 Analytic Tools: Elements of Case Study

For a case study, analysis consists of making a detailed description of the case and it’s
setting (Creswell, 1998). In this research study, the setting is particularly important and as such is important to describe. One’s primary task in a case study is to come to understand the case; to tease out relationships, to probe issues and to aggregate categorical data (Stake, 1995). Data analysis can be either a holistic analysis of the entire case or an embedded analysis of a specific aspect of the case. Holistic analysis was chosen for this case study as it entailed many aspects of the phenomenon of change in mentor teachers thinking and practice in science.

Stake (1995) advocates four forms of data analysis and interpretation in case study research: 1) categorical aggregation; 2) direct interpretation; 3) patterns; and 4) naturalistic generalizations. Categorical aggregation refers to the point in his/her analysis when a researcher seeks a collection of instances, hoping that issue-relevant meanings will emerge from the data. Direct interpretation focuses on single instances within the case and draws meaning from them without looking for multiple instances. As Creswell (1998) described, “it is a process of pulling the data apart and putting them back together in more meaningful ways” (p. 154).

Stake (1995) described these two analysis tools as “[t]wo strategic ways that researchers reach new meanings about cases…through direct interpretation of the individual instance and through aggregation of instances until something can be said about them as a class” (p. 74). As a result of direct interpretation and categorical aggregation, the researcher then looks for and establishes patterns between two or more categories. As Stake (1995) asserts, “the search for meaning often is a search for patterns, for consistency and… (s)ometimes, we will find significant meaning in a single instance, but usually the important meanings will come from reappearance over and over” (p. 78).

As a result of reappearance of these instances in the data, naturalistic generalizations are formed based on these patterns. Stake (1995) defines naturalistic generalizations as “conclusions
arrived at through personal engagement in life’s affairs or by vicarious experience so well constructed that the person feels as if it happened to themselves” (p. 85). These generalizations are often written in the form of assertions, as was the situation in this research study. Using case study as the method of inquiry and analytic tools as advocated by Stake (1995), assertions were generated and supported with evidence from analysis.

4.6 Conceptual Framework Guiding Analytic Tools

As a framework for this research, there were three specific sets of guidelines in reform-oriented science education that were chosen to direct the research design and analysis: The National Science Education Standards (NSES) science teaching standards, NSES professional development standards, and NSES Essential Features of Classroom Inquiry.

In 1996, the National Research Council produced a document that drastically changed the view of science education across the United States. Many individuals from many different backgrounds played a critical role in the development of the National Science Education Standards – teachers, science educators, curriculum developers, school administrators, scientists, engineers, legislators, and parents. These standards called for dramatic changes throughout school systems and emphasized “a new way of teaching and learning about science that reflects how science itself is done, emphasizing inquiry as a way of achieving knowledge and understanding about the world” (NRC, 1996, p. ix)

This document explained the constructs of reform-oriented science and provided guidelines for effective practices. These standards were designed to guide our nation toward becoming a more scientifically literate society.

Scientific literacy, as defined by the NSES (1996), is:

[the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and
economic productivity...[it] means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a persona has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding article about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately. (p. 22)

This is the goal of reform-oriented science – to educate students to become scientifically literate citizens. In order to conduct research within the context of PDSs to explore changes in science education, a framework for understanding how elementary teachers are working in their classrooms in order to move toward this goal of scientific literacy was needed. In addition to providing sets of standards for science content, assessment in science education, science education programs and science education systems, *The National Science Education Standards (NSES)* also provided an extensive set of standards for both science teaching and for professional development for teachers of science. The professional development standards and science teaching standards (NRC, 1996) support teachers’ knowledge about best practices and methods when taking an inquiry stance to teaching science to children.

This research study used a combination of sections from both the *National Science Education Standards* (1996) and *Inquiry and the National Science Standards* (2000) to frame and guide the process of research design and data analysis.

4.6.1 NSES Science Teaching Standards

The science teaching standards (NRC, 1996) describe what teachers of science at all grade levels (in the case of this research, elementary teachers) should know and be able to do in order to be effective teachers of science. These standards are divided into six areas: (1) the
planning of inquiry-based science programs; (2) the actions taken to guide and facilitate student learning; (3) the assessments made of teaching and student learning; (4) the development of environments that enable students to learn science; (5) the creation of communities of science learners; and (6) the planning and development of the school science program.

The researcher used these standards as a guideline for both the development of research questions and most especially for the development of interview questions. Structure from these six standards was imbedded throughout the interview process to assist each participant in the description of their story of practice. This also enabled the researcher to have a general guideline or rubric/continuum on which to interpret each story based on reform-oriented practices.

4.6.2 NSES Professional Development Standards

In order for elementary teachers to be able to meet the teaching standards set forth in the guidelines and to be competent teachers of this vision of science education, most teachers, in general, need to drastically change their practices in the classroom. However, in order to do this, teachers need to receive the proper training and professional development for teachers of science. The professional development standards (NRC, 1996) “present a vision for the development of professional knowledge and skill among teachers” (p. 4). Their focus is on four areas: (1) The learning of science content through inquiry; (2) The integration of knowledge about science with knowledge about learning, pedagogy, and students; (3) The development of the understanding and ability for lifelong learning; and (4) The coherence and integration of professional development programs.

As with the NSES science teaching standards, the researcher used the professional development standards as a framework for the development of interview questions. In order to understand each teacher’s unique story of practice, it was also necessary to know the background
of “how” each participant got to his/her reported level of science teaching practice. Knowing about each participant’s personal professional development was important to interpret and analyze the findings of this research.

4.6.3 NSES Essential Features of Classroom Inquiry

A prominent feature of the NSES is a focus on inquiry. Content Standard A for grades K-4 states: “As a result of activities in grades K-4, all students should develop abilities necessary to do scientific inquiry [and] understanding about scientific inquiry” (pp. 121). In order for students to be able to do this, they must be guided or taught by competent teachers who know how to provide experiences for students that allow for their development of inquiry practices.

Following the development of the National Science Education Standards, the Committee on Development of an Addendum to the National Science Education Standards on Scientific Inquiry was formed and produced and published a handbook in 2000 that was designed to serve as a practical guide for teachers, professional developers, administrators, researchers, and others who wished to respond to this emphasis on inquiry in science education.

As a way to outline or frame each participant’s story of practice within the domain of reform-oriented science, the researcher chose to use The Essential Features of Classroom Inquiry (NRC, 2000) as a model for analysis of each teacher’s story of practice (Appendix A). Inquiry in the science classroom (or reform-oriented practices as identified in this study) emphasizes questions, evidence and explanations within a learning context. Inquiry teaching and learning have five essential features that apply across all grade levels:

(1) Learners are engaged by scientifically oriented questions;
(2) Learners give priority to **evidence**, which allows them to develop and evaluate explanations that address scientifically oriented questions;

(3) Learners formulate **explanations** from evidence to address scientifically oriented questions;

(4) Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding; and

(5) Learners communicate and justify their proposed explanations. (NRC, 2000, p. 25)²

Teaching approaches and instructional materials that make full use of inquiry in the science classroom include all five of these essential features. Therefore, these features provided a framework for evaluation and interpretation of each participant’s story of practice and their movement toward science reform practices in their classrooms.

**4.6.4 Evolution of the Framework**

During the study, the original framework evolved in response to the data that was collected. The final version of the framework focused on a combination of all three of these components. It is important to note that during the course of this research study, a new framework for K-12 science education was developed and released (NRC, 2011). This framework represented the first step in the process to develop new standards in K-12 science education as a result of many years of research following the release of the existing national standards in the mid-1990s. The new framework focuses mainly on a limited set of core ideas in science in order to provide a more in-depth understanding of scientific concepts. Attention to the idea of science as a set of practices stresses the understanding that engaging in scientific inquiry requires “coordination of both knowledge and skill simultaneously” (p. 3-1). These ideas in the

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² See Appendix B for permission to reprint. Reprinted with permission by the National Academy of Sciences, Courtesy of the National Academies Press, Washington, D.C.
new framework continue to be supported throughout this research and are reflected in the teaching practices of participants in the study.

4.7 Researcher’s Role and World-View

The educational researcher is critical to the process of qualitative research and is viewed as an instrument of data collection, data analysis, and interpretation. In qualitative research studies, it is important to offer insight into the beliefs and experiences of the researcher, as these become the lens of interpretation for the study (Rossman & Rallis, 2003). As the researcher for this study, both positive and negative aspects as a result of personal bias are most likely brought to this research table. Therefore, the researcher’s position is important to explain because in a qualitative case study, “the investigator is the primary instrument for gathering and analyzing data” (Merriam, 1988, p. 36). As such, it is important also to recognize that the epistemological position of the researcher is critical to reveal in order to understand possible bias. For example, my epistemological position toward the learning of science is that of a constructivist, or more distinctly, a social constructivist. This philosophy supports the viewpoint that an individual’s learning takes place because of his/her interactions within a group. I hold this position based on my background as a teacher of both children and adults in science, which is discussed further in the next section.

4.7.1 Researcher’s Background

As a former elementary school teacher and former faculty member in elementary science education at a small state university, I have brought to this study my interest in how people learn. More specifically, I have brought my interest in how people learn science as well as how science is taught in elementary schools to the forefront of my research interests.
My father was my role model when it came to learning in science. Trained with a science background, he encouraged me to learn science the way that it was done, as he would say, “in the real world.” If I was supposed to be learning about plant life, he took me for a walk in the woods and we looked at and examined trees or plants. When I was learning about anatomy, he would take me to his trapping shed and we would dissect an animal and investigate the parts. My beliefs about how science is learned are rooted in personal experiences such as these.

I received my bachelor’s degree in elementary and early childhood education 20 years ago. My first teaching job was as a fifth and sixth grade science/health teacher. Everything that I had been taught in my science methods course at university went against my own personal learning experiences in science. However, I taught science the way that I was told that I should teach it, based on textbook information and disconnected use of hands-on activities to offer bits of excitement to the lessons. Unfortunately, as I discovered, my students could often remember in great detail many aspects of the activities that we completed in class, but could recall little “scientific information” when it came time to assess their learning on a test. As a result, I changed the way that I taught science to my elementary students to reflect what I believed at the time to be more authentic learning experiences.

After several years, I left the elementary classroom and received my Master’s degree in science education. I then started teaching elementary science methods as an instructor at a small university. I noticed that my young adults learned science in much the same ways that my elementary students did, and therefore, continued my practice of using reform-oriented methods to support inquiry science learning.

Through my experiences as a science education faculty member and student teaching supervisor, I witnessed numerous reports from elementary teachers regarding their reported
reasons for “not teaching science” due to lack of time, resources, content knowledge, focus on testing in reading and mathematics, as well as others. I often felt as though this anecdotal evidence supported the agenda that reading and mathematics was being pushed in the classroom to the exclusion of the exploration and excitement of science.

Keeping my personal background in mind, while completing my residency within the Penn State community, I was intrigued with the many science experiences that were being discussed about elementary classrooms in the PDS by fellow classmates and professors in graduate classes. This interest provided the desire to pursue research in the area of Professional Development Schools and to learn how mentor teachers were reportedly changing their thinking and teaching of science as a result of their involvement. The anecdotal evidence within the State College PDS was powerful as I listened to classmates and professors who were involved in the program discuss the changes that they had seen take place in elementary science classrooms. It became important to me to try to understand how or why these classrooms reportedly looked so different from those that I had observed for years when it came to science education.

Finally, in addition to all of these factors, perhaps most importantly, my experiences as a mother have contributed to my larger view of science and science teaching as a whole. Working with each of my own children from infancy, I have discovered that science learning is something that comes naturally to children. Science is more than facts and figures to be learned – it is a way of thinking. I have used each of my children’s own innate curiosity as the basis for their learning experiences. I believe that this curiosity is natural to children, however they need guidance to help them make sense of what they see, hear, taste, touch and smell. Allowing them to discover answers to their own questions without simply telling them the answer all of the time has helped each of my children to gain confidence and develop both their skills and their
thinking in science – at least I like to think that this has helped them. My own beliefs about the nature of science as a way of knowing and understanding the natural world guide how I help my children make sense of the world around them whether we are working on a science fair project, playing in our backyard, or taking a walk in the woods. I am positive that they get tired of hearing me say, “Well, why do you think that happened?” or “How do you think we can find out the answer?” however, I believe that these questions are necessary to support authentic learning experiences in science.

Knowing this brief synopsis of my background, my belief about how people learn, my personal epistemology, helps me to make sense of my practice and to guide both my research and my practice. From my experiences, I believe that science is learned through interactions with the environment or other phenomena through our senses, allowing us to build a picture of the world. I believe that this knowledge therefore resides in each individual and learners need to be given opportunities to make sense of what they are learning by negotiating meaning either through experiences with phenomenon or with others. I feel that best practices in science teaching allow for such opportunities to develop and provide support for these kinds of experiences. Therefore, it is important to disclose my biases and to understand how my viewpoint toward teaching and learning science might have an effect on my research.

4.8 Context of Study

The Pennsylvania State University-State College Area School District Professional Development School Collaborative is a twelve-year Holmes Partnership commitment. In fact, this partnership has now extended beyond a PDS into a PDD – a Professional Development District. Currently sixty-two undergraduate elementary education seniors are paired with mentor teachers in the district to complete a one-year internship in the classroom. This case study is
situated within this unique context. A detailed description of this context was reported in Chapter Three.

4.9 Phases of Research Development: Data Collection Schedule, Procedures and Analysis

Data was collected over a period of three years within the context of the Penn State – State College Area School District Professional Development School partnership. The constructs of this study occurred in three distinct phases over the course of these three years. Phase One involved the selection of study participants; Phase Two consisted of initial data collection, analysis and development of claims that resulted as a result of initial interviews; and Phase Three involved the second-round of data collection, data analysis and development of assertions.

4.9.1 Phase One: Participants

4.9.1.1 Participant Selection

During the school year 2004-2005, all PSU-SCASD PDS elementary teachers serving as mentors for Penn State interns were asked to complete a survey. This Mentor Survey was developed by members of the university education faculty as an attempt to gather broad feedback for measuring the impact of the PDS environment in the elementary schools within the district. In this five-page anonymous survey (Appendix C), mentor teachers provided personal demographic information in order to identify such data as years and types of participation in the PDS. Additionally, the survey was designed to elicit changes in thinking and practice by specific content areas (e.g. mathematics, language arts, science, social studies, classroom learning environment). Mentors were asked to identify, on a Likert-type scale, to what degree the PDS had either affirmed their thinking and practice in each curricular area and/or changed their thinking and practice. Additionally, mentors reported how they believed their students may or
may not have been influenced by the PDS collaboration in each curricular area. Teachers were encouraged to write a brief explanation or comment on any or all aspects of the curriculum that they felt was important to share with the university faculty. At the conclusion of the survey, each mentor teacher was given the choice to identify him/herself for the purpose of possible participation in a follow-up interview for research purposes.

Surveys were given to mentor teachers by professional development associates (PDAs) in February 2005. Fifty-one out of the sixty original distributed surveys were returned. The surveys were collected and reviewed. After the initial examination process, the researcher and a university faculty member took the surveys to the Statistical Consulting Center on campus in order to discuss the parameters for using the data quantitatively. Data was aggregated and returned. However, this aggregated data was not used for the purposes of this research. The researcher chose to focus exclusively on the science portion of the survey instrument and data contained therein to conduct the research for this study.

The following table represents a sample of the “science” section of the survey instrument:

<table>
<thead>
<tr>
<th>The extent to which the PDS connection</th>
<th>Great Extent</th>
<th>Some Extent</th>
<th>Little Extent</th>
<th>Not at All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affirmed my thinking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Changed my thinking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Affirmed my practice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Changed my practice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Influenced my students’ learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please provide a brief explanation of your answers:

Table 4.1 Impact Survey Science Data Collection Example

According to the information garnered from the initial review of the surveys (both statistical data and written responses), a large percentage of mentor teachers reported that their
involvement in the PDS environment either changed or affirmed the way that they taught science, which was documented by checkmarks in the boxes “great extent” or “some extent.” This percentage was higher than was reported in other subject areas such as language arts or reading. As a result, inquiry about why teachers’ practice was either changed or affirmed and to what degree became the initial starting point of this study. In response to this inquiry, the following research questions were developed.

1) How do mentor teachers describe their science teaching practices and how have they changed as a result of participation in PDS?
   a. In what ways do PDS mentor teachers’ descriptions of practice reflect contemporary reform ideas and practices in science education?
   b. To what extent do their stories emphasize technical aspects of teaching versus epistemological changes in their thinking and knowledge?
   c. How is student learning in science reflected in teachers’ stories of practice?

2) What is the relationship between the levels and types of involvement in PDS to change in thinking about and practices of teaching science?

3) What is the depth of commitment that mentors convey about changes in science teaching practices?

**4) What do teachers identify as key factors that initiated their change in the way they think about and teach science?
   a. What PDS interactions do mentor teachers identify as having influenced their thinking about and practice of teaching science?\(^3\)

Information from the science section served as initial participant selection. Although many of the respondents indicated change or affirmation in science teaching practices and/or thinking, only twenty-one of the fifty-one returned mentor surveys returned indicated willingness to participate in a follow-up interview. Upon the researcher’s analysis of these twenty-one surveys, all of which reported some degree of affirmation or change in thinking about science or science

\(^3\) This research question was part of the original research context and analysis. Findings associated with this question are reported elsewhere (Badiali, Nolan, Zembal-Saul, & Manno, 2011)
teaching practices, ten mentors were purposefully selected for this study. In an attempt to garner results from a varied population, the original participants were initially selected based on the following key demographics: (1) number of years of participation as a mentor teacher in the PDS, ranging from earliest participation (two years) to longest participation (seven years); (2) degree of reported affirmation or change, ranging from “little” to “great”; (3) current grade level (both primary and intermediate were selected); and (4) reported participation in PDS-related professional development opportunities. Teachers’ responses to the “additional comments” section of the survey also factored in to the selection process. Ten participants were chosen and contacted. Through word of mouth, an additional mentor teacher contacted the researcher and was added to the participant list as she expressed interest in contributing to the study but did not originally have the opportunity to complete a survey. This participant had been a mentor teacher for five years prior to this school year, but had just left her mainstream classroom to become a learning support teacher. As a result of this transfer, she no longer had a PDS intern in her classroom and therefore did not receive the survey during that particular school year.

Each participant completed an Informed Consent form (Appendix D) to participate in the research interviews. In addition, the researcher contacted the faculty member in charge of the PDS research and was given IRB approval to conduct research in this context. After approximately two months of the review and selection process, phase two of the research began.

4.9.1.2 Participant Profiles

The eleven participants in this study were in-service teachers serving as mentors to senior elementary education students. Each PDS mentor teacher hosted an intern in his/her classroom for the entire school year. Ten of the participants were serving as mentors during school year 2004-05 and were selected from the results of the survey instrument. However, one additional
participant, Marla, personally expressed interest in contributing to this research after hearing about the study. During school year 2004-05 Marla served as a PDA, but had previously been a mentor teacher for five years. The participants for this study were eleven elementary school teachers who teach all subject areas in grades K-5. They were all employed by the State College Area School District and each had been teaching in this district for a minimum of fourteen years and a maximum of thirty-three years at the start of the study. The following data provides a brief description the demographic information of each participant as recorded in the PDS Impact Survey (February 2005).

<table>
<thead>
<tr>
<th>Participant</th>
<th># Years Teaching</th>
<th>Current Grade Level</th>
<th># Years Working With PDS Intern</th>
<th># Years Working With PDS Planning Teams</th>
<th># of Times Engaging in Teacher Inquiry</th>
<th># of Times Participating in PD Courses or Workshops</th>
<th>Type PD Courses or Workshops</th>
<th>Other Types of Involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Julie</td>
<td>25</td>
<td>1</td>
<td>7</td>
<td>6 Classroom Learning Environments</td>
<td>4</td>
<td>8</td>
<td>Inquiry(3); Science(1); Technology(1); Social Studies (1); Classroom Learning Environments(3)</td>
<td>Reading intern applications; Interviewing interns</td>
</tr>
<tr>
<td>Margaret</td>
<td>30</td>
<td>1</td>
<td>6</td>
<td>6 Classroom Learning Environments; Science</td>
<td>3</td>
<td>3</td>
<td>Classroom Learning Environments; Peer coaching – KLEW chart (development); Worked with university faculty; Prehistoric Life</td>
<td>Reading intern applications (6); Interviewing interns; Hosting intern in partner classroom (3); Attendance at conferences; contributed to research</td>
</tr>
<tr>
<td>Lynne</td>
<td>15</td>
<td>2</td>
<td>2</td>
<td>3 Social Studies; Science</td>
<td>4</td>
<td>6</td>
<td>Teacher Inquiry (3); Mentoring; Summer- Responsive Classroom; PDS Movement Course</td>
<td>Sabbatical – participated in Math Education &amp; Social Studies Education expansion teams; PDA meetings; Reading intern applications; Interviewing interns; Hosting intern in partner classroom</td>
</tr>
<tr>
<td>Elizabeth</td>
<td>14</td>
<td>K</td>
<td>5</td>
<td>x</td>
<td>x</td>
<td>5</td>
<td>Teacher Inquiry Course; Teacher Mentor Course</td>
<td>Reviewing intern applications; Interviewing interns</td>
</tr>
<tr>
<td>Paul</td>
<td>26</td>
<td>5</td>
<td>3</td>
<td>2 Math</td>
<td>2</td>
<td>1</td>
<td>Inquiry</td>
<td>Reading intern applications; Interviewing interns; PDA</td>
</tr>
<tr>
<td>Greg</td>
<td>21</td>
<td>2</td>
<td>7</td>
<td>x</td>
<td>1</td>
<td>5</td>
<td>Instructor for PDS Workshop</td>
<td>Reading intern applications; Interviewing interns; Hosting intern in partner classroom</td>
</tr>
<tr>
<td>Marla</td>
<td>33</td>
<td>Learning Support</td>
<td>5</td>
<td>4 Social Studies</td>
<td>1</td>
<td>Many</td>
<td>Science Summer Course</td>
<td>Review of intern applications(7yrs); PDA(2yrs); Attendance at PDS Conferences</td>
</tr>
<tr>
<td>Shelly</td>
<td>19</td>
<td>½ split</td>
<td>4</td>
<td>7 Classroom</td>
<td>“All of the time”; Twice</td>
<td>7</td>
<td>x</td>
<td>Reading intern applications;</td>
</tr>
</tbody>
</table>
4.9.1.2-1 Julie

Julie was a twenty-five year teaching veteran. At the time of the initial interview, Julie had been teaching first grade for much of her career and was working as a mentor to her seventh PDS intern. She had worked on PDS planning teams for six years (Classroom Learning Environment team) and had participated in professional development courses or workshops at least eight or nine times, as she recalls. At least two of these workshops were specifically related to science and/or technology. Julie engaged in formal teacher inquiry four times over the past years and at least one of her teacher inquiry projects was a science-specific topic (magnets).

4.9.1.2-2 Margaret

Margaret was a first grade teacher. She worked collaboratively with Julie and has been teaching for twenty-five years. She was just completing work with her seventh intern at the time of her initial interview. Margaret engaged in formal teacher inquiry many times over the past years and she collaborated with Julie on their formal inquiry on magnets in the first grade classroom.

4.9.1.2-3 Lynne
Lynne has been teaching second grade for fifteen years. At the time of her initial interview she was working with only her second PDS intern in her classroom. She had worked for at least three years on two separate PDS Planning Teams (social studies and science) and participated in six PDS workshops or courses, although none of these courses was science-specific. Lynne had four separate experiences formally engaging in teacher inquiry with the majority of these focusing on mathematics education. Additionally, she took a one-year sabbatical leave from her classroom teaching to become a PDA (Professional Development Associate) as part of the State College-Penn State PDS Collaborative.

4.9.1.2-4 Elizabeth

Liz was a kindergarten teacher who, at the time of the initial interview, had been teaching in the district for fourteen years. She had worked as a mentor teacher with a PDS intern in her classroom for five years and had participated in at least five professional development courses or workshops. However, none of these were science-specific. She had never done a teacher inquiry project up until this point.

4.9.1.2-5 Paul

Paul was a fifth grade teacher who had been teaching for twenty-six years. Although he had only hosted three interns in his classroom, Paul was involved in the PDS community for at least five years, serving as a PDA for two of those years, and a highly involved member of the Mathematics Planning Team. He engaged in formal teacher inquiry two times prior to our interview and had taken one PDS course, however, neither of these experiences was science-specific.

4.9.1.2-6 Greg
Greg was a twenty-one year veteran teacher. He was a first grade teacher for many years before transitioning to second grade at the start of the PDS program in the district. He had been involved in the PDS program almost from the beginning and had hosted seven PDS interns in his classroom over the years. He had no involvement in working specifically with PDS planning teams but had engaged in formal teacher inquiry at least once and had participated in five PDS professional development courses and/or workshops, serving as an instructor for one of those workshops. However, none of his PDS involvement was science-specific.

**4.9.1.2-7 Marla**

Marla was a thirty-three year teaching veteran. She mentored five PDS interns over the years and worked with the PDS Social Studies Planning Team for four years. She did not have an intern at the time of this research, as she had recently been transferred into a Learning Support classroom. However, prior to this year, she was a grade teacher and worked with five interns in her classroom. Since becoming involved in the PDS, she engaged in formal teacher inquiry one time and participated in many workshops and courses.

**4.9.1.2-8 Shelly**

Shelly was a first/second grade teacher who taught in the district for nineteen years. At the time of the initial interview, she was mentoring her fourth PDS intern. She worked for seven years on the PDS Classroom Learning Environment Planning Team and had formally engaged in teacher inquiry twice. She had participated in at least seven PDS professional development courses and/or workshops and also served as a Professional Development Associate (PDA) for two years.

**4.9.1.2-9 Karen**
A teaching veteran of twenty-one years, Karen was a second grade teacher who was involved with the PDS program almost since its inception in the district. She has mentored six interns and worked on the Classroom Learning Environment Planning Team for seven years. She engaged in formal teacher inquiry three times, with her main area of focus being on Reading and she participated in at least seven PDS courses or workshops. Additionally, she has attended PDS conferences.

4.9.1.2-10 Bobbie

Bobbie was also a kindergarten teacher in the district, although she did not teach in the same school as Elizabeth. At the time of her initial interview, she had been teaching for thirty-one years and had hosted a PDS intern in her classroom seven times. Along with her involvement as a mentor teacher, Bobbie also worked for at least five years with PDS planning teams (Classroom Learning Environments) and had participated in at least three professional development courses or workshops. She completed one teacher inquiry project and has attended numerous State College School District Inquiry Conferences as well as two PDS conferences. Although she has had much involvement in the PDS program, none of her activities have been specifically related to science.

4.9.1.2-11 Lana

Lana was a fifth grade teacher. Although she had been teaching in the district for nineteen years, she was a new participant in the PDS program. She had hosted “traditional” student teachers in her classroom before, but as the PDS had just expanded to her elementary school, she was now a mentor to a PDS intern. She had not engaged in any formal teacher inquiry nor had she been involved in any PDS-related workshops or courses or been on any PDS Planning Teams.
A more in-depth portrayal of each participant, written as each participant’s “Story of Practice – Story of Change” and described as a result data analysis can be found in Chapter Five.

4.9.2 Phase Two: Data and Analysis

4.9.2.1 Data Collection

Following the selection of study participants, a preliminary interview protocol was constructed based on the research questions. After review by the researcher’s dissertation advisor and one other committee member, adjustments were made and a final interview protocol was completed (see Appendix E). In May 2005, participants were contacted via email and meeting times were scheduled. Participants were sent a letter of introduction as well as copies of the interview questions via email prior to their scheduled visitation (Appendix F). Interviews were held in the participant teachers’ school buildings during the school day and at a time that was convenient for each teacher (i.e. during a prep time or at the end of the school day). Each interview was scheduled to last from 45-60 minutes, which allowed time to focus on asking both the questions from the interview protocol as well as providing an opportunity to extend those questions when appropriate. Conducting an interview during working hours provided a level of ease and comfort with each participant because it did not interfere with time outside of working hours.

Interviews were chosen as the predominant source of data collection because the researcher felt that they would be particularly useful for obtaining the story behind each participant’s experiences. In the case of this research, the interview was designed as a follow-up to the questionnaire/survey in order to investigate the responses that were given by the participants. The researcher combined both structured and unstructured interview styles. A general interview
guide approach (Patton, 2002; Rossman & Rallis, 2003) was followed and provided the framework for conducting interviews. Each participant was provided with the interview questions prior to the researcher’s visit to ensure that the same general areas of information were collected from each participant. Patton (2002) believes that an interview guide is prepared in advance in order to:

…ensure that the same basic lines of inquiry are pursued with each person interviewed. The interview guide provides topics or subject areas within which the interviewer is free to explore, probe and ask questions that will elucidate and illuminate that particular subject. Thus, the interviewer remains free to build a conversation within a particular subject area, to work questions spontaneously, and to establish a conversational style but with the focus on a particular subject that has been predetermined. (p. 343)

The use of a general interview guide format permitted flexibility in wording and in the sequence of the questions while still preserving consistency (Patton, 1990) across all eleven participants. Furthermore, using the interview guide approach allowed for a degree of freedom and adaptability in retrieving information as it also helped to keep the conversations focused on science and provided a method to redirect if the interview started to stray in a different direction.

In the case of the current study, the interview followed a protocol that used five major areas of transition. Part one of each mentor teacher interview aimed to establish setting and research purpose by discussing informed consent, the purpose of the study, and the original survey data with each participant. After these parameters were set, the researcher set out to investigate and gain an understanding of each participant’s involvement in the PDS, specifically focusing on critical incidents in each mentor’s story of practice. Participants were first solicited with a question such as: “Thinking about your involvement with the PDS, can you tell me an interesting story about science in your classroom?” The purpose behind beginning with such an informal question was to allow each mentor teacher to think about and focus on daily happenings
in the classroom before moving forward into more theoretical or empirical beliefs about teaching. Having mentor teachers reflect on these technical aspects of teaching science helped to provide a solid base of practical classroom experiences from which each mentor could reflect on and explain his/her beliefs. Part three of the interview transitioned to focusing on mentor teachers’ science teaching practices and beliefs, centering on how or why they have changed. This conversation then flowed straightforwardly into part four of the protocol that focused on science specific strategies. Finally, part five concluded the interview by having each participant explain his/her connection to a community of practice. (See Appendix G for complete second interview questionnaire).

Interviews were recorded digitally using an iPod™ with an iTalk™ recorder. The average length of each interview was forty-five minutes. Table 4.3 provides an overview of the total minutes for Interview 1.

<table>
<thead>
<tr>
<th>Interview #1</th>
<th>Length of Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Julie</td>
<td>40min.</td>
</tr>
<tr>
<td>Margaret</td>
<td>41min.</td>
</tr>
<tr>
<td>Lynne</td>
<td>61min.</td>
</tr>
<tr>
<td>Liz</td>
<td>61min.</td>
</tr>
<tr>
<td>Paul</td>
<td>43min.</td>
</tr>
<tr>
<td>Greg</td>
<td>30min.</td>
</tr>
<tr>
<td>Marla</td>
<td>39min.</td>
</tr>
<tr>
<td>Shelly</td>
<td>47min.</td>
</tr>
<tr>
<td>Karen</td>
<td>59min.</td>
</tr>
<tr>
<td>Bobbie</td>
<td>43min.</td>
</tr>
<tr>
<td>Lana</td>
<td>25min.</td>
</tr>
</tbody>
</table>

**Total Audio Data for Interviews** 489 minutes (8 hours 9 minutes)

Table 4.3 Length of Participant Interview #1

Audio files were converted from the iPod (.wav) file to a QuickTime® file in order to be entered into the StudioCode™ digital video/audio software for transcription. Each interview was transcribed word-by-word by the researcher. Like the process of analysis itself, the researcher viewed transcription as a process that involved different considerations at various stages. Sitting
down to listen carefully to an interview provided the researcher with the opportunity to re-
experience the interview at a slower pace, maximizing attentiveness to what was said. This
initial analysis of each transcript led to refinements in each of the subsequent interviews to
ensure that the research questions were being adequately addressed and was a method for the
researcher to capture first interpretations of what was happening with each of the participants.

**4.9.2.2 Analysis**

Although each interview was transcribed using StudioCode™ software, the researcher
did not use this same software to code the data. Alternatively, the data analysis tool,
HyperResearch® was chosen. Transcripts were converted to a text (.txt) file and exported to
HyperResearch® software analysis tool. Interview transcripts were entered into the
HyperResearch® database and the process of holistic analysis began.

Analysis of the data followed common analysis features for case study research as outlined
by Stake (1995). He advocates four forms of data analysis and interpretation embedded within
this process: categorical aggregation; direction interpretation; patterns; and naturalistic
generalizations. However, as Creswell (1998) states,

> The researcher engages in the process of moving in analytic circles rather than
using a fixed linear approach. One enters with data of text or images and exits
with an account or a narrative. In between, the researcher touches on several
facets of analysis and circles around and around. (p. 142)

Therefore, as the analysis process is described, it will be important to note that although the
description is laid out using a linear model, the process became quite cyclical in nature.

Following is a description of how data was analyzed after the first round of data collection:

1. **Categorical Aggregation**: As data from the initial interviews was collected, interviews
   were transcribed using StudioCode™ software. Interview transcripts were saved as
   word documents and electronic files for the data were created and organized. These
files were organized systematically on the researcher’s computer and then entered into qualitative data analysis software (HyperResearch®). During this first round of data collection and analysis, no formal relevant science education documents were analyzed, only informal documents that were shown to the researcher during the interviews were used and identified as part of the notes taken during the interview process. After the data from the initial interviews was organized, the transcripts were reviewed, using a holistic approach, by the researcher in order to obtain a sense of the overall data. Data was open-coded using the software analysis tool to form initial categories of information about the case. These categories were then used as a guideline for within-case analysis. Using an open-coding scheme in the initial analysis allowed for reflection on the larger thoughts presented in the data as initial categories/themes emerged from the data analysis. As a result, the researcher created a chart entitled “The Big Ideas” in order to assist in organizing the data. This chart was very large, so a sample of one category is included as follows. The entire chart can be found in Appendix H.

<table>
<thead>
<tr>
<th>Big Ideas/ Categories</th>
<th>Codes</th>
<th>Definition</th>
<th>Sub-Codes</th>
<th>Exemplar Quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaboration with other professionals is critical to supporting change</td>
<td>(1) Collaboration</td>
<td>Collaboration is defined as “working together, especially in a joint, intellectual effort.”</td>
<td>Influence of intern on practice</td>
<td>I really feel like I have learned so much about my own practice from having an intern. It’s just so interesting because when you have to teach somebody something, you really have to think about that it is you do and why... and so each intern has taught me something about myself and made a change for me... they have really been how I learned at all about this because I’ve not taken any PDS science courses yet, so any of the little bit of learning that I’ve done about science and how to teach science differently has really come from an intern and their projects that they do and when they’re teaching science. Elizabeth</td>
</tr>
</tbody>
</table>
|                                             |       |            |           | Teaching colleagues working together | So we plan well together, we have fun, so we can play with science. Like when [we] did this magnet thing, we... played with the magnets and learned a little bit more about magnets ourselves, and then brought that to the classroom. There’s that kind of collaboration. And then, if things don’t go well or if you’re scared about something, to have somebody else to share the experience with who can say,
"Well, that didn’t work for me either," or "Well, I did it this way." Or if she teaches a lesson before I teach it, I’ll go to her and say, "Okay, what happened? What worked, what didn’t work?" And she’ll do the same thing for me. So that it helps improve your teaching just by talking about pluses and minuses with somebody else. *Julie*

What I know is that my science teaching changed because of Connie [university science education faculty]. I’ve always liked science teaching…but our curriculum has not always lent itself to time and wonder, I guess. And it was Connie coming in who just helped that along. *Margaret*

Leah [university science education faculty member from satellite campus] has been coming in and working with me sometimes. She comes in and helps me think about things sometimes and I’m trying to find ways to make them [science lessons] more inquiry-based. *Paul*

I think collaboration is so important in all areas of teaching, but especially when you’re trying new things. First of all, you’ve got a synergy of knowledge or ideas. You know, when two people come together you certainly get better than double the amount of ideas. *Julie*

There was that support that you could get from the university…from the PDS collaborative…and I really liked the support that the PDS brings to science teaching. *Marla*

I don’t think it always takes a collegial group, I mean, there are probably people in every building that take a look at this and go “Wow!” and can do it on their own. But for some of the rest of us, that groups, that collegial group is really important in kind of leaving those feelings of inadequacy in science and also frustration and trying to redesign your science lessons to be more inquiry-based. *Marla*

The opportunities that are there for thinking deeper are not just because of my intern, but because I feel that my expertise from being in the classroom is well respected and valued and Jon is wonderful about that, and Connie is wonderful about that. You know, none of them would ever say they know more than any of us, and so Connie will walk into the classroom and learn something and so the respect on all levels is another reason that I feel allowed to explore why I’m doing things, and change. *Shelley*

| Table 4.4 Sample of Big Ideas, Categories and Codes within Research Data Collection |

This organizational system facilitated the analysis process in that it allowed the
researcher to acquire a sense of each interview as a whole before breaking it down into its parts. The strategy, discussed by Creswell (1998), helped disregard predetermined questions in order to “hear what interviewees said” (p.144). These big ideas, or categories, were few in number as multiple forms of evidence were sought in the participants’ stories of practice to support each of them. Through this process the researcher sought to establish a collection of instances from the data, as meaningful categories emerged.

(2) Direct Interpretation: During the “Direct Interpretation” phase of the analysis, the researcher described both the context of the study as well as the individual participants embedded within the context of this case. As data was analyzed, the researcher first looked at each individual participant. One approach to analyzing data in a qualitative case study is to organize the data by people. The researcher looked at each single instance within this case study and tried to draw meaning from them without necessarily looking for multiple instances. In some cases, there were multiple instances across stories. However, the researcher found that each instance carried meaning for each participant within his/her story of practice and that not everyone’s journey was necessarily the same. A “Story of Practice – Story of Change” was written for each participant to help capture the understanding of each teacher’s change over time. These stories can be read in Chapter Five.

(3) Patterns: As categories emerged and individual participant stories were interpreted, different dimensions of the information surfaced. Patterns emerged within the data and between categories. It was initially thought that the data would be very separate and linear, however, analysis discovered that it was not. Entwined within each
participant’s story of practice was his/her story of change. Throughout the analysis process, representation of the data became increasingly difficult and attempting to create a visual representation on the computer was both frustrating and fruitless. Finally, technology strategies were put aside as the walls of the researcher’s home office were covered with paper and information was manipulated and classified accordingly, creating a visual representation of the findings. As data continued to be refined into more meaningful codes and categories, the researcher created an analysis rubric in order to better understand each mentor’s science teaching practices. Using elements from the NSES professional development and science teaching standards (NRC, 1996) and Essential Features of Classroom Inquiry (NRC, 2000) as guidelines, the following rubric was developed:

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focus on Evidence in Science Teaching</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Using Evidence</strong></td>
<td>Little or no reference to use of evidence (as defined by NRC, 1996) in science teaching</td>
<td>Little reference to evidence in science teaching. Teachers do talk about data collection but rarely use the term evidence</td>
<td>Beginning to apply use of the word evidence to data collected in science</td>
<td>Regularly uses the term evidence to describe information gathered in science</td>
</tr>
<tr>
<td><strong>Collection of Evidence</strong></td>
<td>Evidence described as data being provided to students or very prescribed data collection (i.e. means to an end)</td>
<td>Students sometimes collect evidence, however, it is referred to as data – more often provided by the teacher</td>
<td>Evidence is being collected by students more often and less often provided by teacher</td>
<td>Teacher uses his/her role in the science classroom to assist students in determining “what counts” as evidence</td>
</tr>
<tr>
<td><strong>Analysis of Evidence</strong></td>
<td>Data is rarely used or analyzed during science lessons</td>
<td>Sometimes uses data in science teaching. Focus is as an end product</td>
<td>If data is analyzed, teacher tells students how to analyze data</td>
<td>Teacher uses his/her role in the science classroom to assist students in analysis</td>
</tr>
<tr>
<td><strong>Focus on Explanation in Science Teaching</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Explanation Building</strong></td>
<td>No reference to use of explanation building during science lessons</td>
<td>Little or no reference to use of explanation building</td>
<td>Describes naïve views of explanation building during lessons. Explanations often given to students through definitions or modeled by teacher</td>
<td>Uses explanation building in science teaching. Students are given guidance in formulating explanations</td>
</tr>
<tr>
<td><strong>Role of Explanation</strong></td>
<td>Rote memorization.</td>
<td>Explanations about content are given by teacher</td>
<td>Teacher provides evidence and gives process of</td>
<td>Teacher guides process of</td>
</tr>
<tr>
<td>Classroom Discourse</td>
<td>Focus of Discourse</td>
<td>Frequency of Discourse Practices</td>
<td>Nature of questioning</td>
<td>Science-specific strategies used to promote scientific inquiry</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------</td>
<td>----------------------------------</td>
<td>-----------------------</td>
<td>-------------------------------------------------------------</td>
</tr>
<tr>
<td>Very little explanation of science concepts</td>
<td>Discourse is focused from teacher to student – rote communication and feedback</td>
<td>Teacher engages students in questions provided by teacher, materials or other source</td>
<td>Nature of teacher questioning is on “What?”</td>
<td>Teacher demonstration and factual recall. Few activities, very teacher-directed.</td>
</tr>
<tr>
<td>teacher to build scientific knowledge</td>
<td>Students are given steps and procedures for communication from teacher</td>
<td>Teacher engages students in questions provided by teacher, materials, or other source</td>
<td>Nature of teacher questioning is on “What?”</td>
<td>Hands-on activities – “Facts and Crafts” – teacher-directed Focus on teaching science process skills independently/separately</td>
</tr>
<tr>
<td>possible ways to use evidence to formulate structured explanations</td>
<td>Students are provided broad guidelines by teacher to sharpen communication</td>
<td>Teacher provides opportunity for students to sharpen or clarify questions provided by teacher, materials, or other source</td>
<td>Nature of teacher questioning is on “What?” and “Why?”</td>
<td>Hands-on activities with “dabbling” in student-driven activities. Science process skills emphasized</td>
</tr>
<tr>
<td>formulating explanation from evidence</td>
<td>Students are coached by teacher in development of communication</td>
<td>Teacher often provides opportunity for students to select among questions and/or pose new questions</td>
<td>Nature of teacher questioning is on “What?” and “Why?” or “How?”</td>
<td>Building foundation for student-driven activities/experiences incorporated when “comfortable”. Process skills integrated</td>
</tr>
<tr>
<td>students to construct explanations based on evidence</td>
<td>Teacher provides opportunity for students to form reasonable and logical argument to communicate explanations</td>
<td>Teacher consistently encourages students to pose questions</td>
<td>Nature of teacher questioning is on “What?”</td>
<td>Strong foundation in student-driven activities or experiences used consistently. Process skills viewed as part of every experience</td>
</tr>
</tbody>
</table>

**Table 4.5 Levels of Inquiry Use: Science Teaching Rubric Based on Stories of Practice**

Knowing where each participant was placed on the rubric served as a method to capture each story of practice. As analysis of each story unfolded, classifications of science teaching practices were characterized based on these developed categories. Based on the rubric, analysis of practice before PDS involvement as well as after PDS involvement could be characterized reliably using the same descriptions.

(4) **Naturalistic Generalizations:** Taking the interview data that was analyzed,
generalizations were constructed based on the findings and visual representations of the information garnered from the process were created. Upon completion of the first round of interviews, the following visual representation was created and contained the necessary information needed to adequately synthesize and describe the data that was analyzed.

![Placement of Participants on Continuum Relevant to Science-Teaching Practices after Initial Interview](image)

**Figure 4.1:** Placement of Participants on Continuum Relevant to Science-Teaching Practices after Initial Interview

- Treating students alike and responding to group as whole.
- Rigidly following curriculum.
- Focusing on student acquisition of information.
- Presenting scientific knowledge through lecture, text, and demonstration.
- Asking for recitation of acquired knowledge.
- Testing students for factual information at the end of the unit or chapter.
- Maintaining responsibility and authority.
- Supporting competition.
- Working alone.

- Understanding and responding to individual students’ interests, strengths, experiences and needs.
- Selecting and adapting curriculum.
- Focusing on student understanding and use of why ideas, and inquiry processes.
- Guiding student in active and extended scientific inquiry.
- Providing opportunities for science discussion and debate among students. (SCIENCE TALK)
- Continuously assessing student understanding.
- Sharing responsibility for learning with students.
- Supporting a class community with cooperation, shared responsibility and respect.
- Working with other teachers to enhance the science program.
As Creswell (1998) describes, naturalistic generalizations are developed so that people can learn from the case either for themselves or for applying it to a population of cases. The generalizations made for this case were intended to best represent this specific case for continued research within this context. This analysis approach attempted to understand empirical matters from the perspective of the mentor teachers and to make meaning of the experiences of ordinary people in a natural setting, such as an elementary school. This phase of the research lasted many months and resulted in documentation of general findings in the form of basic assertions.

Over the course of next year, the results of the study were continually refined as data were revisited periodically. The researcher felt that the generalizations that were constructed were substantial and potentially central to science education research literature, however, there was not saturation of data. Generalizations were made, however, in order to substantiate these generalizations and make confident assertions regarding the analysis, additional data were needed.

After conducting additional case study research, it was determined that effective case studies involve the widest array of data collection as the researcher attempts to build an in-depth picture of the case (Creswell, 1998). Multiple forms of data collection are recommended by many of the leading case study theorists and researchers. Creswell (1998) emphasizes four basic types of information to collect: observations, interviews, documents, and audio-visual materials. Yin (2003) refers to six forms: documents, archival records, interviews, direct observation, participant observation, and physical artifacts. Therefore, in order to validate the assertions that were generated, the researcher and her thesis advisor discussed the possibility of conducting a second interview with each of the participants. It was agreed that this would be the best course of action, as well as collecting additional documents and physical artifacts as evidence to support
the findings. After two years, phase three of the research study commenced.

4.9.3 Phase Three: Follow-up

Two years after the original data was collected, in the spring of 2007, the eleven participants were contacted and asked if they would be willing to participate in another interview to answer additional questions regarding their thinking and practice in science. An interview protocol was designed and structured in a manner that was similar to the first interview (Appendix G). Nine out of the original eleven participants agreed to participate in a second round of interviews. One of the two participants who did not complete a follow-up interview chose not to participate because of her classroom situation. She had not had a student intern in the past two years as she was still teaching in a learning support classroom and felt that she did not have anything new to report. The other participant who did not take part in a second interview was on personal leave from her position due to an illness in the family and the researcher did not feel that it was appropriate to encumber her with such a task at this time. However, the remaining participants all completed in-depth personal interviews with the exception of one participant who chose to answer her questions via email.

As in the first round of interviews, each participant was forwarded via email a list of potential questions for the interview. These questions focused around the original generalizations to be used in an effort to either support or confirm the initial analysis results. Each participant was interviewed in his/her school building during regular school hours and each interview was scheduled for a time frame of 45-60 minutes. Table 4.6 provides an overview of the total minutes for interview two.

<table>
<thead>
<tr>
<th>Interview #2</th>
<th>Length of Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Julie</td>
<td>28min.</td>
</tr>
<tr>
<td>Name</td>
<td>Duration</td>
</tr>
<tr>
<td>---------------</td>
<td>----------</td>
</tr>
<tr>
<td>Margaret</td>
<td>34min.</td>
</tr>
<tr>
<td>Lynne</td>
<td>58min.</td>
</tr>
<tr>
<td>Liz</td>
<td></td>
</tr>
<tr>
<td>Paul</td>
<td>31min.</td>
</tr>
<tr>
<td>Greg</td>
<td>22min.</td>
</tr>
<tr>
<td>Marla</td>
<td></td>
</tr>
<tr>
<td>Shelly</td>
<td></td>
</tr>
<tr>
<td>Karen</td>
<td>38min.</td>
</tr>
<tr>
<td>Bobbie</td>
<td>38min.</td>
</tr>
<tr>
<td>Lana</td>
<td>42min.</td>
</tr>
<tr>
<td><strong>Total Audio Data for Interviews</strong></td>
<td><strong>291min.</strong></td>
</tr>
</tbody>
</table>

**Additional Data Sources**

- 1 email response
- 3 inquiry-based science lessons
- 1 teacher inquiry project report
- 1 science curriculum unit – “Dinosaur Addendum”
- KLEW chart

Table 4.6 Length of Participant Interview #2

In addition to the interview data, documents were provided by those participants who wished to share them as examples of the changes that they had made in their science teaching. During the interview process, some of the mentor teachers brought in examples of science charts that they had completed with their students, curriculum units that they had created for the district, and examples of work that they had completed in graduate classes. The availability of these documents enabled the teachers to comfortably communicate and illustrate their stories of change, and allowed the researcher the opportunity to directly evaluate these documents for how they exemplified current views and practices in reform-oriented science education. Information garnered from these documents was noted during the interview process as well as in personal notes written by the researcher following the interview. Also, in some cases, the participants sent electronic copies of their documents for review. These artifacts contributed greatly to the understanding of each teacher’s current ideas of reform-oriented science teaching in the elementary classroom and to the research process.
4.9.3.1 Analysis

Analysis of second interviews followed a similar pattern to analysis for the first interviews. Digital audio files were transcribed by the researcher and entered into HyperResearch® software. Additionally, email documents and other science artifacts that were provided electronically were converted to text (.txt) files and entered into HyperResearch®. Using a holistic analysis approach, the same sequence as described in phase two was followed to analyze the second interviews, using an open-coding system. The researcher began analysis using the same coding system that was created for the first interviews, making modifications as needed throughout the analysis process where there may have been similar and/or new codes needed. Using the assertions that were generated during phase two of the study as the major guide, the researcher looked for patterns and connections to these assertions as she read through the interview transcripts.

Finally, additional artifacts that were provided to the researcher (e.g. science charts and redesigned curriculum units) that were not available in electronic format were reviewed thoroughly and data was analyzed and organized using a highlighting marker and a pair of scissors. These pieces were cut out and fixed to the charts of each assertion hanging on the walls of the office. These documents were used as evidence to support/refute claims that each mentor teacher made concerning his/her science teaching practices and documented as such. Therefore, each artifact was analyzed for placement on a continuum of reform-oriented science teaching practices using the guidelines as described in Table 4.5.

Additionally, all data that was collected from interviews, documents and artifacts were used to support/refute claims that were made in this study based on the mentor teachers’ stories of practice and stories of change and are embedded within the assertions of chapter five.

4.10 Limitations of the Design
One of the limitations of the study design is the external validity, or the generalizability of the study. The eleven participants were all employees in the same school district, as part of the same Professional Development School environment. The transferability of this study to other University/School District partnerships is unknown. It is assumed that one could find similar results in another PDS environment, however, since PDSs differ so greatly in form and structure, these findings are limited to characterizing this singular PDS.

Secondly, the researcher did not conduct first-hand observations of the science classrooms. Due to constraints of both time and location, the researcher did not conduct participant observation of science in the classroom to corroborate each story of practice. Therefore, the results of this research rely heavily on each participant’s self-reported story of practice, and his/her interpretation of the journey through the process of teaching science. Without direct observation of the science teaching “in action,” it is necessary to infer meaning based on personal description. Even though the researcher feels that she was able to gather enough evidence to clearly tell each story of practice, she also firmly believes that first-hand classroom observations could have made this study more powerful.

4.11 Summary and Preview

This chapter presented an overview of the methods of this exploratory inquiry. It provided the reader with a brief contextual overview of the history of qualitative research and why this paradigm was chosen as the method of inquiry in this research study. This chapter also provided a look at the researcher’s role and background in this research process while also providing an overview of how data was prepared, collected and analyzed and how the researcher sought to establish trustworthiness in this research project. Additionally, a brief description of each study participant was provided. In the next chapter, extensive descriptions of each
participant and his/her story of practice and story of change are provided, along with a graphic representation of each mentor teacher’s placement on a continuum of reform-oriented science teaching practices. This will provide the reader with an in-depth insight into each participant as he/she understands and interprets his/her own story.
In this chapter, the first research question was used as a framework to present descriptions of the eleven participants in this study through each teacher’s Story of Practice and Story of Change.

Research Question 1: How do mentor teachers describe their science teaching practices and how they have changed as a result of participation in PDS?

a. In what ways do PDS mentor teachers’ descriptions of practice reflect contemporary reform ideas and practices in science education?

b. To what extent do their stories emphasize technical aspects of teaching versus epistemological changes in their thinking and knowledge?

c. How is student learning in science reflected in teachers’ stories of practice?

Although the sub-questions are not be specifically addressed in this chapter, they are addressed through analysis of each of the stories and reported in Chapter Six. Each participant’s story is outlined here. This is where the research story begins – the story of science teaching practices in eleven elementary classrooms across the district and how mentor teachers changed their thinking and practice in science as a result of their participation in this PDS partnership.

Each story is written in detail below following a similar pattern of description for each mentor teacher: 1) Introduction to the PDS; 2) Science teaching prior to PDS involvement; 3) Science teaching throughout PDS involvement; and 4) Story of practice two years later. Highlighted within each story are specific examples of quotes from mentor teachers and how they related to the codes used to analyze each story. Actual codes are included, italicized in brackets, for identification either within or after the data quote. This method is designed to present the reader with an overall portrayal of practice and the change process of each individual.
5.1 Participant 1: Julie’s Story of Practice, Story of Change

Julie is a twenty-five year teaching veteran and has taught both kindergarten and first grade during her tenure as a classroom teacher. Science is a subject that she expressed was one of her favorites to teach. When asked to give a description of her science classroom on a typical day, she enthusiastically described it as being “busy” and “full of energy.” Evidence of this was noted during her initial interview as the walls in her classroom were covered with students’ work and the room was filled with both on-going science projects (an incubator with chicken eggs) and remnants of past projects (a hand-washing investigation science chart). On the date of her first interview, the seating in her classroom was arranged in cooperative-group learning style, with three to four desks per group. Her classroom ceiling was filled with child-created solar system models that the children had just completed during a unit on Space, and numerous other artifacts reflective of past/present science learning were scattered throughout the room.

5.1.1 Introduction to the PDS

When the Professional Development School (PDS) project first began in her school district, Julie recalled thinking that it sounded like an interesting and appealing concept. Julie had hosted student teachers in her classroom before, but only for one semester at a time in the traditional student teaching placement concept, which was quite different from this idea of working together with an intern for an entire school year. She recalled the experiences of working with traditional student teachers as being very “disconnected” from her every day classroom.

She’d [the intern] say, “I need to teach a lesson on flowers.” [Julie would reply], "But we're not studying flowers" [followed by the student teacher saying] "…but I need to teach a lesson on flowers.” (J1:29:38)
Julie, frustrated by the disconnect that she felt at times between the university requirements and the school district curriculum, expressed her eagerness to experience an alternative to what she felt was an outdated partnership. She remembered speaking at length with a colleague at the university and sharing ideas about this project. As a result of that conversation, she volunteered to be one of the first teachers to host an intern when the project was initially piloted. Unfortunately, the PDS project was piloted at another school in the district and not the school where she was teaching. Julie expressed feeling disappointed about this at first, but continued into the beginning of her school year as she had for the previous eighteen years, knowing that she would have her chance to be a mentor in future years if the program was successful and expanded to her building.

A few months later, one of the mentor teachers in the pilot school left unexpectedly in the middle of the school year, leaving one intern without a mentor for the remainder of the school year. When Julie’s colleague at the university called her to ask if she would consider taking on this intern, Julie excitedly said, “Yes!” and took over as a mentor teacher for the remainder of the school year.

The following school year, the program expanded to Julie’s school building and she continued to work with an intern in her classroom consistently over the next seven years. During this time, Julie also worked with PDS planning teams in the area of “Classroom Learning Environments” and was involved with the analysis of district curriculum units of study as the district was beginning to use an inquiry stance in the development or redesign of curriculum. Her introduction to the PDS was as a leader right from the inception and Julie was involved in as many activities as she felt she could handle from the start.

5.1.2 Science Teaching Prior to PDS Involvement
Prior to becoming a mentor teacher in the PDS, Julie described the focus of her science teaching as one of helping the children to learn scientific facts through the use of hands-on activities. She described her pedagogical style as one that reflected the focus of getting the children excited to learn. Julie thought that hands-on activities in science were fun for the children and helped them to learn scientific facts through tactile learning. She also believed that hands-on activities were the best way to help children learn science. In fact, as long as the students were doing something with their hands and not just reading from a textbook, Julie stated that she believed they were learning science. In Julie’s kindergarten classroom, she developed science activities that she had planned around science topics that included many hands-on activities for the children.

So we [Julie and Margaret, her teaching colleague] developed what we thought was pretty good science for kindergarten at the time. It was, you know, month-long investigations. And we would do things on evaporation, and make rock crystals, or we would make ice cream or we would have, we did a thing on planes, ramps... So we’d do them in months, and every week they’d have a new little experiment or something. But it was fairly teacher-directed – it was hands-on, but it was fairly teacher-directed. And we thought, at least they were doing something.” [teacher-directed science] (J1-08:17)

Julie’s use of hands-on, teacher-directed activities for her students substantiated the idea that her young students needed concrete experiences in order to help them learn. She felt that the hands-on activities supported the learning of facts and information by engaging the children in such concrete experiences.

The district science curriculum focused on units of study that were taught over a period of several weeks but focused more on a rote learning method of teaching – learning facts without developing a deep understanding of those facts. For twenty years, Julie followed the school district science curriculum and used teaching methods that were outlined in the teacher guides, sometimes adding additional hands-on activities when she felt it was necessary or appropriate.
She described herself as being content to teach the science units in this way, mainly because she wasn’t really sure what else she either could do, or was supposed to do. She said,

And so I knew that I really liked these units, but I really, I was told what [emphasis added] to teach, so I couldn't really design my own [unit] and I didn't know what [else] to do with them. (J1-08:17)

Therefore, Julie did not take initiative to change the required curriculum. However, at times she modified it slightly in order to include more hands-on activities that she felt were important.

“…what I called…“facts and crafts.” You know, teach a little fact, do a little craft. That’s what we did… (J1-04:42)

She provided her students with concrete learning experiences that often connected with art projects, a phenomenon that she described as “facts and crafts.” Her teaching style reflected the style of other documented cases of elementary teachers who used hands-on activities as the primary method of instruction to make science “fun” for the children and this is what science was like in Julie’s classroom for nearly two decades.

5.1.3 Science Teaching Throughout PDS Involvement

As a result of the seven and a half years that Julie worked as a mentor teacher in the PDS, she acknowledged and confirmed that she changed both her thinking and her practice as it related to science education in her classroom. In the years before PDS, Julie focused on periodically incorporating teacher-directed, hands-on activities into the pre-designed district science curriculum units as a way to make them, as she described it, more “fun” for the children. After Julie worked as a mentor teacher and on PDS planning teams for a few years, she began to think more intentionally about her science teaching and how her students were learning in science. As a result, she took more initiative in the re-design of the pre-packaged district science units to make them more inquiry-based.
Before Julie even started to teach a science unit in her classroom, she approached the curriculum from a completely different viewpoint than she had done previously. Prior to her PDS involvement, Julie stated that she “didn’t know what else to do with the curriculum units.” She taught what she was expected to teach following the guidelines of the written curriculum, mostly because she didn’t feel as if she had other options except for the ability to make slight modifications to match her teaching style. However, after working directly with her very first full-year intern, Julie witnessed some examples of a “different way” to teach science. From her science methods class, Julie’s intern used inquiry as the focus for teaching science and incorporated several reform-oriented methods. Upon watching this, Julie began to make the connections between her dissatisfaction and a more authentic way of teaching science. The following quote describes the influence that her intern had on her:

But then, my first full-year intern was, loved science, and loved working with Connie. And was, you know, did a lot of work with science, actually did her inquiry project on using a science table to extend learning - teaching by putting out other things that they could do doing their free time. So that was her inquiry project. Then I just met Connie through her, and got involved with thinking about science differently. [influence of intern on practice] (J1-01:58)

As a result of her changed perspective, before Julie even started teaching her science units, she reportedly questioned the materials that were contained within those units and how she presented them to the children. Her practice of teaching science still included pre-planning, but she now used a lens of inquiry to modify those units. The following quote provides an example of how Julie’s dissatisfaction prompted her to reflect on her practice and to make changes.

I question what I'm told to teach more now, and if I don't like the way something is laid out, I'll look for a different way to do it. [teacher reflection on practice] For instance, we have to teach this underwater life unit, which was always about the ocean and the different parts of the ocean. And we're about as far from the ocean as you can get. [Laughter] So for Margaret and I it was like, well this just doesn't make sense anymore [dissatisfaction]. What can we do to make these concepts? So we went to Connie and Connie gave us some ideas, and we
completely changed the way we taught that unit. [lesson modification toward reform] And now when I looked at, I'm on this, actually this science committee for the district, thinking about making changes in the primary science units, and we're looking at those STC books. And one of them, the unit is very much like what we've been doing now, a couple of times, with our underwater life unit, creating these pond communities. And we've been doing it now, the last 2 times we taught this unit. (J1-33:47)

A more specific example of a unit that Julie modified using the lens of inquiry was the first grade Prehistoric Life Unit. The “Dinosaur Addendum” as it was known across the district among several of the elementary teachers, who taught it in their classrooms, reflected many reform-oriented methods of teaching science to children. First, the focus of the addendum was not on teacher-directed lessons that involved memorization of dinosaur facts, nor did it focus on the creation of cute or fun hands-on activities to follow-up on that teaching. The focus of the addendum was on child-centered curriculum that allowed for the students to learn and apply their knowledge as scientists do.

Well, it [the focus of the unit] is mostly determining what the mystery dinosaur is. Actually working like a paleontologist, using what we know about ourselves or other animals and applying them to an animal that you can’t see. . . is kind of what they’re doing. So then, it’s very, very engaging. So the students actually learn more than just dinosaur names, and what they ate and stuff. They really come to understand them as animals and understand what it means to be a carnivore and what their skull would look like and what their teeth might look like. [lesson modification toward reform] (J1-06:29)

Julie reported that she changed the focus of the unit from one that focused more on memorization of things like dinosaur names and whether they were herbivores or carnivores to one of exploration in which the students inquire and discover characteristics of dinosaurs and apply that information to identification and explanations. Upon closer review of this addendum, evidence was found to support her claim that the students investigated, questioned, gathered data, and used that data to generate explanations, all while working in the classroom as paleontologists would work in the field. The students used methods of scientific inquiry and as a result
expanded their knowledge of dinosaur facts and developed their science process skills through the collection, manipulation and interpretation of evidence. Julie explained that her science teaching practices reflected this inquiry method and her role was no longer that of a person who supplies knowledge as in a teacher-directed classroom, but instead reflected the model of teacher-as-guide to support student inquiries as she interacted with her students. She said,

So we changed it [the school district’s Prehistoric Life Unit] and made it so the children work in teams, paleontology teams, and each team gets a clue from a dig site and then has to understand, make sense of what the clue means. So if they got a clue that they found a footprint, then we do some work with our feet and legs and learn that there is a ratio. And then they get the ratio for dinosaurs and do some work with the footprint, and figure out how big the dinosaur is. And then the next week they do some work on stride, and they learn about stride, and they get some information to tell them whether the dinosaur walked or ran, or on two feet or four feet. And then they get something about skulls, and we learn about teeth and eye plates and all that jazz, and then they get a picture of a skull. And from there, they’re piecing together what they think the dinosaur is that their paleontologist is digging up. And then at the end, they get a piece of the skeleton that they put together, and they discover what the mystery dinosaur is. (J1-04:52)

In this example from her first grade classroom, Julie had structured (or re-structured) the lessons in such a way that the students were given ownership of their own learning process. Science was not something that was being done to them. Science was something that they were doing.

Julie’s description of her teaching reflected a classroom that was doing more student-driven science. Julie used questioning methods, a basic inquiry strategy, to help the children focus on the processes of doing the science rather than always focusing on the outcome.

Well, certainly personally I feel like, or professionally, I guess this is, I feel like I’m a much better science teacher. I’m becoming very comfortable with questioning. I feel I’m getting much better at asking those questions to get my students to think. [focus on questioning] (J1-33:47)

As a complement to doing more student-driven science, Julie described her use of student wonderings and evidence in a way that she had not used them previously. She focused her lessons on what the students wanted to learn and used her questioning skills to guide them
through the inquiry. An example of this, she described her teaching of a magnet unit that she and her colleague, Margaret, adapted incorporating more inquiry-based practices. She stated,

…like with the magnet unit, using their wonderings to propel the unit more than the content that the district says you have to teach. And using the idea of using that evidence, and making them back up their claims with the evidence, is very - I had used KWL before, but not with this KLEW thing, and not focusing more on the wonderings. [science-specific learning strategy; KLEW chart] The wonderings in the past were like, Yeah if they matched, we did them, but if they didn't match, we didn't really care. I was like "Oh, we just won't care [about that one]"…and even being able to [care about it]. And I think, this magnet experience has really helped us I think, think about how to get to those wonderings with primary students because they don't raise their hand and say, "Gee, I wonder this . . ." You know, they just don't. So being able to get to what the testable questions are has… I think, we've grown through this last experience with that. (J1-14:13)

Julie used science-specific strategies, such as KLEW charts and science talks, to enhance her questioning skills and to make science learning more authentic. As Julie taught this unit on magnets in her classroom, she no longer was quick to answer her students’ questions with, as she said, the “right answer.” Instead, she listened to the science talk going on in the classroom and often turned the students’ questions back into new questions for them to investigate.

As the students worked, we walked around listening to their ideas and asking questions. For instance, one pair was sorting by “heavy and light”. We asked them to explain how they decided if something was heavy or light. They designed a test to make the determination. By asking the students to think, test and explain we were getting them ready to “be scientists.” [science-specific learning strategy; science talk] (Julie, 2005 Inquiry Conference Presentation Paper).

The focus of Julie’s teaching in science was on listening to what the students were saying to her and to one another during their science experiences. She used these conversations and these student wonderings to structure the lessons in such a way that she still met the requirements of the district curriculum while using reform-oriented science methods to guide her teaching.
Additionally, as Julie described her science teaching practices, she talked about the integration of science-specific technology into the curriculum, which was not something that she had used in science before. Heart probes, sound probes and light probes were used as a way to help the children to “see”, for example, the phenomenon of sound waves instead of just talking about them or listening to them.

They've used the sound probe, which really showed them things that you couldn't show otherwise...[use of technology] so we were able to put them down, you know, print them out. So it wasn't just watching it and then having it disappear, we actually made copies of them, so after they did it and they watched them, then they could look at them and really analyze, as much as first-graders can analyze, the differences in the waves. So I thought it was very, I mean first-graders, for them to be able to visualize something is always good. (J1-23:38)

In summary, Julie’s practice of teaching science in her first grade classroom as a result of her seven and a half years of experience as a PDS mentor teacher can best be summarized using her own words:

So, it [science] is more observable. So, also making science more appropriate for our students in that these are things they can physically see, or like those life science things, and observe, and notice, and document. Or for science stuff like the magnets, or light and sound, where they can physically design experiments and those kinds of things. So I think that's really changed. And [I am] a more confident science teacher. (J1-35:30)

5.1.4 Story of Practice - Two Years Later

Julie continued her professional development between the time of her two interviews in that she continued to host two additional interns in her classroom as well as tackling a new role as a co-teacher of the university PDS elementary science methods course. Julie described this experience as one of being extremely “eye-opening” and important to her personal reflection of how she taught science to her first graders.

[Co-teaching the science methods course] was a big, big change for me, and helping her teach the PDS course was really, you know whenever you teach something you always learn from it. [personal reflection] (J2-01:37)
As she often modeled exemplary science lessons with the PDS interns in her college class, the interns would often ask her why she made certain teaching choices throughout the lesson. Julie stated that this caused her to reflect more deeply on her practice and the choices that she makes on a daily basis in the science classroom. This type of professional development allowed Julie time for personal reflection as well. As she prepared lessons for the interns, she reflected on how she approached science concepts with her first graders. Consequently, two years later, Julie still described her classroom as a place where children learned as scientists – a place where they learned how to inquire, to study, to observe and to formulate explanations based on their own findings and understanding, and her science teaching practices supported this. As an example, Julie explained how she was in the process of modifying a future science unit on the topic of animals. She described how she and her teaching colleagues were trying to move the unit from a more fact-based learning unit to one that reflected inquiry-based practices. She described,

Well, we used to look at all of the different classifications of animals and what makes a mammal and what makes a reptile. We’re not going to focus on that at all. We might do insects. We’re talking about maybe the two layers because they are so interdependent anyway. So, look at birds and study insects and do not as much research or learning the facts. It will be more of what we can observe, [lesson modification toward reform] so that will be a little bit different… but we might veer off here depending on what the students want to do. And I think that fact that if we can get them, not researching mammals, but out observing birds and building bird feeders…Then we’re going to…collect data on the birds, get some birdfeeders and watch the birds and collect data on which birds are coming to which feeders and why…and we’re going to be looking at our forest in our backyard, and we’re going to be creating a field guide for our backyard [building explanations from evidence]. (J2-15:27)

This example demonstrates how Julie continued to grow, change, and implement reform-oriented teaching practices into her curriculum on a regular basis. She did not revert to her former teaching practices in science, but rather continued to develop based on her professional development opportunities and personal experiences in her classroom. Her science curriculum
continued to focus on using contemporary reform-oriented practices as the basis for the pedagogical strategies that she used on a daily basis in the classroom.

5.2 Participant 2: Margaret’s Story of Practice, Story of Change

Margaret has been a primary teacher for over thirty years. She is a woman who expressed deep conviction for children and their learning. She was the only person out of eleven participants who brought an armload of artifacts from her students’ science experiences to share during her interview. She reflected such pride in her students’ accomplishments that the researcher felt that she sometimes had difficulty stepping back to see that it may be because of her change in focus that her students were doing such incredible things in the classroom.

5.2.1 Introduction to the PDS

Margaret became involved in the PDS partnership as soon as it expanded to her elementary school, which was one year after the pilot year. Because Margaret worked very closely with Julie, she saw the benefits of the program when Julie became a mentor teacher halfway through that pilot year. Knowing how much her colleague Julie had enjoyed being a mentor teacher, Margaret signed on as soon as she was able.

In science, Margaret reported that having an intern in her classroom opened the door to a new way of approaching science.

Working with interns has been absolutely phenomenal for me because from their science class, young professionals are coming in with ideas. And I see, hmmm, o.k. - I'm going to put it this way - I see that in my class I learn from, I learn from the interns. [influence of intern on practice] Well, this is what I'm supposed to do? What do you think we can do with this? (M1-22:52)

Margaret reported having experienced a new way of thinking about science as a result of having her first intern in her classroom. Working as a collaborative team, Margaret and her intern along with Julie and her intern planned together on a daily basis in science. Having an intern in the
classroom for whom she was responsible pushed Margaret to examine her own teaching practices in a different way. Her first intern, as well as successive interns, each had his/her own strengths and weaknesses and Margaret observed and considered each of these special abilities as she applied it to her own teaching style.

And I have learned, my intern last year was a tremendous questioner…we would really push off each other and she was a tremendous questioner, so I think we learn from them as well, and from their projects and their questions and helping them… and if I'm helping someone else to learn, I learn as well. [teacher reflection on practice] I mean they have to come in with, from Connie or Kate or whoever, with their lesson plans. This is what I'm thinking, all right, so you see how it's set up and you know you want to do the inquiry. (M1-22:52)

Margaret recognized that her responsibility as a mentor teacher and her regular interactions with her interns allowed her to reflect on her own teaching practice on a daily basis.

5.2.2 Science Teaching Prior to PDS Involvement

During the 1970s, Margaret could have been categorized as a traditional science teacher. She used the teacher’s manual as a curriculum that was both prescribed and teacher-directed. Although the science movement at that time was to help children become more knowledgeable citizens, this was often achieved through rote memorization of facts. She described her teaching practices prior to PDS as follows:

Back in the old days, I think when I first started teaching I taught 3rd grade and you know you were given a textbook. You read from the textbook, you answer whatever questions there are and there it is. [teacher-directed science] I mean, yeah, but that's thirty-some years ago! (M1-24:31)

As Margaret’s teaching career advanced, so did her ideas on how to teach science. When she changed grade levels and found a colleague with whom she could work closely, she and Julie started to experiment more with how to move science from a textbook-focused subject to a more hands-on – focused subject. She described these former curriculum modifications that she and Julie made to the science units by saying,
I really have enjoyed, I work with Julie... and I have always... collaborated on a lot of projects, [collaboration; teaching colleagues working together] and we thought we were pretty cool, or whatever word, innovative, when we thought about hands-on stuff - because at least we were giving kids touches of it. [activity-focused lessons] You know, at least touch your science stuff - you don't need books, you know. And when you're doing hands-on science and they're doing things, they are questioning, and that was all well and good. (M1-02:48)

So, Margaret spent many years teaching her children using the lens of activity-based science teaching, or what many teachers referred to as “hands-on science”. The school district in which she taught encouraged these types of teaching practices and she and her colleague were providing their students with fun activities on a weekly basis – what Julie described earlier as “facts and crafts”. Margaret reported that she felt that using this strategy was at least better, or at least more fun, for the students than just memorizing science facts from a textbook. Based on her own descriptions of her classroom practice, Margaret’s teaching style prior to PDS could be categorized as reflecting “activity-mania”. Her students were still focused on learning the many facts in the science curriculum, but the learning was enhanced with hands-on science activities that attempted to reinforce the science concepts through touching and doing.

5.2.3 Science Teaching Throughout PDS Involvement

Over the course of her seven-year tenure as a PDS mentor teacher, Margaret recognized that she made significant changes in the way that she both thought about and taught science in her classroom. Compared to her earlier practice with a strong focus on activity-based learning, her teaching now reflected an inquiry approach to learning science, which was guided by student questions and exploration. She explained,

I think about how 2 years ago how I taught science and how I teach science now, totally different. I mean, thinking about 30 years ago... but I mean, I am allowing even now, its almost more questions and more answers to say, "I don't know, but how can we find that out?" [focus on questioning] And as long as we drive it, and I see it driven toward that curriculum and to answer what we need to do, then those questions don't bother me at all. And I think it's pretty important that the
children are allowed to answer those and inquire because I think then it also opens up a whole avenue of a way of learning for them. (M1-30:39)

Formerly, as what could be classified as a traditional science teacher, Margaret allowed the textbook to guide what the students learned on any given day. In the seven years that she was involved in the PDS, Margaret spoke of using the wonderings and experiences of her students to guide her daily science lessons. When she first began teaching back in the 1970s, Margaret taught science mainly from the textbook – not necessarily because she wanted to or because she thought that this was the best way to teach science, but rather because that was how she was encouraged to teach. She was given a textbook and asked to teach the information contained in the book. Not until she left the public school system for a few years and worked specifically in the field of early childhood education did she come to be able to even begin to view science differently. She taught young children for many years and she believed that her experiences with teaching young children instilled in her the belief that children are natural inquisitors and have an instinctive love of science. Also, being in a system where she was no longer told that she had to teach a science text affirmed that understanding. Once she returned to the public school system and worked with an intern in a system that now encouraged inquiry-based science teaching practices, Margaret was able to put her beliefs into practice.

Over the years, Margaret focused more and more on using a lens of evidence/explanation to guide the science learning in her classroom – built from the questions of her children. The following excerpt from Margaret’s first interview, which is a description of a hand-washing investigation in her classroom, supported this observation:

And setting it up with how they’re thinking about the wonderings, and that's why I brought this hand-washing experiment with me, because we had done this in the past - this hand-washing activity - and I thought it was, we did it from the hypothesis. We did it from the idea that there was data and group data and then what did they learn? So, this time, when we did it, it was
great because we kind of brought up the idea of hand washing and why should you wash your hands? [focus on student wonderings]. And they [the students] gave us the reasons, you know, why you really need to. (M1-07:02)

By focusing on what the students wanted to know about a topic, Margaret incorporated reform-oriented teaching methods into her science lesson. A focus on student wonderings transformed their learning into something that had meaning for them. Margaret used those wonderings to access their prior knowledge about the topic. When she did this, she discovered that her students knew far more than she thought they would have known. This method of creating a discourse environment in the classroom is an important inquiry practice. She described the conversation as follows:

And I have never had a kid, it was so cool, I said, “So what are these things that are on your hands?” Well, they're germs. I mean, and some kid, of course, you know, you get the different thinking, said “microorganisms!” I said, “What?!?” I said, “What is that?” They said, “Well, they're germy things, they can cause stuff, you know, germs.” And he said, “Well, it's like when you have a boo-boo on your…” - I mean this kid has a microorganism and then he talks like a boo-boo – “and then you get a boo-boo on your knee and if you touch it you can get germs in you, you can get sick from stuff like that.” Or you can, how else did they use the word "germs"? From, you know, wiping your nose and things like that. So they really knew, I was really quite impressed with the idea that they could take dirty hands into this thing that there were germs and then microorganisms but then bring it back to the other kids and say, “Well, they're the things that make you sick.” [student prior knowledge] (M1-07:02)

As Margaret described her interactions with her students on the topic of hand washing, she encouraged them to use what they already knew about germs based on their personal experiences as evidence to build their understanding, or explanations, of the concept of why they should wash their hands. She allowed the children to use their own terms, knowledge, and experiences, to develop to their answer instead of simply telling them an answer. This method of inquiry was critical in allowing the students to build their own understanding. Margaret continued to discuss
how her teaching practice supported this meaning-making and understanding in science. She said,

And so, when we talked about the germs and things, how could we think about the best way to get rid of those, then they brought in, “Well, you wash your hands.” Well, how can we think about doing something at school if we wanted to wash our hands, and I, of course, had four ways that Julie and I had thought of. You know, we'd wash our hands with soap and water, we'd wash our hands with water, we'd wash our hands with the anti-bacterial and then we don't [wash our hands]. You know, that's how I thought it through. And so this one kid said, "Well, I think we should use wet wipes." And I thought, ok, why not? [focus on student wonderings] I mean, so they brought, I mean, really, in my mind, I had set it up hoping they'd ask the right questions so we'd go a certain way, [conflict with former practice] but they brought in their own information. (M1-07:02)

As can be gleaned from this example, Margaret still, at times, felt as though, after over thirty years of teaching, she could predict the best methods with which to conduct the inquiry. However, she was often surprised, as she was in this case by the student who wanted to use wet wipes, and was compelled to remind herself that science did not always unfold as planned. As a reflective practitioner and a teacher who described her practice as reform-oriented, she then used this information to guide her students through an investigation using reform-oriented teaching methods.

…and I then set it up in a fair test group with them and asked them what would be fair. How many people we should have in each group, how we should set that up and what do we want to put the germs on? [evidence gathering] (M1-07:02)

Rather than simply dividing the children into groups and giving them a pre-determined task, Margaret allowed the children to determine fairness and to develop a testing method for gathering their evidence. Her questioning techniques guided them through the process, rather than dictating a process to them. She continued to describe how this process unfolded.

I told them what I had thought about and we then decided on bread, that we would do it on the bread. And what would, what would happen to the bread. And they said, "These microorganisms that cause germs or you to get sick, would cause mold." Now don't ask me how they knew that, but they just said, the one kid said,
it causes mold, and somebody said, "Oh yeah, I've seen mold." I mean, the conversation went, “Yeah, if you leave mold around too long, or bread around too long, it will get moldy.” [science-specific learning strategy; science talk] But then they were really interested in what the dirt would do to the bread. (M1-07:02)

By incorporating student discourse into the lesson, Margaret learned more about her students’ understandings and thought processes. She recognized that her students’ knowledge was based on past experiences and she used those experiences to develop their curiosity and their investigation of the question. Margaret went on to describe how her students gathered evidence through their investigation and then used that evidence to develop their explanations and reasons why they should wash their hands. She reported,

And they really had great questions that came up with, but it came from, Julie and I had set this up previously as more teacher-directed, but then we brought it back to them [emphasis added] doing it - from the 4 stations to the 5 - and then…where we talked about it and they had what they learned and their evidence – It's all good evidence. They compared it to the other groups. The dirty hands group had them - because we put them up and they compared. [Reading from the student data chart they created in the classroom] – “And washing your hands is important for removing germs that make you sick because dirty hands group had the moldiest bread, washing group, washing hands group had the least.” So they [emphasis added] drew that conclusion. “The bread was moldiest when you do not wash your hands” - it's because they saw it. “I saw the mold on the bread.” [building explanations from evidence] And “wet wipe napkin caused white mold” - that was the funniest thing. But they said, “I've never seen that before and I know it is mold because I saw it.” (M1-07:02)

In this self-report of her science class, Margaret’s teaching practices clearly reflected reform-oriented teaching methods with a strong focus on helping her students to collect evidence and to build explanations from their experiences. Her change in practice allowed her to be more focused on looking at the relevancy of the curriculum to the life of each child in her classroom, to have somehow made science more meaningful to each student. She reported that she has become empowered by her focus on teaching science as inquiry.
And when you're doing hands-on science and they're doing things, they are questioning, and that was all well and good. But it was really the whole idea of now, letting the curriculum go - not really, but taking it from the children's point of view, has been so empowering. [lesson modification toward reform] (M1-02:48)

After her seven years of involvement with the PDS, Margaret reflected that as a result of her participation that she recognized the importance of a child-centered curriculum verses a teacher-directed curriculum. She elaborated,

Well, they have excellent wonderings. And if we really hear what they're saying, and I know that we have an objective, and it's kind of in that science talk, how can you tweek that wondering? I mean, where are we going to take that wondering? How are we going to get that evidence? [teacher reflection on practice] (M1-07:02)

Margaret stated that the most important thing to her in the science classroom was that the children were learning. Not simply memorizing some facts or doing an activity, but truly being able to comprehend the science topics and concepts that were being introduced in the classroom. Going back to Margaret’s description of the hand-washing investigation that the children completed in her classroom supported her belief.

But then the idea that I've grown on is, you know, what are, what did they learn? This kid put, "If you put dirt on a piece of bread, you will get a lot of mold." Now, I wouldn't have thought that should be the answer, but that's what he learned. I thought that was pretty cool. And, let's see, this little girl I thought was cool, too. She said that "you should wash your hands to be healthy, and if you're healthy you feel good." Now, I didn't help them with these, that's what they drew... I mean, it came from our Science Talk, [science-specific learning strategy: science talk] we had a science talk and from that science talk then they went back and wrote this. And, I think what I've learned from inquiry is that letting the children come up with their own answers is pretty important, [student learning in science] and I thought that was pretty important. (M1-11:54)

Not only understanding her students’ science learning, but also being able to offer children the opportunity to encounter science in their everyday lives as part of their elementary school experiences was critical to Margaret as she told her science story. She felt that science was that
part of the school curriculum that was often over-looked, yet the one that was often the most
critical to helping children to enjoy what they were learning in school.

[The heart experiment] was one of the ways that one of the little boys that I dearly
love, that motivated him to read and write - science. I mean, science was, you
know, it wasn't reading, it wasn't math, it was science that did that. [motivation
toward science] And I just think, “How can we not put that in their lives?” (M1-
31:39)

In summary, like Julie, Margaret’s participation as a mentor teacher in this PDS program
advanced her science teaching practices to a level that is rarely seen in elementary classrooms.
She used a lens of evidence/explanation through her teaching and continued to question and
reflect upon her methods of teaching science on a regular basis. As evidenced both through her
wide array of PDS experiences as well as her descriptions of her own science teaching
experiences, her story clearly reflects one of a change toward more reform-oriented science
teaching practices.

5.2.4 Story of Practice – Two Years Later

Two years following her initial interview, Margaret described herself as still “learning
and growing” as a science educator. She continued to work closely with her teaching teammate,
Julie, on all of her science units, but she also talked more about working closely with her other
teammate, Kelly, as well. She had not taken any science-specific science courses or workshops
in those two years, but Margaret’s biggest change over the two years was that she, for the first
time in nine years, did not have an intern. Even though she didn’t have an intern, she continued
to work collaboratively within her grade level and reported on her growth by saying,

I think it’s the idea of being able to have a passion, as well as a collaboration, as
well as the affirmation not only from the students but from my colleagues
[teaching colleagues working together] that we are doing good [science]. (M2-
08:17)
Although nearing retirement, Margaret continued to try new practices in her science classroom. She described, in detail, a project on Field Guides and studying nature that she and her colleagues were “improving” by building in reform-oriented practices for the students. She continued to develop professionally and personally in her understanding of best practices for science in her classroom.

5.3 Participant 3: Greg’s Story of Practice, Story of Change

Greg has been teaching elementary school for twenty-one years. Since Greg was employed in one of the four original elementary schools that piloted PDS work, he has been involved as a mentor teacher for seven consecutive years since it’s inception into his school. At the time of his first interview, Greg taught second grade.

5.3.1 Introduction to the PDS

In 1998, Greg was transferred across town to a new elementary school and discovered that he would also be teaching at a different grade level. His new elementary school was going to be one of the first schools in the district to pilot the new PDS program. He was just moved from a first grade classroom to a second grade classroom and felt a bit apprehensive about the endeavor when he received a telephone call from a university faculty member who asked him if he would be willing to take an intern. The teacher whom Greg was replacing was slated to have an intern before she vacated her teaching position, and the university was desperate to find a new mentor for this intern. Greg described his initial reaction to be one of hesitation. Not only was he in a new school but also he was also in a new grade level trying to learn a new curriculum. In fact, Greg described his original thoughts of being a mentor teacher as focused on his belief that he wouldn’t have much to “teach” an intern. However, after some convincing, Greg decided to
go ahead and take the intern. He felt so overwhelmed at this point that he reported that he thought at least the extra help would be nice. Not really knowing where to begin or what to expect, Greg accepted the mentor position. Now, Greg has had an intern every year since then, and, as he stated, “I’ve had one [intern] every year and can’t imagine teaching second grade without having that extra person in there.” However, other than serving as a mentor teacher, Greg has not engaged in many other PDS activities over the course of the past seven years. He has spent time reading intern applications and interviewing interns as part of the PDS student selection process at least six times and has hosted an intern in a partner classroom twice. Unfortunately, Greg has not taken part in working with PDS planning teams or formally collaborating with university faculty, and has only once acknowledged formally engaging in teacher inquiry on his own for completion of his Master’s thesis. Additionally, rather than participating in science PDS professional development courses, he has contributed to one of the PDS courses for at least five years in leading a workshop on how puppetry can be used effectively in the classroom.

5.3.2 Science Teaching Prior to PDS Involvement

Greg began his career in teaching twenty-one years ago. He had always taught in the primary grades and currently teaches second grade. Greg was honest in his admittance that he always felt much more comfortable teaching literature and language arts than he has science. He believed that, as a primary teacher, that was where his strengths lay, even though, as Greg eagerly shared, growing up, his mother had been a high school science teacher. He had grown up around science and was comfortable with the content, but preferred teaching language arts curricula. When asked about how he used to teach science prior to his involvement with the PDS (if it was any different than how he currently taught) he stated that he had always been a “hands-
on” teacher. He believed that his job as a teacher was to provide his students, especially the younger children, with concrete opportunities to work with materials in order to help them learn.

In our informal conversation prior to sitting down for our formal interview, Greg referred to the ancient Chinese proverb, “I hear and I forget; I see and I remember; I do and I understand” as being a motto that guided him daily in the classroom.

For science, this proverb supported Greg’s belief that he was a teacher who focused on learning by doing – using hands-on activities to support the learning of science facts in his second grade classroom. Like many of his colleagues within the district at the time, this focus was very commonplace and a shared way of practicing science in the elementary classroom.

Additionally, he described his pre-PDS science classroom as one that followed closely the curriculum that was set forth by the district. This curriculum, as stated earlier, was based on science units that each teacher taught in his/her classroom during each nine-week quarter. Since Greg taught in the primary grades, these units were rotated through on a two-year basis. There were eight science units, four were taught each year over a two-year period before beginning the rotation again.

One example of a curricular unit that Greg described was the Prehistoric Life Unit that he taught in second grade. He reflected that before the PDS, he taught this unit in a very teacher-directed style. He said:

It [the unit] wasn’t even that [emphasis added] hands-on. We were studying each of the dinosaurs. I had put together little booklets with cut and paste pages. It was not really inquiry-based. [teacher-directed practice] (G1-21:10)

Greg stated that he followed these curricular units as best as he could, often times leaving out much of the information due to lack of time. He described the units as being fairly teacher-directed, with hands-on activities implemented every once and a while, but the main focus as
being memorization and recall. He rarely used the hands-on activities in his primary classroom due to lack of time for preparation or participation. Greg reflected that he felt at that time that his students were adequately learning in science through the use of literature and sporadic hands-on activities in his classroom because they could recall facts about such things as dinosaurs, and therefore he never really considered making changes to the district curriculum before his involvement in PDS.

5.3.3 Science Teaching Throughout PDS Involvement

As a result of his involvement as a PDS mentor teacher, Greg stated that he has made a few minor changes in the practices in his second grade science classroom. As he described his science classroom for the researcher, Greg illustrated his teaching role as one of “helper”. He explained that the science portion of his curriculum was one that he “turned over” to his pre-service intern near the very beginning of each school year. Although he discussed the minor changes or modifications that have been implemented in his classroom, he felt that he could not always accept the responsibility for the ideas behind those changes. His intern was given the opportunity to be the lead teacher from early in the school year, and Greg provided assistance as needed throughout the science lesson. He did not teach the science lessons himself, but acted more as a mentor, allowing his intern to implement strategies from his/her science methods class.

I’d say probably more times than not I encourage my intern [influence of intern on practice], well, and part of it has to do with, the intern takes science on pretty soon usually, by November and so I'm not the one doing a lot of the science teaching it's the intern, but I always encourage my intern to feel free to try whatever they want to. (G1-12:53)

Therefore, when Greg was asked to describe a typical science lesson in his current classroom, he used descriptors such as “engaged” and “discovering”. Following the model of science teaching used by his student intern, the children were reportedly more active and excited about science.
...just the fresh ideas and the excitement that an intern, someone at the beginning of their teaching career brings. It really does rub off when you're around someone like that - when you've taught twenty-two years like I have, you know, sometimes you feel like "Oh, how many more years can I do this?" But being around someone who's eager and like I said, I get lots of good ideas from the interns. [influence of intern on practice] (G1-27:15)

Greg was encouraged by the many creative and engaging activities planned and implemented by his interns and stated that if he was to be the lead teacher instead of giving that responsibility to his intern, that he would be sure to implement many of these new ideas and models. He elaborated,

...then I make notes, you know when they do particularly stellar lessons, I'll say "Can I have copy of that for my files?" and so I've really built up a lot of really good hands-on science-type lessons thanks to the interns, but I've never actually done a lot of them myself because mainly because I've had an intern every year and they, like I said, pick up science pretty quickly and now, I'll assist them as an aide, you know, if they need my help. (G1-15:03)

Although Greg was not actually taking on the lead role of teaching science, he did describe his science teaching practices as being very different than they were prior to having an intern.

Well, it's definitely a lot more hands-on science, and it's inquiry-based a lot more than the, some of our units haven't been revised for years...and the ideas my interns bring to my classroom from their science courses compliment our curriculum and enrich it. I get good ideas, too... and, well I think that they certainly learn a lot more with anything that they are actually doing [emphasis added]. [student learning in science] (G1-22:13)

The children participated in more hands-on activities and were encouraged to think about their answers more often than they were previously. Greg reported that he believed that his students learned more in science as a result of these inquiry-based science teaching practices. In fact, Greg also stated that his science lessons usually took a lot more time to teach or complete because of the modifications in practice. He felt that he was heading down the right path toward teaching inquiry-based science. He also believed that the PDS connection has influenced his students’ learning in science.
I think the biggest area of influence has been the benefit to the children of having a second teacher in the class who brings fresh ideas and enthusiasm. (G1-27:15)

Greg and his interns tried several science strategies in the classroom over the years. They implemented new technology such as heart monitors and sound probes and have tried using KLEW charts instead of KWl charts in science, as modeled in the interns’ science methods classes. As a result, Greg felt that not only were the children learning “good” science, but also they were also able to meet the science standards using inquiry techniques, which was of particular importance to him.

Well he [the intern] worked out something with the kids where he had magnet stations around the room and the magnet was from the ground up with a string and another magnet and it was holding it in place and there was a field in between and the kids did experiments trying to see how far away the magnet could be without the field losing it's power and that kind of thing [inquiry activity]… I would say it's all inquiry-based…. And I can tell you that my intern this year was wonderful because he basically took a look at our science standards and for half of the standards, because he's really science-minded, he came up with his own experiments. He went, he sort of deviated from the State College manuals and I just let him sort of take off with it and he did some really interesting things with magnets and magnetic fields that weren't in our unit and yet, he was able to check-off the science standards [conflict with former practice]. (G1-13:28)

As he described the investigations in which his students participated, Greg remained focused on making sure that his students were still learning the concepts that were outlined in the district science standards. This was of particular importance to him because although he allowed his interns to teach in this manner, he often felt as though this type of science teaching was not considered “tried and true” as of yet. Considering these changes that Greg described in his science teaching practices, he described his struggle with keeping up with other colleagues when he revealed that he did not always feel so comfortable teaching science using reform-oriented methods. However, the support that he reported from his interns and from within the PDS community has kept him from reverting to his former teaching practices. He said,
Greg’s personal growth in changing his science teaching practices has continued slowly, quite possibly because of his feelings of intimidation toward science. However, his change continues to move steadily, although slowly, since his introduction to the PDS seven years ago. His science teaching practices may not currently reflect the cutting edge of science reform, but it is important and critical to note that Greg has made changes in his thinking and practice toward reform-oriented science over these seven years. He has never stifled his interns from trying out new strategies in his science classroom and has used these opportunities to reflect on his own beliefs about how science should be taught in the primary classroom.

5.3.4 Story of Practice – Two Years Later

Two years following his initial interview, Greg had not made many changes in his science teaching practice. He continued to work with interns during those two years, but had not participated in any professional development workshops or courses in that time period. He was able to speak more directly and in a slightly more sophisticated manner about strategies that he observed his intern using in science such as the KLEW chart and science talk, however, he continued to encourage his interns to lead most of the science teaching. Interpreting Greg’s story was a challenge in that it seemed as though his reports were based on the experiences of watching others rather than with his own experiences. Although he watched and assisted his interns in order to become more sophisticated in his understanding of practice, unfortunately, his lack of confidence to take a teaching leadership role in the science classroom has held him back from implementing more reform-oriented science teaching practices.
5.4 Participant 4: Elizabeth’s Story of Practice, Story of Change

At the time of initial data collection, Elizabeth was a fourteen-year teaching veteran. She had been teaching kindergarten for most of her career and had worked with five interns over those fourteen years. She had not engaged in any science-specific professional development during her work as a mentor teachers, however, she did spend some time participating in a teacher inquiry course and a mentor teacher support course.

5.4.1 Introduction to the PDS

Elizabeth got her start in the PDS by watching her colleagues. She was an elementary school teacher for a few years after she graduated from college, but took nearly ten years off while she was raising her children. When she came back to teaching nine years ago, things in the district were similar to when she had left. However, approximately two years later, she began hearing about this new PDS partnership. The elementary school where she was teaching was one of the original four schools to be a part of the program.

Elizabeth stated that the PDS program sounded like something that she would be interested in, however, she reported that she didn’t feel as if she had been back in the classroom long enough to be a strong, effective mentor teacher. So, she waited another two years. During this time, Elizabeth took some PDS courses and talked with her colleagues about the program. She was amazed at how her colleagues seemed to enjoy working with their interns, so after her fourth year back in the classroom, she signed up to become a mentor teacher. Needless to say, she has had an intern in her classroom every year since then.

Elizabeth felt for many years that she needed to be “ready” to be a mentor teacher. What this meant to her was that she needed to feel comfortable in her kindergarten classroom both with
the curriculum and with her classroom management before she thought that she would be ready to mentor a young professional. However, as Elizabeth noted so clearly:

I really feel like I have learned so much about my own practice from having an intern. [influence of intern on practice] It's just so interesting because when you have to teach somebody something, you really have to think about what it is you do and why… and so each intern has taught me something about myself and made a change for me… they have really been how I learned at all about this because I've not taken any like PDS science courses yet so any of the little bit of learning that I've done about science and how to teach science differently has really come from an intern and their projects that they do and when they're teaching science, they're trying to incorporate all of that. (E1-30:19)

Elizabeth’s experience as a mentor teacher has afforded her the opportunity to engage in a different type of learning as a result of working with a PDS intern. These interns have influenced her practice and allowed her the opportunity to develop her science teaching practices.

5.4.2 Science Teaching Prior to PDS Involvement

Elizabeth had been teaching kindergarten for nine years. During this time, she recognized the importance of teaching science to young children. She felt that reading, writing and math were essential to the growth and development of young children, but science created the wonder in each child that made each thing that was done in the classroom more exciting. For this reason, she always taught science through discovery. She said,

Well, I think in the past I think I taught more, I mean I've always done science with as much exploration [exploration-based science] as I can, so if I'm studying insects, I bring insects from outside like we, every fall we watch monarchs turn into butterflies or monarch caterpillars turn in to butterflies and I usually have a praying mantis and a couple times we've mated praying mantis', not that the kids see because they kill the males…and then getting the egg sack and spraying/catching them which is what we ended up doing last year, you know so that's always been something that I've done. (E1-28:12)

In kindergarten, Elizabeth felt as though her children’s learning was very exploration-based in science. As she described, Elizabeth always brought monarch caterpillars into the classroom to share with the children and encouraged them to watch the metamorphosis from
caterpillar to butterfly. She also would bring in a pair of praying mantids at times to mate them and the following spring the children would watch tiny baby mantids hatch from the egg sacs that they had collected. Any type of hands-on opportunity that Elizabeth could offer her students she felt was a chance for them to experience the world through their senses and to enjoy what they were doing. The children learned by watching and doing and were afforded opportunities to talk about what they had learned on a regular basis.

Elizabeth’s science teaching practices prior to her involvement in the PDS fell into the category of receiving more direction from the teacher or the material presented. Often, the science topics or concepts that were explored were the same each year, with children being given the opportunity to observe and learn. Students may have sometimes asked questions, but were rarely guided through the process of how to investigate those questions. Much of the learning in Elizabeth’s kindergarten classroom was dictated by Elizabeth, although she provided the children with opportunities to explore in science and also provided numerous hands-on activities to support their learning experiences. Making connections through crafts and other projects was a large part of Elizabeth’s teaching repertoire. She felt that her children were learning interesting things in science and having a good time while they were doing it. Elizabeth was satisfied with her children’s learning and with her teaching. She focused on providing activities that helped her children come to a solution rather than talking about the solution and then giving them an experience that helped to reinforce it.

5.4.3 Science Teaching Throughout PDS Involvement

When first asked about how her teaching had changed as a result of her PDS involvement, Elizabeth quickly replied, “I use inquiry in science much more than I did before.” Making connections and asking the children to think through everything and to figure it out has allowed
Elizabeth to use “inquiry” in nearly every aspect of her teaching. She reported that it became a way of thinking for her. For her, simply taking a walk outside by herself became a learning experience. She could no longer walk past an interesting insect without becoming curious and bringing it into her classroom to have the students determine what it was and what it was doing. It was a whole way of thinking that was new for her – her entire thought processes changed. She described:

Because the PDS encourages reflection in classes, [support for growth through PDS involvement] I have had lots of opportunity to reflect on my practice [teacher reflection on practice] and make changes to try to improve my practice. Having an intern is a lot of work, but is really worth the effort for the growth it encourages in me and the benefits it gives to the children. (E1-21:40)

Elizabeth did appropriate things with her children in science before PDS and provided them with what she described as fun and meaningful explorations. She believed that her science teaching practices provided enough learning structure until she became a mentor teacher and began working with her interns in science. The interns began teaching science a bit differently than she was used to teaching it. Each intern she had involved the use of activities and exploration to guide science teaching, however, with a new, more in-depth strategy tied to the learning. The children were being asked to develop their own questions, to explain their thinking, and to expand their understanding of a science concept in ways that Elizabeth had not tried before. Through observing her interns work on their science lessons and projects during the fall semester for their science methods course, Elizabeth learned how to enhance her own teaching and the learning of her children. As she explained, her interns sparked her change:

The idea came first, of course, and then the practice did change. It didn't change right away in science. I think the first year I kind of watched you know and thought about it and then and then the next year spent time thinking about how could I change that to be more of an investigation and more thinking it through than just telling information or doing the facts… And I really feel like, I have learned so much about my own practice from having an intern. [influence of
As a result of her role as mentor, Elizabeth reflected on her own practice. She reported focusing carefully on finding out what her students already knew about a topic before she taught it. This was a practice that she did not use very often prior to her PDS involvement. Although her pre-PDS science teaching practice focused on exploration, Elizabeth rarely took the opportunity to discuss with her students what they may have already known about the subject. Her lessons were still very teacher-directed, guiding the students through series of questions or activities. Elizabeth changed this practice one hundred and eighty degrees. For example, she explained to the researcher that her focus in science now was more on finding out what her students already knew about a topic before they began a lesson instead of just having an experience:

I think having the kids really thinking through on their own, you know, and lots of times that’s the first step that I do. So I'll just say, "What do you think about this? Or what do you think might be happening?" And if it was a concept that was really difficult, I probably wouldn't have asked the kids that, but it's really interesting to see what they're thinking, and some, that kind of gives you a point to start with and that's what I think has been a very important thing for me as opposed to just starting in with then, you know just starting to read stories or whatever. It's just to say, what do you guys think about how this works? [focus on questioning] (E1-40:04)

This focus on empowering the children in their own learning experiences was a big step for Elizabeth toward reform-oriented practices and providing her students with ownership in their learning experiences. Questioning became one of the areas where Elizabeth felt that she made the biggest change. She asked more questions that helped to guide the children in their learning, to explore their own understanding, instead of always asking questions that focused on the right answer.
The one thing you can do is continue to ask questions that will lead them, to guide them to the answer so if they're not knowing the answer then you present them with questions that might guide them a little deeper. So that maybe through the guided questions, then you'd be able to get the science, for them to find the answer, you know. [focus on questioning] (E1-33:36)

Elizabeth changed the types of questions she asked, also. Although she still asked what questions, she expanded her questions to include how and why questions as well. No longer did she teach science simply as a set of facts or as exploration without developing questioning and investigative techniques. An example of how Elizabeth changed the types of questions that she asked her students follows:

You know, now I will do that, I mean, I might have said, "What do you know about insects?" because I would figure that they would know something about insects, but I might not have asked, "Well, how do you think day and night, why do you think there's day and night?" or something more complex kind of idea. (E1-41:28)

As she changed her questioning techniques, she also saw changes in what she believed about her younger students and the importance of understanding their prior knowledge. Elizabeth’s reflection on her practice allowed her to gain a better understanding of what she believed about her students. She reported:

You know, like if I really didn't think that the kids would, for example day and night. I don't think that I would have expected any kids to know, or maybe one or two to know, about what was day or night, so I wouldn't even bother asking that question. You know, because I'd think, "Well, they don't know, so why go there?" But now I do more, more topics. I will just see, just to kind of get a feeling for what is it that they do [emphasis added] think. Because I knew they didn't necessarily know, but I didn't know what they did [emphasis added] think. [teacher reflection on practice] (E1-41:28)

Not only did Elizabeth report a change in questioning and reflection on her practice, but she also reported a change in the use of technology in her science classroom. Elizabeth was still a bit unsure of how to best use technology to enhance her students’ learning in science. She described that her growth in the use of technology has improved in that she had a better
understanding of how to use the technology, but she still struggled with how to best implement technology tools into her lessons. As she described,

The one thing we did do in the space unit this year was we were talking about day and night and about how you know how that works with earth and the seasons and all that. And there was a really nice video that we were able to watch from that, so we [my intern and I] were able to put that on then the kids could come and watch. [use of technology] You know, a little bit better than, you know, we do, we act it out and we do all different things, so that's kind of how I've used the technology not so much with [emphasis added] the kids but for [emphasis added] the kids. (E1-12:03)

With her interns support, her use of technology changed from an inactive to an active role as she became more confident in trying new things. Elizabeth believed that her focus on doing science with her young learners was the biggest contributor to the learning process. She described the importance of incorporating hands-on activities into every science lesson. However, her reported use of hands-on activities was much more focused on reinforcing the science concepts than on creating a science craft as it was in her previous descriptions. The following quote described a change that she made in a lesson on insects to reflect inquiry-based science teaching practices:

Anytime that we can do [emphasis added] things, like we have plant units and we talk about, we grow plants and then make observations about the plants to try to figure out...so I think that's an area I still have a lot of work to do, [teacher reflection on practice] but I think that as much as possible you know we try to help the kids kind of gain information by discovering themselves. And the other thing I try to do, this is not exactly the same although for kindergarten I try to incorporate hands-on activities to kind of reinforce the things we're learning, so if they're learning about ladybugs or insects or something like that then I might have a craft where we have two sets of wings, like a tissue paper wings and a paper wing which would be more like leathery wings to show that there's four wings. We've already talked about that, but again, it's not exactly as much of the discovery. [lesson modification toward reform] (E1-28:41)

She went on in her description of this modification to her science teaching practices to explain how she had learned the importance in using activities as a method to build evidence to assist in children’s understanding of a concept (explanation building) rather than as craft follow-ups.
But I think the idea of really trying to look carefully at how the kids can do [emphasis added] activities so that it helps lead them to the solution, rather than talking about the solution and then giving them an experience that helps reinforce it. You know, for them to actually figure out why they think this is happening. [building explanations from evidence] (E1-28:41)

In addition to her personal changes in practice, Elizabeth’s belief in the changes that have taken place in the district as a result of their collaboration with the university through the PDS partnership affected her classroom environment greatly. She discussed the use of investigations in her science classroom as a different approach than just exploration of a concept. Just this subtle change in the use of the word investigation rather than observation implies a more in-depth approach to teaching science. She said,

I think the way that we teach science now and teaching math where we think it through and you have to think, if something's not working, why isn't it working? And that's the thing. I mean, I don't think I ever would have had that strategy in a way. I think in some ways the science, the way we teach science now with having the kids thinking through everything and trying to figure things out is so beneficial. But I think a lot of it, and I don't think I would have thought of that until just now, [personal reflection] but I think a lot of it is because of all the way we're teaching math now is very investigating, the way we're teaching science is very much investigating, and it allows you to think through things in a different way. So I really do think that in some ways my whole thought processes have changed. (E1-21:40)

Investigation implies a learning process that implements many skills necessary to answer a question, whereas observation does not imply involvement on many levels. As Elizabeth described, her thought processes have changed and as a result, her science teaching practices changed as well.

Finally, one of the most interesting things that Elizabeth shared was her vision for her future science classroom. As a result of her involvement in the PDS, she now questioned her science teaching practices much more than she did previously and was interested in learning how to make more of her science units more inquiry-based. For example, in her interview, she
expressed her dissatisfaction with one of the kindergarten units that she felt was not appropriate as written to encourage inquiry at the kindergarten level. She described,

   Like 'space'. We study space as one of our science units and while there are some things you can do, there's just a lot of facts about space. [dissatisfaction] So that's something that I'd like to think about how we might actually be able to change some of those things. (E1-28:41)

Many of the other participants in the study were simply focused on explaining the changes that they have made in their science teaching practices to date. Elizabeth, on the other hand, wanted to express that she was still in the learning phases and looked forward to the changes that she would make in the future. As such, Elizabeth’s story of practice can best be summarized using her own words:

   Well, I think that that did [emphasis added] happen for me in that when I started thinking about science in a different way, then I started teaching science in a different way. (E1-48:57)

As a result of the influences of her interns, her students, and her PDS colleagues, Elizabeth reflected on her teaching practice in science and made changes that led her down a path toward more inquiry-based science teaching. Although her strategies were novice and often reflected generic inquiry skills, her self-report revealed effective development toward the use of reform-oriented methods in her classroom.

5.4.4 Story of Practice – Two Years Later

   Elizabeth was unable to participate in part two of this study due to a family situation.

5.5 Participant 5: Bobbie’s Story of Practice, Story of Change

   At the time of our initial interview, Bobbie had been teaching school for thirty-one years. She was a kindergarten teacher and had spent her entire career in the primary grades. She was active in attending the yearly PDS Inquiry Conference and completed one inquiry project herself.
5.5.1 Introduction to the PDS

Bobbie came into the PDS program upon its initial inception as a pilot program as her school was the first school in the district to participate in the pre-service intern program. She was asked by one of the university faculty members as well as by her administrator to become a mentor teacher and she explained that she accepted at their request, albeit reluctantly. She entered the program as a skeptic. Her husband was a university professor and Bobbie had experienced past relationships with the university where many ideas were handed down to the teachers without any discussion. At first, she thought that this, too, would be a passing program, just another experiment done to the teachers at the hands of the university.

Bobbie had had student teachers in years past through the traditional student teaching program, so she thought that this new program might be a bit of a challenge for her. However, it was a challenge that, as time passed, she was felt was more of a true partnership than she had experienced with the university in the past.

At the time of her initial interview, Bobbie had worked with seven PDS interns in her classroom and she continued to have interns on a consistent basis. Besides having an intern for many years, Bobbie served for at least five years on PDS planning teams (specifically the Classroom Learning Environment team). In addition to her five years of planning team service, Bobbie attended the PDS Inquiry Conference every spring and contributed to other research within the PDS two other times. Also, Bobbie attended two national PDS conferences and each year she assisted in the reading of intern applications and contributed her time to the intern interview process.

Although her service within the PDS collaboration was vast, Bobbie did not have any professional development that was specific to science. The only experiences that she had that
contributed to her own growth and development in the science classroom were either through working with her intern or at district in-service workshops on science topics.

Having come into the program as a skeptic, she reported that this partnership exceeded her expectations as far as commitment to classroom teachers was concerned. An example that she provided to support this change was when she said:

But they've tried just about everything and they listen to everything that the teachers say...So, there is an obvious continued collaboration...But there's always this work between everyone and you always, you don't feel like there's any closed door sessions, in anything that's important and that you're working with in that it's just a sense of trust. [collaboration; mutual respect] (B1-37:07)

This continued sense of trust was an important structure in affecting change in Bobbie’s science teaching practices.

5.5.2 Science Teaching Prior to PDS Involvement

Prior to becoming a PDS mentor teacher, Bobbie typically taught science following the examples of many of her other colleagues in the district. She used numerous “cute” hands-on activities in conjunction with her science lessons to support the learning of scientific facts. She said,

It's, how it used to be, "Oh, this is such a cute idea and this activity is going to be so much fun"...and you want it to be enjoyable for the kids. [activity-based science] (B1-27:26)

These activities were used as extensions of the learning, and Bobbie felt that they helped to make science more fun for the children. One specific example that supported her description of this method of teaching science was Bobbie’s explanation of the magnet unit that she used to teach prior to becoming a PDS mentor teacher.

We have specific activities that we would have the kids do [in the magnet unit]. And typically what I would do prior to the letting the children discover and see where their interest is, we would sit down and every day I [teacher-directed science] would explain to the kids, "OK, now this is the center that we are going
to do and we're going to see if the magnet will pull things out of water - we're going to see if it will pull things out of sand - this is magnetic and this is magnetic.” And I’d have like five or six magnet centers [activity-based science]. (B1-13:48)

The use of science centers in her kindergarten classroom allowed for science activities to take place in a structured environment. These science centers involved craft-like activities or basic observation or exploration of science phenomena. However, outcomes of the activities were almost always the same and rarely strayed from what Bobbie expected.

Like so many of her colleagues at the time, Bobbie reported that she felt hands-on science was the best way to help children learn a science concept. Bobbie described her belief that if the children were having fun while they were doing science then she believed that the children were also learning the science concept. However, also like many of her colleagues who had just become PDS mentor teachers, her understanding of how science could, or should, be taught in the classroom was about to change.

5.5.3 Science Teaching Throughout PDS Involvement

Knowing that Bobbie’s typical science lesson prior to becoming a PDS mentor teacher was very hands-on, yet teacher-directed, was an interesting point to begin describing her science teaching practices following her PDS involvement. For Bobbie, having an intern in the classroom challenged her to think about science in a different way. She explained that because her interns “view science from that perspective [inquiry perspective], that brought it into my classroom through the interns.” She elaborated on this by stating:

I've found that inquiry's just a little more challenging in kindergarten and I've appreciated the interns every year working on their science units that we have established and trying to make it more inquiry-based [influence of intern] and so that has helped me to not be so quick with activities that have such a start point and an end point and to be able to take it where the children lead. So, I think that's probably the most important aspect as far as the science that I really ever had considered before. And I've taught thirty-three, something like that, years,
and so I've been around forever! It's so nice to have interns every year that always, they always have such wonderful ideas, to even help old teachers, you know? [collaboration; support] (B1-08:27)

When asked about student learning science, Bobbie reported that she always believed that young children especially needed to explore with materials and to be kept busy in the classroom. She described the change in her practice in the following manner:

How it [science teaching] used to be, "Oh, this is such a cute idea and this activity is going to be so much fun" and you want it to be enjoyable for the kids, but now it's deeper than that. You know, what really are the children getting at? What is this telling us about how the children are responding to whatever science unit that we're doing? [teacher reflection on practice] And I think that has evolved as it's become more commonplace to be thinking in a more inquiry way. (B1-27:26)

So, Bobbie’s first intern started her down a path of thinking differently about how she taught science. Whereas her teaching prior to PDS involvement was more teacher-directed and focused on the completion of teacher-designed projects or activities, she now described her view as one of “teaching science as inquiry” and being focused on the experiences that each child took away from the investigation. She described her change in the following manner:

Yeah, more hands-on, and not so much "you do this first, you do this second and this is what you're supposed to be doing at the end"… Getting the interns started me thinking from more of an inquiry slant as opposed to everything laid out. [influence of intern on practice] So I would say, just from the very beginning, it was it matched with the way I feel about children and it perhaps wasn't the most efficient way, as far as getting all the things ready for the next 2 weeks of this unit and saying "On this day we'll do this" and it would be pretty scripted that way. It was, "Well, let's just see where this takes us." [lesson modification toward reform] (B1-26:52)

Although Bobbie expressed the difficulty in moving away from the safety of her pre-planned science lessons, she also described the benefits of turning the learning into something that each child took ownership in each day. Taking an inquiry orientation toward her science teaching gave her more flexibility in meeting the needs of her students. She described an example of how
seemingly simple the modifications she made to her lessons allowed her students to have more meaningful learning experiences that reflected the inquiry process.

It's interesting how you can put the same things in front of children and it's just not so directive and just not scripted. So what you have to do first and then do this and this. You know, here's a fishbowl of water and here's a tub of sand and here's just some things here and we talk about magnets and as it evolves and we sit down and, "What did you find out about magnets today?" and "What did you do at your center that you worked at today?" [lesson modification toward reform] [questioning] So, it's very important to me that children have choices and this has given them even more controlled choice time because still they're working with the same materials, but it's them discovering… you have more flexibility in meeting each of the children's needs through an inquiry-based science [curriculum], too. (B1-13:48)

Making these changes to her practice was not easy for Bobbie. She described how the challenges of time and flexibility sometimes made it more difficult to follow the path of inquiry in science.

And so looking at that in the science aspect…just having time to make sure all of the supplies and all of the materials are there and ready for the kids to experiment with has probably been the biggest challenge in terms of making sure that you're trying to have it be as inquiry-based as possible. [challenge to change; time] (B1-19:09)

However, she reported that she realized her view of time as a constraint was the wrong view to take when it came to teaching science. Since science in her kindergarten classroom was focused on doing and exploring, Bobbie stated that it was important to plan for and allow the extra time that it almost always took to both talk to the children and allow time to experience the science. She reported on how she met this challenge head-on:

Because they [kindergarteners] are just beginning, and kindergarteners generally speaking always have questions, will always ask, you know they haven't put that barrier up to, "Oh yeah, let's just get this done" because they have such natural inquisitive minds and they're so interested in everything they do, so I can't really say that I feel that it's been so obvious the difference. I feel like the difference has been primarily from my standpoint in what I offer the children…[teacher reflection on practice] and its ok [to take the time to ask], “Is there any other way that we can figure this out?” There's always that question now where it was ok,
but you didn't want to pull those other kinds of paths that kids might take. You know, some will say, "Oh I just figured it out" and [the teacher says] "Oh, you have to tell us what your brain was thinking, because what you were thinking might let somebody else have a new way of thinking about it, too." So that wasn't as prevalent before [as it is now] - well, is there another way? How else could we do that? (B1-26:21)

Bobbie changed the focus of her science teaching from activity-based stations to questioning in order to support deeper understanding of science concepts by her children. Although her story did not reflect the use of many science-specific inquiry strategies, she did report using general inquiry strategies like in-depth questioning and increased focus on student discourse to support science learning.

In summary, through her story of practice, Bobbie experienced professional growth in her science teaching practices. She took more of an inquiry orientation toward everything that she did in her kindergarten classroom as a result of her involvement in PDS, including in the way that she taught science. Her main focus in her science teaching shifted as a result of working with an intern in her classroom. As a direct result of her involvement in the PDS collaborative, Bobbie has moved from teaching hands-on activities for the purpose of learning science facts, to using hands-on activities as a way to help her students explore science concepts and begin to ask questions about what they are learning in science.

5.5.4 Story of Practice – Two Years Later

Bobbie’s story of practice two years following her initial interview was very similar to Greg’s story. Bobbie continued to work with interns during those two years, but had not participated in any professional development workshops or courses in that time period. She did at times speak more directly and in a slightly more sophisticated manner about science-specific strategies that she observed her intern using in science, however her reported teaching practices remained very similar to the practices that she described two years earlier.
5.6 Participant 6: Marla’s Story of Practice, Story of Change

At the time of initial data collection, Marla had been teaching at the elementary level for thirty-three years. During those years, she taught in several grade levels as well as acting as a learning support teacher. During her five years as a mentor teacher, she taught fifth grade.

5.6.1 Introduction to the PDS

Much like Bobbie, Marla came to the PDS in the beginning years as a skeptic. She, too, had been teaching in the district for nearly twenty years when the university first approached her school about this program and as she reported, she was leery of the proposition. She had experienced one program after another being tried out through university projects, and was therefore doubtful that this program would provide the support and long-term collaboration that was necessary. She expressed her skepticism by saying,

I came to PDS kind of through the skeptic route in that PDS came to [my elementary school] and I decided that I was going to watch just for a little bit. So, I did. I watched for a year or so and then I had an administrator that I just adored and she tried the old bribery route. You know, "Try this!" And even then, before I tried it, I really had to call John [university faculty member] and we talked through a couple of issues. [community of support] (Ma1-03:00)

Marla hesitantly decided to become a mentor to an intern starting the following year. She continued as a mentor for three years before she was convinced that the PDS collaboration was sincere and therefore wanted the chance to learn more and do more as both a mentor teacher and a teacher leader. And so, she left the classroom to become a Professional Development Associate for two years. She described how this experience shaped her as a teacher and mentor.

Oh, that was huge [my experience as a Professional Development Associate]. And that opportunity to still be involved with children in education at different levels and to become an observer again was just an awful like a free college education at a different level. The opportunity to observe teachers, the opportunity to observe interns and students, the opportunity to really reflect upon
your own practice and beliefs, oh my! [teacher reflection on practice] And then, the difference in discussion that as a PDA you actually really think and talk about the theory behind things, pedagogy, but teachers are so immersed in the minutia of the day that you don't often have that opportunity to step back and view the whole. [community of support; mutual respect] (Ma1-37:21)

After entering the program as one of its biggest skeptics, Marla became one of its staunchest supporters. As she stated, “So I came to PDS as a skeptic at first and had a really great experience with my first intern and then of course, (I was) hooked!”

5.6.2 Science Teaching Prior to PDS Involvement

Marla’s description of her science teaching practices prior to her PDS involvement was a story similar to several other participants in the study. Marla used the district science curriculum and followed it to the letter. She described her curriculum as being in a “box”. Everything she needed to teach her science lessons came in a box. She used the supplies to teach hands-on science activities, but that was all she got, just supplies. She described the experience as being very self-guided as she received little to no professional development support from the district, and at times she did not even necessarily receive all of the materials in the “science box” (i.e. dead batteries in the electricity box). She described her frustration with the curriculum and lack of support needed to be an effective science teacher as follows:

In the past, science had been, you know, we had science units very much like we had social studies units. So, in our unit planning we would say, "Oh, all right, we're working on medieval as our social studies theme and simple machines as our science theme. And everyone would bring their science unit that had been written by a group of teachers and our curriculum specialist and we'd kind of go through the main topics and everything was pretty much written down for you. Here's lesson number one or concept number one and here are some ideas to teach concept number one and here's concept number two and again here are some things or some ideas to teach concept number two. [teacher-directed science] [activity-based lessons] And the district really had tried to "box" science so that if you were teaching science, say simple machines, a box would arrive from the central office and everything you needed was kind of in the box. So, [when I was] teaching concept number one, I can go to the box and pull out the materials. And frequently the materials weren't there which was frustrating or frequently if
you were teaching energy and electricity and you go to the box and the box is supposed to have batteries and the batteries are dead. [dissatisfaction] (Ma1-02:31)

Not only was Marla frustrated, she was also dissatisfied with the science curriculum. When Marla was finished with each box, she sent it back to the curriculum office and got a new science box. She followed the unit guidelines and felt as though her science teaching was minimally effective. She liked that there were often several hands-on activities that accompanied each science unit, and that the children thought that these were often fun and enjoyable. She believed that teaching science in a traditional manner and enhancing it with hands-on activities was an appropriate teaching method as this was supported by her school district. This was how Marla taught science for nearly twenty years in her classroom.

5.6.3 Science Teaching Throughout PDS Involvement

Marla described her change in science teaching as something that happened almost immediately at the beginning of the first school year that she was a mentor teacher as a result of watching her intern teach. She said,

So, right away, in watching my very first intern teach science, you could see the difference. I mean you could see the inquiry approach, you could see the kids respond to that and that was really a noticeable difference to me. Right away it was like, "Cool, this is really neat." [influence of intern on practice] (Ma1-02:31)

She didn’t believe that this was coincidental, however. Marla stated that she had been frustrated with the science curriculum in the district for many years, but she felt that she neither had the time nor the background necessary to affect a change in her science teaching practices. She believed that children needed to complete hands-on activities in order to have more meaningful science experiences, but she felt ill prepared to provide these for the students unless the activities and supplies were in the curriculum science box.
I was really open to any kind of science change because science in the past had been so frustrating and you have, science has [emphasis added] to be hands-on. You know, I can't imagine trying to teach any science concepts without having kids actually doing something. [dissatisfaction] (Ma1-02:31)

Therefore, Marla began to make small changes to her practice. As a mentor teacher, she felt compelled to become a better science teacher so that she could model better practices for her interns. She reported that there was a growing need for self-reflection on practice in order to be more effective as a mentor.

Interns are constantly in the classroom and just spurring you on, too. Watching their teaching and trying to be the best that you can as a teacher educator, as a model for them, and you're working together and trying that. [teacher reflection on practice] (Ma1-12:21)

As she observed the science lessons that her interns taught, she described how she reflected on her own practice and made many mental changes to how she wanted to teach future science lessons of her own. She continued to report on the importance of self-reflection when she said,

I think there is that blending of the new ideas they are bringing in and your wanting to support them. So if they come in and say, "Gee, I really would like to try this kind of science lesson"… you definitely wanted to support them in that. So, there's that push, you know, to help as a mentor. But there's also kind of a responsibility that you wear as a mentor, that you take on as a mentor, to do the best that you can for that person and it's not that you wouldn't do the best that you can for the kids, but I think you're making every effort to, to demonstrate best practice teaching. (Ma1-14:43)

The importance of developing skills as both a mentor and a science teacher was essential to Marla in her challenge to change. She described how she tackled this challenge by reaching out to others within the PDS to assist her.

So, what would happen in the early years is we would go to unit planning, which the district provides for us as we change from unit to unit, and we would go, “You know…here's the science unit.” And then you'd get this, "Hmm, how are we going to do this? You know, how can we change this to be more inquiry-based?" And instead of one [emphasis added] person thinking how can we change this to be more inquiry-based, you had that collegial group. You had the like-minds, kind of thinking together. And that's a tremendous boost to change when you
have a group of people that are working together to make that change. 
[collaboration; teaching colleagues working together] (Ma1-02:31)

Working alongside teaching colleagues was critical to Marla’s change process. She described the importance of knowing that she was not alone on her journey as a factor that inspired her to continue to move forward toward developing a more inquiry-based focus on science teaching:

I think the other thing that really spurred me to change my science teaching was that everyone involved with the PDS was having a similar experience. [community of support; learning from one another]. Wow, I really like this new approach to science. (Ma1-02:31)

As Marla continued her journey toward reform-oriented teaching, she elaborated on how she made small changes at first. Changes that seemed simple, almost obvious, but that were critical to her understanding of teaching science using the lens of inquiry. She explained,

I think one of the easiest things that we now do is give the kids a little bit of free exploration time in the very beginning, which sounds so elementary, you know, why weren't we doing that before? Were we so bent on teaching some sort of concept that we forgot to really allow the kids time to explore? That free exploration is huge. [lesson modification toward reform] (Ma1-30:26)

As Marla made these small changes, she then noticed a change in the way that her students reacted to science lessons. She stated,

Oh, they loved it! Because they're the ones then sharing their discoveries with you and then there's this rich discussion [discourse] - "Well, I'm not sure that that's true" - and suddenly you have a “buy in” by more of the kids because it's not just, “Here is a paper, here are the steps for the experiment, tell me what you find and tell me by writing several sentences.” It's a discovery and everyone is involved and excited about it and they’re jumping out of their skin trying to tell you what they have found [student motivation/excitement toward science] and the evidence that they have that supports their findings [evidence building]. (Ma1-31:48:45)

Taking these small steps at first allowed Marla to experience and to reflect on the excitement and relevance that these changes were making for her children in her classroom. By allowing discourse to naturally develop among the children, Marla was able to recognize the importance
of talk in the classroom. This small change affected how her students acted and interacted in the classroom and sparked their interests in concepts.

As part of her learning process, Marla enrolled in several summer science workshops and other professional development opportunities in science with the intent to learn more in-depth about inquiry-based science teaching practices. Marla described, as part of her original skepticism, that the university often treated professional development as something that was done to teachers, not for them. However, with this PDS project, she felt that a true community of learners was being developed which allowed for her to enhance her teaching practices. She said,

The other piece that really helped me with science education and the inquiry stance into the realm of every day for the teachers in our district is the fact that there were summer courses that were offered that were tailored specifically to our needs. Think about your own education, and when was the last time a university said to you, "What would you like to learn?" Let's look at your own curriculum, let's look at your needs, how can we design a course that fits your needs?" You know, how many times has that happened to you? [community of support; PDS groups for supporting science] (Ma1-19:14)

After taking these summer courses, Marla described how her practice reflected an even more detailed lens of teaching science as inquiry. She reported on the use of science-specific learning strategies and the importance of gathering and interpreting evidence to support explanations.

I think the other thing that inquiry has taught me is, well, we had always done KWL charts, you know. I like the introduction of the "evidence" - support your reasoning. [science-specific learning strategy; KLEW chart]. That's, huge. Don't just tell me, “This is what I think.” Well, why? Supporting your reasoning is huge. [building explanations from evidence] And just the open-endedness of the inquiry-based science and the scaffolding, I mean, it just makes it so much more fun for everyone - for the kids, for the teacher. I think those are some of the key things. (Ma1-30:26)

By nature of the design of a science-specific learning strategy such as a KLEW chart, the focus of her teaching shifted toward building explanations from evidence. Professional development experiences afforded her the chance to learn more in-depth how to incorporate these strategies
more effectively in the classroom and as a result, she reported a gratifying sense of accomplishment in her science teaching practice.

Marla’s changed approach to teaching and learning in science came as a result of work with her interns, her colleagues, university faculty and her own students. She described the learning in her classroom now, as compared to prior to her PDS involvement, as being more genuine and more “real.”

I think it's learning that is so genuine that it just becomes part of who they are and the way they deal with information in the future. I mean, it's really neat when you have a kid say, "Well, what's the evidence, what's your evidence for that?" Oh, ok, that tells you that they understand the whole process. Which is really exciting!

In summary, Marla’s story of change toward more reform-oriented science teaching practices included the use of reform-oriented teaching methods that were reflective of her personal and professional development opportunities in science.

5.6.4 Story of Practice – Two Years Later

In speaking with Marla two years later, she did not have any changes to report. She continued to work as a learning support specialize and therefore was not in the position to be an active mentor teacher. She expressed her continued support of and participation in the program whenever appropriate and assistance to her colleagues involved on a daily basis.

5.7 Participant 7: Shelley’s Story of Practice, Story of Change

Shelley has been teaching school for nineteen years and at the time of her first interview taught in a mixed first/second grade classroom. Shelly was a self-described “mover and shaker.” She described herself as the kind of teacher who very rarely did things the same way twice in her
classroom. Even if she found a teaching method or particular activity that worked well in her classroom, she would still look for ways to enhance it. As an example, she reported:

I'm a teacher that every single year, I don't like to put my blinders on and do it the same way because I [emphasis added] get bored. I'm someone that likes change, and I think that's a personality thing, not a necessary definition of a teacher, it's just me. Personally, I like change. So, I'm not one that files away everything I've done from year to year so that I can pull it out and do it again...each year I've looked for, “Ok, what's going to be my challenge this year that will make me grow and will allow me to learn something new, and keep me fresh in what I'm doing?” (S1-03:23)

As Shelley described her practice to the researcher, it was apparent that she was looking to make a change, and her involvement with the PDS program afforded her the perfect opportunity to capitalize on that resourcefulness.

5.7.1 Introduction to the PDS

Shelley reported that she needed a challenge. She had been teaching for a little over ten years and was at the point in her career where she was ready to try some new things. She was involved at the very start of the PDS implementation into her elementary school seven years ago. She described her need to become involved by saying,

So, I needed a new challenge. I was trained in IST, so I could go through the different things that I decided were going to be my challenges. When PDS came along, I thought, well, ok, that's a good thing to do. (S1-03:23)

Shelley applied for and accepted a position of mentor teacher for a PDS intern and commenced her journey of learning. Shelley stated that she accepted the role of mentor teacher with ease. She had worked with traditional student teachers from the university a few times prior to trying the PDS experience and expressed joy in the opportunities she had to work with young people who were excited about teaching. Through these experiences, she had also worked with John, one of the university faculty members who was a lead member in the development of the PDS
program, and felt comfortable with the goals and ideals of the program because of the trust that she placed in him. She stated,

I always liked having 495 or student teachers. I love working with kids that age. I think it's really, they're at a super exciting point in their lives and it's fun to be around them, and it's fun to have their energy around and it's exciting to share that part of someone's life with them. And to help, to answer questions they may have and to learn from them and their thoughts. So, when PDS came along, that was the next exciting challenge. I've known John for a while, I knew him before that, just through, I've worked with his wife with some of these kids that I was talking about. And so that was, and I just really believed in what they were doing and in the education these kids were getting to be teachers and in the education I was getting by working with them and sharing and loved the interaction between the university staff and you know, it was very collaborative. I just really thought that was great. [collaboration]  (S1-03:23)

This collaboration, she felt, was personally gratifying. Shelley also stated that the opportunity to be a part of the PDS was more than just another personal challenge for her. It was also a way for her to make a difference in the teaching community. She valued the importance that was placed on building relationships among all involved in the education process.

And it was built on relationships, so it spends a lot of time building those relationships that I think are essential in situations like that. [collaboration] And, the idea, I'd had a lot of 495 students and student teachers that you know were prescribed a lesson they had to do and they came in and did it and the same old story that you know, it didn't fit with what we were doing, but that was ok. But this is so much better. (S1-03:23)

Therefore, Shelley was excited to be involved in the PDS because of the meaningful connections she felt that it could make between the university and the elementary schools.

5.7.2 Science Teaching Prior to PDS Involvement

Shelley belonged to that rare group of elementary teachers that actually liked science. Before she decided to become an elementary teacher, she started college as a science major.

I was always a science person, too. I actually started out in nuclear engineering, science and math. (S1-28:32)
However, after a few undergraduate semesters, Shelley decided to forego the science route and become an elementary school teacher. She began her career in the State College School District and has been teaching there for nineteen years. As she sat down with the researcher and explained her science classroom prior to her involvement with the PDS, her description contained hints of frustration and sometimes annoyance with the district curriculum. She said,

> Our science units are pitiful. The one that we have now was written in 1977? So, you can imagine, it's a useless document… other than the objectives. [dissatisfaction] You know, you want them to be able to talk about sinking and floating and why. But how you went about doing it, I mean, it's a book about that thick full of worksheets… [teacher-directed science] and with the “Seasons” unit, you know, “What would you wear? Cut out the clothes you would wear in winter weather and glue them on the little naked child.” You know, with something that was written in 1977, that's what you get. (S1-32:21)

Shelley explained that as a teacher who personally loved science, she was disheartened at the way she was being asked to teach science to young children. These methods were very teacher–directed and she felt often went directly against her training about early childhood learning in the classroom and the concept of child-centeredness. This caused her to question her own beliefs about how young children learn. She said,

> Before PDS, my thoughts about a child-centered classroom were very different than what I think now. My definition, my working definition in my mind was that a classroom where the children make choices, that you know, but somewhere in my mind, that was chaos. That if I provided, if I corrected someone, or provided a structured assignment then I was negating that child-centeredness… [teacher reflection on practice] (S1-08:34)

Her frustration with the district curriculum and the abstractness of the science concepts she was being asked to introduce at such a young age caused her to be dissatisfied with her teaching practice at times. She described her frustration as follows:

> I go back to dinosaurs because it's such a high interest unit for primary kids. And the teaching of fossils and dinosaurs is, like I said, it's incredibly abstract, it's a long, long time ago. They can't understand 5 years ago let alone millions and
millions of ago. But they can memorize their names and how to spell them. [traditional science teaching methods] (S1-16:57)

Therefore, prior to the years of her PDS involvement, her science teaching practices reflected methods that allowed her students to do things such as memorize dinosaur names and how to spell them. However, just because her students may have been successful in completing these tasks, she still did not feel as though they were learning as they should be in science. Being a person who liked science so much, having to work with children who were not excited about science caused much frustration for her. She described,

We could start a new unit and you know, a month into a unit, unless I sent a newsletter home, parents didn't have any idea what we were studying. [lack of excitement in science] (S1-08:34)

So, without having a structure from which to learn or build, Shelley spent much of the first decade of her teaching experiences trying to resolve issues in science and trying to find a method that suited both her beliefs about young learners and her knowledge of science content. She believed that her science teaching practices reflected efficient practices at that particular point in time to help her students gain an interest in science in their early years.

**5.7.3 Science Teaching Throughout PDS Involvement**

From her first experience as a mentor teacher, Shelley acknowledged the affect that her intern had on her teaching practice in science. She said,

Watching what the interns were learning and how they were bringing that into the classroom and how the students reacted to that. [influence of intern on practice] (S1-32:11)

Having an intern in her classroom and observing the pedagogical changes that they were implementing as a result of their methods course requirements provided insight to how science could and should be taught, according to Shelley. As a result of working with an intern in her
classroom, Shelley was forced to examine her science teaching practices in order to be an effective mentor. She said,

It was definitely an evolution of - what PDS has done for me, in science and in all areas, is, it has forced me to examine my belief system and why I believe the way I do because I need to help someone else understand why I'm doing things the way I'm doing, with an intern in my room. (S1-12:50)

As she shifted her focus from the learning of facts to the understanding of concepts, Shelley expressed that she found that her students not only seemed to learn more in science, but also enjoyed it much more, as well.

It just was a really powerful thing, not just to watch the interns, but to watch the students. And so, it really gets me thinking, you know, this works, this is good. They're excited about it, and they're learning, [excitement toward science] how can I change the next piece of this unit, or the next lesson that we typically did this way or that way? (S1-32:21)

Shelley reflected on how her views of a child-centered science classroom progressed as a result of her years of working in the PDS community.

I completely disagree with [what I used to believe about a child-centered classroom]. [personal reflection] Child-centeredness does not mean that I am out of control. I'm not a huge control freak, anyway, but it's quite the contrary. My job is to provide the control and the opportunities for the students within that umbrella, to make choices and to make discoveries, which is where the science piece falls easily into that thought. So, with my definition of a child-centered classroom having evolved, my definition of my science teaching evolved and it evolved into, “How can I provide the opportunities, the structure, the lessons?” It doesn't even mean I can't talk to them for twenty minutes before we start. That's ok it's still child-centered. But to do an experiment where I've provided the structure and they're either building the layers and adding the fossils in…but they're [emphasis added] seeing it, they're feeling it, they're discovering something abstract in a very concrete way. I find that a whole lot more of them have an understanding. [lesson modification toward reform] (S1-08:34)

Her science teaching practices were rooted in her beliefs about how best to create a child-centered, inquiry-based environment for her students. One way that she explained that she did
this was to provide experiences that were more authentic and not based on completing worksheets and memorizing facts. She described,

I never [emphasis added] run a worksheet anymore. I might run a lab sheet, but they have to make a prediction, and then, here is a writing piece. I don't think it's bad to write about science - scientists do that. But never, never, never, they might have a checklist, but it's more to force them to make a prediction and to explain why? There's always a why on it. Or to compare. You know, do you think this will sink or float? Yes or no. Why? What makes you think that? Now, what happened? Did it sink or float? What do you think? Why? [lesson modification toward reform] (S1-32:21)

Shelley credited improved questioning as one of the biggest factors of change in her science teaching. She believed in the importance of higher-order questioning and practiced it whenever possible, but now she focused on the children’s answers and their explanations for those answers. By watching her interns, she learned to ask many more why or how do you know that type questions in order to encourage her students to explain their thinking, now with a focus on using their prior knowledge or experiences as evidence to support their explanations. As evidence of this, she stated,

And how, the piece that the interns do that I think allowed me to change my practice was the pre-assessment, the post-assessment, what did you learn and how do you speak about it? That is very powerful because they're, because the kids are learning. [student learning in science] And we never test primary kids on how many facts do you remember about or anything like that, but just the way they could speak about what they were learning and the excitement that they brought to it. (S1-32:11)

As Shelley reported, she felt that it was critical to engage her students in discourse in the classroom in order to provide a safe environment where they felt encouraged to share their ideas as they engaged in the science talk. She said,

My students, who come up with the most bizarre ideas of how to solve a problem! I've learned through class meeting that you keep a stone face, you don't, every idea is a good one, you write them all down, you let them choose. I find sometimes that these ideas that they've come up with, that I would never in my wildest dreams, not only have thought of, but, ten years ago would never have
even let them try, sometimes work the best. [lesson modification toward reform] (S1-20:48)

As Shelley discussed the ways that she encouraged conversation in her classroom, she reflected on her use of such science-specific strategies to enhance her ability to teach science as inquiry in the classroom. One such strategy that she discussed was the use of “science talks” with her primary students and the importance of encouraging discourse among her children. She described,

I definitely [use] a science talk. And I will do them in different ways depending on what we've learned. I might have five different kids explain something to the whole group or I might say, turn to your neighbor and share your idea, or I might - it depends on what it is and how we do it. So they take different forms, but science doesn't end when the experiment is finished. [science-specific learning strategy; science talk] (S1-27:34)

Another science-specific strategy that Shelley tried to use in her classroom was the KLEW chart. Shelley admitted that at times she has struggled with the mechanics of using the chart as she still did not fully grasp the best way to help her students focus on the “evidence” portion of the chart. However, she tried it on several occasions and continued to learn how it could best serve her needs in the classroom.

What I find in my own personal teaching is that going back to that [KLEW] chart is a challenge for me. So, the chart itself is not as useful as the idea. Then having a conversation with someone else and explaining it. You know, “What did you learn?” is not where it ends. “How do you know?” - that is where it ends. But I don't do a very good job of compiling everything we learned about a particular topic at the end, and that's what I think the KLEW chart gives you is that compilation - that OK, now look at it all together – that, [emphasis added] I think, is powerful. [science-specific learning strategy; KLEW chart] (S1-26:13)

Using science-specific strategies in her classroom helped Shelly to change the focus of the learning to provide opportunities for students to construct explanations based on evidence. Even though she reported that she did not always utilize it to its full potential in the classroom, she understood the importance of its function. This is reflective of inquiry-based science teaching.
Another important change that Shelley expressed as a result of her involvement with the PDS was the influence of the way that she taught science also affected the way that she taught other subjects, particularly math and reading. An example of how she believed her reading teaching changed toward following an inquiry orientation similar to that in science was as follows:

I think the way that we teach science is showing up a whole lot more in the way that we teach everything else now, too. In that experiment, let's draw, let's predict, let's draw conclusions, let's discuss why we think this is the answer. And that was more of a science, that's what you did when you did 'science' in that half-hour block of time that you set aside for science. And now it's a piece of math, and now it's a piece of even the way we read books. You know, look at the front cover, what do you think is going to happen in this book? Why do you think that? Now, look at the pictures and see if that confirms, if there's any evidence in there that confirms why you thought that this was going to happen? [building explanations from evidence] And that's, you're seeing that inquiry-based science across the board now. (S1-38:43)

Also, Shelley described how her practice in science influenced her math teaching:

Hand in hand with that is the way that the PDS has taught me to look at math. And it's very much like science. The way we learned math was, here's the answer, if it's wrong, there's a red checkmark next to it, period. And the way we do it now is more [inquiry-based]. (S1-24:10)

She compared this process to what she did in her science class. She explained the connections to gathering evidence and using that evidence to build explanations that showed understanding. Shelley reported,

And [it’s] just like science, science is the same way - did that float? Yes. Why? Why do you think? Why did this float and this not float? Compare these things. You know, what is the same about them? What's different about them? It's not, “Yes, this floated, not this didn't, finished.” Yeah - it's the explanation… the thought process, the discussion, the noisiness in the room that makes it powerful, not that they got the right answer. And I say to my students all the time, the answer to me is the least important part. It's the explanation and your thought about it. [building explanations from evidence] And even, you know, raising their hand, one person gives an answer, then I want ten more people to give their answer, or their explanation, and in science, if they have a partner, I want them to discuss it and be able to tell what their partner's idea was to me, not what their
idea was. Because primary kids are so, you know have blinders on, they see it their way, and if you force them to have a conversation [discourse] and present the other person's perspective, then they're learning that, they're thinking about that. (S1-24:10)

Finally, Shelley acknowledged that one of the things that impacted her most over the years as she changed toward using reform-oriented teaching methods was the effect she observed that this change had on her students. Her students were excited about science. Prior to her involvement in the PDS as a mentor teacher, she stated that her students rarely talked about science outside of the classroom lesson for the day. Now, however, she reported that her students eagerly shared science ideas not only in school, but at home as well. She said,

We start a new unit now and, right now it's Underwater Life, so our social studies and science are really meshed, and day two of the new unit, ten kids have shells in their hands that they can't wait to share! It's just, they're so excited about it that I don't have to say, "Tell your parents." They go home and can't wait to find things... but they're so excited about what we're learning that they can't wait to learn more and to tell their parents about it and to bring things in so that they can share what they know. [motivation/excitement toward science] (S1-08:35)

This observation, Shelley reported, encouraged her to continue to learn more about reform-oriented teaching practices as they related to teaching inquiry-based science in her classroom.

In addition to her role as mentor teacher for four years, Shelley took on other responsibilities within the PDS. She worked on course planning teams, completed inquiry projects in her classroom and was out of the classroom serving the PDS community as a PDA for two years.

I've done about all of it. I was a PDA, I was on the course-creation team for Classroom Learning Environments, I've been, I've taken the inquiry course several times and done an inquiry project. (S1-40:33)

Shelley considered these professional development opportunities to be life changing. Over the course of the past years, as a result of her involvement in the PDS community, she has also completed her graduate coursework and is currently working toward completing her Ph.D.
5.7.4 Story of Practice – Two Years Later

At the time of her second interview, Shelley was working with a PDS intern that, as she described, was unlike any other intern that she had worked with previously. Her intern was a returning adult learner who had “a great deal of science experiences and access to materials.” This experience, as she explained, helped her to see more possibilities for teaching science concepts, but also, as she reported, had the potential to hinder her growth after her intern graduated because she felt that it would just be too time consuming and difficult without this “extra set of hands.” Still, Shelley reported that she continued to use several science-specific teaching strategies in her classroom environment and described a new strategy that she tried with her intern. She wrote,

This year we also tired [sic] to solely create experiences based on the student wonderings. [focus on student wonderings] It was again, labor intensive, but we found that the objectives and outcomes of the unit were easily reached by following the lead of the students. (Shelley; final email)

Shelley explained that her new ideas were not as frequent as they had been in the past, and her science units have stayed primarily the same, except for these first attempts at creating science experiences based on student wonderings. Given more time to practice and perfect this practice of using student wonderings, Shelley reported that she could expand the learning experiences in her classroom and as a result, create a very reform-oriented classroom environment.

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5.8 Participant 8: Paul’s Story of Practice, Story of Change

Paul has been teaching in the district for twenty-six years. During that time he spent most of his career teaching third grade and only recently made the transition to fifth grade. Paul identified himself as being from the “old school” of teaching. For nearly two decades prior to his school becoming involved with the PDS movement, he reported that he essentially followed the
same plan of teaching each year, making small changes if necessary, but chiefly doing what everyone else was doing and he never really questioned his motives or methods.

5.8.1 Introduction to the PDS

Paul was first introduced to the PDS only a few years after its inception. He had worked with university students through the traditional student teaching model for many years and volunteered for the opportunity to work with the new PDS interns near the start of the program. After being a mentor teacher for three consecutive years, Paul applied for a PDA (professional development associate) position within the PDS partnership. This position afforded him the opportunity to leave his own classroom for two full school years and become a liaison between the university faculty, mentor teachers, and interns. Paul reported that he jumped at the chance for this position. After twenty-plus years of teaching, he, as he stated, “wanted to shake some of the cobwebs out”. He also looked forward to the opportunity to think about his own teaching and to watch other great teachers and again in his own words, “steal lots of ideas!”

During his two-year tenure as a PDA, Paul began to feel empowered as an educator and excited about the kinds of things that he saw taking place in his school district. After completion of his two years as PDA, he stepped back into the role of mentor teacher.

5.8.2 Science Teaching Prior to PDS Involvement

During his twenty-six year tenure as an elementary teacher, Paul reported that he had seen numerous changes in the practice of teaching science. The method that he particularly liked was that of “teaching science as process.” This science teaching method focused on teaching the students to become proficient at certain science process skills such as observation, classification and measurement. As Paul described,

What I will call "process science" before, and I looked specifically for, “Are they making inferences?” [science process skills] Then I would have checklists as
they were doing experiments and see if they were doing this particular, what I thought those science ideas were, and I had very rigid notions about this, “This is what it will look like when they're doing this and this is what it will look like when they're doing that.” I expected them to be saying some very specific things and giving very specific [answers], according to what I thought science was, or the processes of science were. [teacher-directed science] (P1-06:06)

Paul reported that he felt very comfortable teaching science in this manner as it provided him with very specific outcomes to look for with the students. By using checklists of process skills, he would teach these basic skills through the use of hands-on materials and activities. As the students practiced each skill through activities and basic tests, he could assess mastery of the science process skills. This, he felt, was effective teaching as the students were engaged and learned how to do such things as observe, infer and measure properly.

This type of teaching, Paul conveyed, was very structured. It allowed him to have a classroom that was orderly and where everyone worked toward the same common outcome in science. He described,

And then, "cookbook" - you know, well when they do this experiment, this proves this idea. And if it doesn't, they did something wrong. So if they don't come to this conclusion, they've messed up somehow, the kids have messed up and I need to straighten them out and so we'll get together and I'll, we'll redo the experiment or we'll do another one and I'll explain to them why they shouldn't have gotten the results that they got, you know, they made a mistake, they made an error. [teacher-directed science] (P1-06:50)

Paul’s science teaching practices prior to his experiences as a mentor teacher and a PDA were very rigid, structured, and teacher-directed, and he used hands-on activities as the basis for his teaching and to support the learning of facts and skills in science.

5.8.3 Science Teaching Following PDS Involvement

Paul described himself as “reluctantly confident” when it came to trying out new teaching methods in his classroom. He recognized that he believed himself to be a good teacher, but in recent years he struggled with many questions about the appropriateness of many of the topics in
science education that teachers were being asked to teach. He described his most basic change in teaching as being able to let go of the rigidity of using checklists and making sure that all of the students were always doing exactly the same things in the classroom. He said,

It [my science teaching] has changed to where it's a little less rigid, a little more human. We all make mistakes. [teacher reflection on practice] Even scientists who are doing the same experiment won't come up with the same conclusions and same thoughts and ideas. So, I don't get too upset if I have 6 experiments going or 6 ideas going that they come up with different thoughts or ideas. You want to guide them - you know you kind of take what they know and you're herding them now instead of maybe putting a ring through their nose and dragging them along, yeah. So it's kind of just sort of guiding them through, you know, things and accepting sometimes that maybe they're not at a level that they're going to come to what science says about the idea or concept and be, feeling more relaxed about it I guess and know that I'm passing the baton on to other people who are taking it from people and passing it on to people that hopefully, collectively though, get some good science experiences out of it. (P1-06:50)

Paul became increasingly critical of his own teaching practices during his time as a PDA as well as his time as a mentor teacher. However, being a part of this community offered him a new perspective on how to approach change when it came to his teaching practice. He said,

It was the PDA meetings where we would sit around, and you worked with the university professors who kind of have, had the attitude that, “Well we're going to get this done no matter what. We're going to accomplish this, we're interested in this so we're going to try to make this happen.” [community of support; PDS groups] (P1-08:43)

Upon his return to the classroom after being a PDA for two years, Paul reported that he adopted a “can-do” attitude and focused on making the learning experiences in his classroom exceptional for his students. This change in his approach to teaching came as he recognized his dissatisfaction with the way he had been teaching science and as a result of observations of other teaching practices during his role as a PDA. He described his former teaching personality as follows:

I used to be the person who would say, "Well, if you're going to try something...," I would look for every way that it possibly couldn't work. You know, before we
even sat down and talked about it, I would say, "Well, that's not going to work because the kids will never, or the principal will never, or I can't get the money to..." [personal dissatisfaction] (P1-08:43)

Paul’s approach to change in practice opened up new doors for him. Upon his return to his role as a mentor teacher, he was dissatisfied with the science units that he had been teaching for nearly twenty years. He recognized his desire to change them to become more inquiry-based and incorporate new methods of teaching that he had observed as a PDA. As a result, he contacted a science education methods professor from a neighboring branch campus and began working closely with her on the implementation of inquiry-based science lessons in his classroom. He described,

I don't think they [the district curriculum units] lend themselves to inquiry, but Leah’s [university science education faculty member from satellite campus] been coming in and working with me sometimes. She comes in and helps me think about things sometimes and I'm trying to find ways to make them more inquiry-based. [collaboration; influence of science education faculty] (P1-17:17)

As a result of working with Leah, Paul determined that his teaching methods needed to be different in order to become more reform-oriented, but he was unsure as to how to go about making these changes effectively. Though his work with Leah, he became more confident in these methods and was not reluctant or opposed to making these necessary changes. In fact, he began to problematize his practice and to experiment with ways to make it more meaningful to both himself and his students. He described his progress at implementing new practices by stating,

She [Leah] comes in and helps me think about things sometimes and I'm trying to find ways to make them more inquiry-based. And I'm not making much progress with that. I don't think it's... and I don't know whether it's that the units are so global. (P1-17:17)
Paul was very critical of his practice and his progress. He reported that he did not always feel as though he was effective in his practice. He went on to explain his struggle with several fifth grade science units. He said,

Well, plate tectonics, for example. I mean, you can put clay sheets together and that whole thing, but after the initial... I mean I don't know what playing around there is with the plate tectonics or the human body, when you're studying the systems of the human body. You know, I don't know, it seems like there are, you could go to some places, but there are other things that it just seems like it's more of an abstraction and it's hard to make it concrete and hard to have the kids experience it. If you're just doing the human body reports, that's really a Health unit, I think, and not a science unit, not a science inquiry unit. So, I'm making little steps I think. [teacher reflection on practice] (P1-17:17)

As he felt that he made progress, he gave an example of a change that he made in his teaching practice during a lesson on plate tectonics. This example demonstrated a shift toward implementing reform-oriented methods in the classroom. He described his lesson as follows:

Last year with the plate tectonics, I have "mountain building" for instance, that's my objective. And I did mess around with some Oobleck stuff some cornstarch, because over eons, earth's mantle or the crust actually acts like a semi-solid. You can think of it that way - it just takes millions of years for it to move instead of like Oobleck. So I tried to help the kids draw that analogy. We played with Oobleck and did all kinds of things with it, and now we're just, you know, why am I doing this with mountain building? What does this have to do with the plate tectonics you've been studying and how mountains are formed and things like that? (P1-17:17)

This change in practice was a struggle for Paul, but one that he met with eagerness and enthusiasm. He acknowledged his hesitancy with the change process at times, but also recognized the importance of the change for both himself and his students. His new approach to science teaching was one of challenge and openness to new ideas and less-structured classroom experiences. He said,

Not be such an academic goal, you know and let the kids be kids and I mean, it sounds like, I don't just sit there and don't do anything, I have a job and I am trying to get them to be more scientific, more mathematical, or more like a social studies person through the lesson. But I don't get as upset with "oh these kids,
they didn't get it." You know, I'm checking your multiple choice papers, now I read journals or something and can say, well, they're moving in a new direction - - yeah, and it's not terribly comfortable, I mean, there are still remnants of my old self where I think, "Boy, is this worth it?" [teacher reflection on practice] I mean, it's really messy and sloppy compared to what I used to do with a lot of textbooks and stuff. (P1-15:22)

Finally, as a result of Paul’s involvement in the PDS as both a mentor teacher and a PDA, he became much more involved in the PDS community. Prior to PDS, he reported that he rarely discussed his teaching methods with anyone other than perhaps other teachers in his grade level as they discussed classroom happenings. However, as he stated,

John introduced us to, "critical friends" groups, only he calls it "critical inquiry groups" I think. So I'm in a couple of those now. [community of support] (P1-15:22)

Paul’s participation in these discussion groups has contributed greatly to his change process and as he reported, has allowed him the opportunity to share ideas as well as teaching successes and disappointments in an effort to improve his science teaching practices. Although Paul was very self-critical and felt as though he was not as advanced as his colleagues in science practices, his reported practice revealed elements of reform methods that were science-specific and reflective of reform-oriented science methods.

5.8.4 Story of Practice – Two Years Later

Two years later, Paul was still making changes in his classroom. He expressed some frustration, not necessarily with his teaching style or practices anymore, but more frustration with the science concepts that he has been asked to teach. He said,

I guess I'm more familiar with the content so that helps, but I'm still a little disappointed in the level of science that we are doing, like microorganisms, [They] aren’t really high on any elementary level, they are always in 7th or 8th grade. It’s more lecture types of things. So trying to get any minds-on stuff with some of the content that we have is a little daunting, however, but not that I’m going to give up! It’s hard to try to fit it [microorganisms] into an inquiry stance… I mean, you can do things where you are classifying organisms first, but
the actual sitting down with the content and having the kids go through all of it just seems a little too abstract for them. Not that they can’t sit down and memorize facts in a “Jeopardy!” type way but that’s not the best way [to teach it].

[teacher reflection on practice] (P2-02:39)

Paul reported that his focus in science class was still on inquiry-based science. To him, this meant that his students were engaged in meaningful activities and experiences that caused them to challenge their own thinking about science questions and issues and enabled them to engage both mentally and physically with these concepts. “Minds-on” science, which involved all of the senses experiencing science together, was important for him to offer to his students, however, he felt that he could attain these goals much easier with physical science opportunities, which weren’t being incorporated into his grade level science topics as much as he thought they should be. He stated,

It’s more abstract at the fifth grade level, I think so. Environmental science is not too bad. We don’t do too many physical science things though. I don’t know if that is an excuse for not finding experiments or hands on activities for the kids to do, but physical science seems to lend itself more to experimenting or playing or trying things out. (P2-05:29)

Finally, for Paul, development over the course of the two years has been slow and sometimes frustrating, but also rewarding at times. Despite his frustration with the abstract nature of several of the science units that fifth grade had been given to teach, he worked diligently at trying to incorporate aspects of gathering evidence and supporting explanations with evidence through his development of a mini-unit for the fifth grade Animal Kingdom unit. This mini-unit followed the 3-day teach model that the interns create and implement in the classroom during their fall semester science methods course. Paul described it as follows:

I developed this whole “Sponge Bob Square Pants” thing. [lesson modification toward reform] I was given sponges and mollusks in my rotation in science and my children were at the age where they were watching Sponge Bob on TV. So, I thought, “Hmmm, there’s a sponge and there’s a squid there. If I could get a starfish in there - that would be good, so I asked and I got “Patrick” in there as a
starfish. So, it’s my question, not theirs, but I set up a scenario where Patrick was watching TV, a national geographic special, and they said that all animals were related. So [Patrick] wants to be related to Squidward and Sponge Bob. So Sponge Bob and Patrick are excited, but Squidward is less than excited. So the research question is “Are they related?” and that is their driving question. I set up note taking for characteristics, habitat, animals that they are related to, and what they eat. The students take notes from materials that I have - we don’t have time to go down to the library or use the internet like we probably should - and then they write a little mini letter to me at the end that says “Mr. Smith, I think they are or are not related because…” and they support their answer and explanation with the research that they have collected. [building explanations from evidence] (P2-09:35)

Although this is only one small three-day science lesson, this example is evidence that Paul continued on his path of change toward implementing reform-oriented science teaching practices. Although he reported that he continued to remain frustrated with the slow progress and abstractness of the fifth grade science units, he held strong to his inquiry orientation and remained persistent in his goals to create meaningful opportunities for his students to learn in the ways that he believed were consistent with that orientation.

5.9 Participant 9: Lana’s Story of Practice, Story of Change

At the start of this research project, Lana had been teaching school for nineteen years, all of which were spent in the intermediate grades. She was completing her second year as a mentor teacher and contributed her time on a PDS planning team. She had not participated in any other PDS activities or courses other than being a witness to colleagues in her building who were mentor teachers over the years.

5.9.1 Introduction to the PDS

As stated above, Lana began her career with Penn State nearly twenty years ago. She received her bachelor’s degree in elementary education through Penn State University, many
years before the PDS program had been implemented between the university and the local school district. After graduation, Lana began working in the State College School District as a fifth grade teacher. The PDS program did not begin at the school where she taught, but she had heard about the project for many years before her school became part of the project. She had heard from colleagues involved in the PDS that the program was very good, but never became involved with any of the PDS courses over those years. However, Lana did enroll in the graduate program at the university and has been taking course toward her master’s degree. As stated above, although Lana hadn’t taken any PDS courses at the time of this interview, being involved in the graduate school had given her some additional connections to university faculty who were involved in the PDS program. Through her conversations and dealings with them, she learned more about the program and respected the work that they were doing in the district. However, this information was not enough to compel her to get involved with the PDS at first.

A few years later, Lana’s former undergraduate student teaching supervisor was a professor who left the university for a short time, but had recently returned to Penn State to work specifically with the PDS program. When Lana discovered this, she reported that he was the catalyst that encouraged her to become more involved. As a result, she pursued learning more about the program. She now knew someone in an authoritative position within the program whom she knew, respected and was interested in working with again.

5.9.2 Science Teaching Prior to PDS Involvement

Lana was fairly new to the PDS program at the time of her first interview. Prior to her involvement as a mentor teacher, Lana’s teaching style in science could easily be categorized as “traditional”, meaning that, as she reported, she believed that there was a very specific method to teaching science that involved learning facts to help students better understand the science
concept, with an occasional hands-on activity used to reinforce the fact-based teaching. She was very proud of the fact that she helped to write the science units that were being used in the district. She stated,

I actually wrote with another district teacher [pre-PDS] the science units that are in place in the State College School District. (La1-3:12)

However, although she reported that she co-wrote these units and felt comfortable teaching them as written, she also felt that she needed to sometimes modify them to suit her needs in the classroom. She said,

Oh, I have the freedom in every science unit, as long as I cover my outcomes that which they prescribe, which could be, plate tectonics for instance. I really could teach any lesson I wanted to as long as I will have the outcome that they [the district] [teacher-directed science] do…our units are fairly, they're complete. It's lesson one, lesson two, lesson three - with this outcome…And that's ok because as written I think they [district science units] are fine, it's just that I'm not sure for me personally, every group of students I have, those activities are appropriate for in the format that they're written. I need to modify them obviously. [teacher reflection on practice] (La1-07:12)

Lana’s reported ideas of modification to her science teaching practices focused mostly on learning science through lecture and very structured activities that left little room for exploration. Lana reported that she liked structure and was very outcome-based when it came to science. Her ideas about inquiry-based science as a method of reform were as follows:

I always get concerned when we jump on a bandwagon for something new and I do believe in inquiry-based instruction, however, there’s a time and a place when it’s most appropriate and it’s not appropriate everywhere. (La1-04:31)

It can be concluded that prior to her experience as a mentor teacher in the PDS, Lana’s science teaching practices were very traditional in nature and could be supported best by her own statement: “I could teach any lesson I wanted to as long as I will have the outcome that they do.”

5.9.3 Science Teaching Following PDS Involvement
In the early 1990s, as maintained above, Lana was part of the planning team that wrote, along with another district teacher, the science units that were in place in the school district. Lana designed these units based on the discovery learning theory. Science concepts were chosen for each grade level and designed using activities to reinforce the ideas behind the concepts.

When Lana heard about the things that some of her colleagues were doing in science and the changes that they were making to their own science teaching practices, she wanted to know more. She wanted to, as she said, “see what they were doing”. Lana had been an elementary teacher for nearly twenty years and was concerned that many of her colleagues were jumping on a bandwagon for something new in the area of science. She had seen it happen many times before throughout her career, and was both intrigued by the new ideas, yet apprehensive to the change. Lana expressed her belief in inquiry-based instruction, however she also believed that there was a time and a place for this kind of learning in science. She did not consider it to be appropriate in every instance.

When Lana began working with her first intern, she witnessed some new activities and approaches to science. One of the first such inquiry-based experiences was an activity called “Mystery Boxes.” She described her initial reaction to the method:

Oh, they [lessons introduced by intern] worked quite well, I thought. There was a "mystery box" activity that she did which was just adorable and I have to say I could see it working all the way, you know, K through graduate work by the way… I liked it because while, in my opinion, it didn't look at a concept [emphasis added], instead it looked at a practice [emphasis added] that scientists and every person that we know goes through to answer the questions about what they can't see, what they don't know, what they need to know. [science process skills] So, I liked it a lot. (La1-09:45)

Even though Lana stated that she liked what she observed, she remained apprehensive toward these new ideas about science teaching and was not quick to try them out herself. She stated,
The inquiry, I’ve always known about, so that’s fine. But I will say, I’m very careful with the inquiry though – to make sure that the inquiry is appropriate for the activity. I don’t think inquiry-based science has to be going on the web and finding information, which I think it can easily become, and I’ve seen it become. So, I’m very careful about when they [the interns] tell me they want to do an inquiry-based science lesson that they need to sit down and go through the steps with me to make sure that I’m [emphasis added] feeling comfortable. (La1-09:45)

Lana often seemed to flip-flop back and forth as she explained her science teaching practices. She often contradicted herself as she talked through a scenario. For example, in the above quote, Lana discussed her knowledge about inquiry, but also being hesitant about using it all of the time. She talked about inquiry-based science as if it was simply another teaching strategy and not a way of thinking about science teaching and learning. To support this inference, in the following excerpt from her story, Lana described her teaching practices by knowing exactly how the lesson was going to turn out before she would even consider trying it in the classroom. She said,

So, I think definitely for me, it's been talking about it, and I'll be honest with you, I tend to have to talk about, have to think about something, talk about it, and get a thorough plan for it before I'll try it in the classroom, just because, I always come back to, “What's my main charge?” which are the kids in the classroom. So, I tend not to want to experiment until I'm pretty sure what I think will be a successful experience for them, [teacher-directed science] so I definitely talked about it, and have to think about it. (La1-17:33)

Throughout her interview, she demonstrated apprehension toward a child-centered or child-led curriculum and described her science teaching as very teacher-directed. She remained hesitant to let go of her traditional beliefs as she was in the beginning stages of examining her current curriculum and practice. As she described one of the district science units,

…the animal kingdom, which sounds like we do a lot with it, but we don’t. And it’s probably the one I feel the most strife about because …we are presenting the different phyla…we teach them about the phyla and the animals in it and they take notes. So, we don’t do a lot of interactions with that. [teacher-directed science] So, it’s the one I feel a little bit torn about. [conflict with practice] However, I will say I think there’s some merit in doing that as well. (La1-04:31)
It could be inferred that these inconsistencies in her descriptions were due to her inexperience as a mentor teacher or due to the fact that she might still have been unwilling to let go of her practice because what she witnessed with her intern was all still very new to her. In listening to her story, however, one could infer that she wanted to be able to “talk the talk” but was reluctant to “walk the walk” when it came to using reform-oriented science teaching practices. For example, when asked about her idea of a good science lesson, she recalled a lesson that was very exploratory based, but lacked a focus on using evidence to build explanations. She described,

We did… a lesson that we call "crazy colloids", but which is an AIMS activity called..."oobleck". I think that's an excellent one for instance, whereas they’re given a mystery so to speak that they need to explore and that's what I think they need to do. They need to take an object, a thing, an idea, a concept, [and] they need to explore it. [exploration-based science] And then I have no problem with "let's go on the web and let's look at Google and let's see what we can find under ‘colloid’ or ‘solid/liquid’ or whatever”, no problem with that. But I think that's kind of the last step that I want to see. (La1-11:13)

Lana’s description reflected focus on an activity-based learning experience that allowed for play and exploration followed by teaching factual information to support the activity. By allowing students to play and then research to find an answer, without providing an opportunity for discourse or questioning does not support reform-oriented teaching methods. However, she continued her description by discussing the importance of student understanding of their learning. She described,

And the children, I want to see them actually involved in questioning their own understanding about what a liquid is, what a solid is, what anything is and then coming up with characteristics [lesson modification toward reform] and actually taking time to explore all of that… but finding the answers they come up with a really good product. And I think that's an attraction - that you get a wonderful product at the end, but I think it's the middle that's missing sometimes. (La1-11:13)

This “middle” that Lana referred to is the aspect of inquiry-based science that is critical. It involves questioning, student discourse and a focus on evidence gathering in order to support the
building of explanations. Other than this one example of what she considered an inquiry science
lesson in her classroom, she often contradicted her story and it was inferred that these types of
experiences were not necessarily the norm in her classroom. She was much more comfortable
following prescribed lesson plans in order to keep the structure and outcome consistent. She said,

I also, with this last intern, I made it very clear about my ideas with, this is my
outcome, these are the activities that are prescribed [teacher-directed science]
but…I did encourage her…to look for different activities that still would produce
the same outcome with children. (La1-09:05)

Additionally, Lana described her use of science talks in the classroom as a strategy that she
learned from her PDS involvement. Nevertheless, her description still alluded to strict teacher-
directed talk in the classroom and fewer interactive experiences for the students. She stated,

Yeah, we often do them [science talks]. Especially the first unit when we did
environmental sciences… That one… often turns out to be a very good one to do
since we are talking more about issues and impact of environment and things like
that rather than doing interactive activities. [traditional science teaching
practices] (La1-13:59)

Lana’s idea of a science talk was just of talking about science concepts. She did not report an
understanding of the use of talk as a science-specific strategy with the purpose of making
students’ knowledge public.

Finally, one of the most interesting aspects of Lana’s story as she reported it was how she
was affected by her first intern in the classroom. She stated,

She [my intern] herself didn’t [spark anything in me]. I mean, she was excellent –
she had a lot of ideas. I think, more for me, it was her questions to me that when I
would respond to her would spark my questioning, “Why was I doing
something?” (La1-08:39)

This influence of the intern was contradictory to each of the other participants involved in this
study. Perhaps this is why Lana reported on the survey that she felt as though her science
teaching practices had changed very little as a result of her PDS involvement. Being in the
beginning stages of mentoring caused her to examine and problematize her practice more closely before she actually took steps to make changes to her practice.

5.9.4 Story of Practice – Two Years Later

Upon returning to interview Lana two years after her first interview, it was interesting to sit down and talk candidly with her about her teaching beliefs and practices in science. Her original story of practice as she reported it was difficult to interpret because she often contradicted herself as she spoke. On one hand she would talk about interesting things that she witnessed and tried in her classroom when it came to reform-oriented science practices, but then would revert to talking about very traditional science teaching methods. Her story, as it unfolded, became difficult to analyze, interpret and categorize. As the researcher, it became apparent that some things needed to be clarified. Interestingly, near the very beginning of her second interview, Lana was the one who sat down and clarified everything for the researcher from the onset. She stated,

It [science teaching since last interview and prior to PDS involvement] hasn’t changed dramatically, honestly. I think the thing that used to be there that’s gone - or I shouldn’t say it’s gone, it’s been altered, changed or modified - there used to be a much more of a reliance on accountability for myself and that accountability was a lot of lab journals, a lot of data collection that was then used to maybe support, defend or refute a hypothesis that they came up with. I think now it’s changed to this – I think there is a much more of a reliance on posing a situation to the children, discussing avenues that they could take to – I’m not going to use the word inquire – but to wonder on various subjects and how they could go about finding the material that can again, support, refute or whatever, their ideas. [lesson modification toward reform] I think that’s where it’s changed. (La2-03:40)

She went on to say,

But the irony is is that I thought my beliefs were always there but obviously my activities that I did even with what I thought were the beliefs [about inquiry-based science teaching] did not support those beliefs. [teacher reflection on practice] (La2-09:44)
Two years ago, Lana, in her interview, tried to “talk the talk” of reform science, but had a difficult time trying to implement these practices. She described,

The irony to me is, my thoughts in conceptual math have really not wavered since beginning my graduate work and when I really look at what I’m doing now in science it’s starting [emphasis added] to mirror my beliefs in math and I might have said before that I was conceptual in my ideas about science and I wasn’t probably, I truly wasn’t. [conflict with former practice] And I think it’s because of these units with activities written that are already made up for me. It’s hard, not hard, but it’s a struggle sometimes to realize that, to look at the outcome instead of the activities to take you to the outcome. (La2-09:44)

It seemed that over the course of the two years since Lana first told her story, something had changed. The only thing that Lana had done differently in direct relation to science was to have had two more interns in her classroom. She did not take any science courses or workshops, but continued to work with interns and experienced what they brought to the classroom setting for science. She reported,

I’m feeling much more comfortable with it [trying new science methods] instead of me being a person who pushes them [the interns] in a direction. As well as I’ve had to give up a little of the outcome-oriented [teaching] and to be comfortable with that. And to be comfortable with, it has taken me to actually, to almost bite my tongue, to grit my teeth and to let it happen knowing that I need to stop sometimes measuring student’s success by them being able to answer my questions and looking at the questions they ask. [focus on questioning] And honestly, the first time it happened, I really did have to just almost tell myself to shut my mouth and to let it happen. And after it happened a few times, I’m fine. (La2–06:25)

It was difficult for Lana over time to begin to make these small changes to her practice. However, she found ways to help herself justify trying new methods in the classroom by incorporating such things as rubrics and self-assessment tools. She said,

[It has been] difficult to be ok with it [inquiry-based science teaching] and to much more look at the process and not at the outcome and it’s been hard. I still feel like I need to be held accountable. The struggle with me has been to develop ways to make them accountable… so I’ve relied heavily on rubrics. I’ve relied heavily on self-assessments and what did you find? Also much more of my
accountability is what did you do, not what did you find, what’s your answer kind of thing. [lesson modification toward reform] (La2-06:25)

Modifications of the types of questions that she asked the students and redirecting her focus from outcome-based to include the entire process of getting to the outcome and the understanding of that process was a difficult yet critical change in Lana’s practice. When asked if she ever felt as if her change was directly related to a feeling of doing something wrong when it came to her teaching, Lana replied,

No, it never was that for me. My big thing was that inquiry is not always necessary. That was one of my beliefs for a successful gathering of knowledge in science. But my second one honestly was “Been there, done that.” I thought it will happen again in 5 more years, like a pendulum swinging. But then when I really looked at it, I never really saw the pendulum in inquiry and I’ve been hear for 20 years. It’s really not a curriculum, it’s really not a teaching style. [inquiry as pedagogy] It’s really a philosophy of learning in my opinion and it makes the most sense to be in science but truthfully it’s in every subject. It just happens to be that science is where we look at it with the PDS students. It’s in math, in reading, it’s in social studies, it truly is. (La2-15:52)

Over the course of her involvement as a PDS mentor teacher over two more years, Lana’s beliefs about inquiry-based science teaching had changed. Although these changes were not drastic, they were significant in her path toward both using and understanding the value of reform-oriented science teaching methods.

I think each student begins the year being the receiver of information and as the year progresses, what I see is they aren’t scientists, they’re not little lab technicians collecting this data, but rather what I see is that they start to realize that every question that they have, every notion that they think of is really all contributing to their knowledge base and their ability to find answers, solutions to these questions that they have. [student learning through inquiry] So it’s almost like, and they don’t know it, I almost look at it as when I was a child and we looked at National Geographic for instance. It wasn’t that we hadn’t heard it before but we looked at pictures and read articles and then it just started the churning of the questioning. It’s interesting because I’m even seeing it with learners that I would call reluctant learners. It used to be I used to see truly inquiry-minds only with gifted kids or ones that would have varied background based on experiences their families have provided. But now we offer that to everyone. (La2-32:22)
In summary, Lana began to show increased motivation toward trying reform-oriented teaching methods in her classroom during the two years following her initial interview. Using these methods allowed her to begin to understand inquiry-based science at a different level upon which she, although still hesitant at times, looked forward to trying more in the future.

5.10 Participant 10: Karen’s Story of Practice, Story of Change

Karen was a twenty-one year teaching veteran, spending the majority of those years teaching second grade in the State College school district. She had worked with six interns at the time of her first interview and had also engaged in numerous PDS experiences. She reported that she engaged in formal teacher inquiry projects three times and participated in professional development courses and workshops at least seven times. Her main areas of interest in the PDS were in Reading and Classroom Learning Environments.

5.10.1 Introduction to the PDS

Karen’s introduction to the PDS came as a result of knowing one of the originating university faculty members. Karen recalled taking a graduate level course on the topic of classroom management with him while her husband was on sabbatical leave and working out of the area. She recalled that she “clicked with him instantly” as his teaching philosophy meshed with hers very well.

Karen reported that during the time that she was in this course, she learned about the PDS. Unfortunately, the opportunity to become a mentor teacher was only available at one local school, and this was not where she taught. However, when the opportunity opened up to other schools in the district, her school included, she jumped at the chance.
But I was involved the next year when it opened up to other people. And you know it sounded like, I'd always had student teachers, and so, having someone, having an intern for a full year was probably one of the things that I thought would be a really good idea. And, you know, right away, quickly, I loved the program and so my involvement has been consistent. (K1-06:39)

5.10.2 Science Teaching Prior to PDS Involvement

Prior to her involvement as a mentor teacher in the PDS, Karen described her teaching as very didactic and scripted. In fact, she reported that she used to use the district curriculum science boxes and nearly followed them to the letter. As an example, she described how she used to teach her second graders about dinosaurs. She reported,

Most of the time it was more presenting information about different dinosaurs in a factual way and maybe an art project to go with it [activity-based science] rather than an “inquiry”. I mean, I think it is very much inquiry when the kids get clues and have to use that information to deduct, you know? I just think that whole idea is certainly much more of a doing process. So it really, in fact a lot of things that are in my unit box I don’t use anymore because I just don’t have time to present as much information factually. But then on the other side of it the kids do research projects. (K2-12:46)

Hands-on activities and factual recall were the “old stand-bys” as Karen recalled. She reported that she taught by talking at the children and when it came to incorporating activities, she used many stations in her science classroom and had her children rotate through from one activity to the next. She believed that getting her children moving around the classroom helped them learn and stay focused.

I do not want to go back to the old way….I could so easily get rid of these things because I just don’t teach by preaching anymore, where I’m up there saying, “Gotta remember this, gotta remember that, gotta remember that.” At least in primary, it’s just not the best way to get kids to learn. It’s hard for them to sit still. They are much better off moving around and doing things, some kind of a process, a doing thing, and talking to each other about it. (K2-20:50)

Her science teaching practices were very teacher-directed. However, as Karen recalled her former teaching practice, she remained confident that her change toward using more reform-
oriented teaching methods as a result of having an inquiry orientation toward science was for the best.

5.10.3 Science Teaching Following PDS Involvement

As a primary teacher, Karen strongly believed that children loved science and she had observed this over her twenty-one year teaching career. She stated,

I think kids love science and I think teachers may not always know that, but I think kids love science. And if you ask them, you'd probably get most kids to raise their hands and say they like science. [student excitement toward science] (K1-50.37)

Karen was a mentor teacher for six years at the time of her initial interview. After working with her interns over this period of time, she still believed that children loved science, whether they were being taught using her former ways of teaching, or what she referred to as her “new ways of teaching.” However, she much preferred the new skills that she had acquired over the years and her changed beliefs toward how children should learn science. She explained her teaching practice as follows:

The emphasis isn’t so much on teacher here, kids here, I’m giving [emphasis added] you this information… But the whole idea is that you give kids a chance to make choices and however you do it, whether it's a big list of choices or a small list of choices, the kids still have that sense of choosing. [child-centered] So, for example, if you had done a unit on Dinosaurs, and you wanted the kids to show what they’d learned, they could pick a dinosaur and do research on it and figure out how they wanted to present their research so that they not only have a choice about what they present but how they present it. So, it's not only content, but process. (K1-18:17)

For Karen, having an intern in the classroom helped to spark her thinking about teaching science using a lens of inquiry. She stated,

But I have learned a little bit and a lot of the things that the interns have come in to the class with has been helpful [influence of intern on practice]…I think often times what the interns bring in does help me to think outside the box. (K1-10:48)
As a result of working with her interns and being involved in several workshops and courses that focused on adopting an inquiry orientation, her focus in science changed from one of knowledge delivery to one of knowledge sharing. For example, she said,

I have got some really good strong thinkers in my class this year and you know, you limit yourself so much, if you take a curriculum guide and you say, “Well, I need to do this, this, this, this and this.” You know, you miss so much of what the kids know or want to know that maybe it related but not mainstream. But it's so, you know I just think it's so great to pick the kids brains on things - this is what they know, this is what they want to know - I don't know, I really like that KLEW chart. [science-specific learning strategy; KLEW chart] It works well. (K1-23:28)

One strategy that Karen adopted, as mentioned above, was using a KLEW chart in the classroom. This science-specific strategy was introduced by each of her interns over the years and one that she found to be both useful and beneficial. She explained,

Another thing that the science course that the interns always bring back is the KLEW chart. K-L-E-W. And I had always learned it as KWL. But I like the thing, I like the evidence idea, what's your evidence, and the interns, or my interns have been really good about that, so we always get a great big piece of bulletin board paper that might stretch the width of two of those book shelves and you know, he, that's what Mike did this year, he had four, you know the four parts to it, and in the very beginning it's just really a nice way to see what they do know about the topic, but as he goes along he worked really hard to get the kids. And my other interns have done the same thing. What's your evidence? What's your proof that, of what we've learned? And I think, I think that whole idea is really important in science, not that you've seen something or that you can tell a fact, but what's your evidence for it? So, to me, that's a really nice little piece that that's been important in science in my room since I've had interns. (K1-21:20)

Karen used KLEW charts in her classroom often, with the assistance of her interns. As a result, she reported that she focused more on evidence and explanation in her science lessons. By changing her focus from fact- and activity-based teaching to teaching that was inquiry-based and incorporated science-specific strategies as she became comfortable with them, Karen’s change process reached beyond her intern’s lessons to her own science curriculum and her views began to evolve. She stated,
I think that [my teaching philosophy with science] has evolved. You know, I don't think it's always, I've probably in the past have been much more - follow the guide and do what it says [teacher-directed science] - rather than thinking outside the box. But because our units are not all the greatest, I think often times that [what] the interns bring in is does help me to think outside the box. [teacher reflection on practice] I think that idea of process is important to the kids today. It's like anything else, you know, especially in this day of knowledge being at your, or facts being at our fingertips, but the kids need to know how to find things out, not necessarily just always knowing the fact of something. (K1-28:11)

As a result of her belief that students were more than just fact-learners, she got involved in helping to rewrite one of the district science units to incorporate reform-oriented teaching methods. She said,

I think, our science units in the district, a lot of them are in need of redoing, you know. And I think, I think the direction.. I.. a number of years ago I was involved in the rewriting the magnet unit, so I had some input into that. Magnets are a little easier to get experiments that you can, I mean, it's just the natural place for experiments... which you have to study a different way, that's exactly right. But I think the way our units used to be written, it was just full of facts. And I think science, it's not just facts, to me. I think the important thing about science is the process of it all. [change in thinking] That you learn to ask good questions, to figure out, if I have this question, how can I answer it, and then to go about trying to answer it, so, I think it's important to teach that process. [lesson modification toward reform] And I think that's probably how my thinking about science has probably evolved and I mean obviously I've been at this teaching game for quite a while. (K1-26:50)

Karen’s evolution was from a fact-based, hands-on activity type teacher to a teacher who believed that science was best both taught and learned by incorporating science-specific teaching strategies in the lessons.

5.10.4 Story of Practice – Two Years Later

Two years following her initial interview, Karen reported that she continued to do many of the same types of things in her science classroom as she had before. She continued to implement science-specific strategies and believed that a strong focus on the concept of evidence was needed. Her self-report reflected confidence that she had become more comfortable and
focused with using evidence as a result of her work with two more interns over the years. She described,

…the concept of evidence…I would never do one [KLEW chart] without the evidence part. Because I think that is important for the kids to say “I know this because…” We do it in language - we ask the kids to read for information. We say, “Well, you know, this why. Where is it in the book that gives you this information?” But I think from a science point of view I think that is really important for the kids to be able to verbalize that, point to it and say, “Yes, I know this fact because.” I mean in the beginning they predict, they tell what they think they know but I think it’s really important for them to be able to prove or at least find something that supports their opinion or their expectations. (K2-26:35)

She had not taken any other PDS courses or workshops directly related to science during the two years since her initial interview, but remained committed to the changes she had made in her science teaching practices.

5.11 Participant 11: Lynne’s Story of Practice, Story of Change

Lynne is a second grade elementary teacher who has been teaching for fifteen years in the State College Area School District. Lynne reported that she was the type of teacher who did not shy away from change. In fact, she described herself most often as a leader for change in her school. She felt that she was honest and straightforward with her colleagues. Perhaps the best way to capture her dynamic personality is to refer to this quote from her interview transcript:

Everyone who teaches with me knows how I feel about [some of the inconsistencies with the science units]. They put my name on the agenda for unit planning, you know, five minutes for Linda to complain, and I’m like, “If you know I’m going to complain, can we do something about it? Why do I have to keep bringing this up? … Now would be a good time to change [the unit]. (L1-17:22)

Through her descriptions of herself and her teaching practice, it was apparent to the researcher that she did not shy away from a challenge and, like most teachers, just wanted her children to
leave her classroom with a better understanding and more meaningful view of science as it related to the world around them.

5.11.1 Introduction to the PDS

Lynne can’t actually remember when she first formally heard about the PDS. She had been teaching in the district for fifteen years, however, her school was not a part of the PDS project until two years ago. Ironically, her biological children went to elementary school in one of the original PDS schools, so Lynne had heard about interns and the PDS partnership for many years second-hand. It intrigued her at first and sounded like a project about which she would like to learn more. On the other hand, she acknowledged the full-year pre-service internship (student teaching assignment) as a possible deterrent to her acceptance of the program. She really was not certain that she could accept an intern in her classroom for a full school year as she was afraid that there would be too much dictation by the university as to what they (the university) wanted her to do. She described her hesitance to get involved:

My kids, actually some of mine had former interns for their teachers as well. I remember hearing stuff about the PDS thing and thinking, "What is this?" You know, it sounds kind of interesting, I don't know if I could having someone in my room all year and they're going to telling me what they want me to do, and, so you know, you have to find this stuff out. (L1-09:07)

When Lynne considered taking a sabbatical leave, she contacted some of her teaching colleagues and inquired about working with the PDS during her year of study. She acknowledged that she wanted to learn more about the program before she would consider signing on if and when the PDS started at her school. However, because her school was not accepting interns at that time, she signed up to be a professional development associate (PDA).

Kate, that's our PDA who's a real science person, too, she's one of the people who teaches science courses - so, they helped plan some lessons that I kind of just watched and listened to, and thought, this is really cool. You know, what are the kids going to learn from this? [community of support; learning from colleagues]
You know, how are they going to build their understanding of some of the body systems. (L1-9:07)

During her one year sabbatical, Lynne volunteered on a weekly basis in a first and second grade PDS classroom as well as in a fifth grade PDS classroom. She assisted the classroom teacher and intern with numerous lessons and activities throughout the school year where she learned more about teaching through the lens of inquiry while she conducted research for her sabbatical project. Her sabbatical project focused on two aspects of the PDS community. First, because she had heard so many positive things about the PDS over the years, she was interested in understanding what it was that her teaching colleagues felt made the PDS so special. Also, the PDS prepared to expand from thirty mentors and thirty interns to sixty of each spread throughout the school district. Lynne wanted to investigate the feelings of her colleagues about this expansion and how they felt that this might affect their work in the PDS. The second part of Lynne’s project focused on the “renewal” process of her teaching peers. She was interested in understanding why many of her colleagues who were nearing retirement age were not becoming bored and burned out and wanted to know if and how the PDS affected this renewal.

In addition to her own research and volunteering in classrooms, Lynne took two university courses offered through the PDS. The focus of each of these courses was on “Inquiry in the Classroom” and they shaped Lynne’s beliefs about what it means to effectively teach all subjects through the lens of inquiry. As a result of her sabbatical work in the PDS, Lynne decided to return to the classroom as a mentor teacher to a PDS intern and tackle this realm of PDS work.

5.11.2 Science Teaching Prior to PDS Involvement

For Lynne, mathematics was the curricular area in which she felt most comfortable teaching. Eight years previous to her taking her sabbatical to work with the PDS, Lynne signed
up for a Mathematics Teacher Development Program run through the university. It was a three-year commitment and involved looking at children’s mathematics through different resources. Three out of the original five-team members from her school building dropped out before completing the program. This frustrated Lynne very much. She wanted to implement change in her school and her colleagues were giving up too easily. However, Lynne recognized that while her confidence as a math teacher was excelling, the areas of science and social studies were lagging far behind in the development of herself as a teacher.

When it came time to teach science in her second grade classroom, Lynne did what the district asked her to do. She used the district curriculum units and taught them, as she described, essentially as they were prescribed to be taught. These units involved several hands-on activities and fact-based learning, which she felt she taught “just fine.” In fact, Lynne described her teaching prior to her work as a mentor teacher as “different.” She said,

But what was interesting to me is the word you said that I think was "different". It's not necessarily, as you said, that the way you were teaching before was bad, it's that there are better ways. (L1-9:07)

She reported that she never felt that her science teaching was bad prior to her involvement in the PDS, just that it was different. Additionally, she stated that she used a lot of picture books to supplement the science units and that she felt that many of her students learned science by looking at the pictures and reading the books.

A lot of their [students’] learning has been through pictures and through books, you know, learning things through books [teacher-directed science]. (L1-30:43)

By learning through reading stories in science, Lynne’s teaching was very teacher-directed and reflected traditional teaching practices such as reading, lecture, and occasional hands-on activities.

5.11.3 Science Teaching Following PDS Involvement
Lynne’s focus over the years as a result of participating in the math program was her struggle with how to change her thinking, how to change her teaching, and how to affect what her students were learning in math. Since she didn’t have an intern in her classroom, she was doing it all on her own and found it to be quite difficult. Therefore, when Lynne’s school became part of the PDS collaborative after her sabbatical leave, Lynne quickly signed up to become a new mentor teacher. In the beginning, she found that with the intern in her classroom, she became more comfortable with her math teaching as this had been an area of focus for her for so long. She had developed a set of beliefs and practices that were shared and articulated to her intern with confidence. She was able to talk with a significant other on a daily basis about these beliefs and to reflect on her own practice. Unfortunately, since Lynne had spent many years focusing her teaching practices on how math should best be taught in the elementary classroom, she felt that science and social studies lagged behind in her development of herself as a teacher.

So, for the longest time, my focus has been on mathematics and my struggle with how to change my thinking, how to change my teaching, how to change what my students are learning. (L1-9:07)

As a result of her sabbatical year, Lynne recognized the need for change in her science classroom. She signed up to be a mentor teacher and with the help of her intern, she began to tackle this issue. She said,

So, that's why I think in the survey I had put to some extent my science teaching, I think, is finally really starting to change because of the last, my sabbatical year and last year and this year I kept hearing about evidence, evidence, evidence, they have to provide evidence. And I'm like well how the heck do you get 2nd graders to do that? My intern this year was able to show me some ways to do that. [influence of intern on practice] (L1-09:07)

Lynne’s focus on her own change in mathematics set the stage for her development in science. Her first PDS intern was a critical factor in helping her to begin to understand how math and
science are closely connected and how use her expertise in math to help her students learn in a more meaningful way in science. She described how this connection affected her thinking in science:

What I finally started doing this year was connecting the way I think about math and the way I think about science more and asking them, I've been asking them for seven, six years now, "Well, how did you get that answer?" for math. Why do you think that's the answer? [focus on questioning] If I don't know then I can use the same terminology with science. What makes you think they're endothermic? Well, because, you know, they have to eat constantly, they don't eat once and not eat again for two weeks so they must be endothermic because they have to regulate body temperature. And, I don't know why it took me so long to catch on to the fact that you can use some of those same words, and when I started to think about that, I went, "OK" it's like this giant light bulb that should have gone off like three years ago, finally lit itself and I said, you know, I see more connections now between the two. (L1-17:22)

To help her make these transitions and change her science teaching practices, her intern was able to show her some ways to meet the needs of her students in science. Also, her intern was able to gather equipment through her university science class and bring it to the classroom. At one point, her intern brought in another classroom teacher from the district who was serving in the district as a PDA and that had been implementing inquiry-based science teaching practices for many years. The intern and the PDA planned some science lessons together and taught them. While Lynne assisted slightly in the planning, she took the position of observer at first - she sat back and watched the intern and the PDA teach science lessons on the human body to her students and thought, “Wow, this is really cool.”

So, they helped plan some lessons that I kind of just watched and listened to, and thought, this is really cool. You know, what are the kids going to learn from this? You know, how are they going to build their understanding of some of the body systems? [community of support; learning from teaching colleagues] [influence of intern] (L1-09:07)

By taking the pressure to be successful out of her hands and watching more experienced others’ teaching practices, this became the springboard for Lynne’s personal growth and
development in elementary science education. She still used hands-on activities in class, but no longer considered them to be just activities. Rather, she now considered providing her students with meaningful experiences in science. One of the specific things that she noticed was that as she provided the students with authentic experiences and improved her questioning techniques (i.e., asking *how do you know?* type questions) she was amazed at the results of the things that she observed second graders learning. They were learning things that she had never considered them being able to understand prior to her new understandings of how to teach science. She described,

> And, so that I think was a little bit hard, but yet, they talked about it, they know what endothermic and ectothermic are because I remember reading somewhere, try not to use the terms "warm-blooded" and "cold-blooded" because it has a misconception. And, hopefully most of our kids, you said, “Well, what did that mean?” “Well, it regulates it’s own body temperature.” I’m like, 2nd graders know what that is? [student learning in science] That's really cool. Yet that's not something I thought could happen. (L1-17:22)

This was learning that she previously had not considered possible for children their age. She added,

> …and I was astounded at some of the discoveries that the kids not only made but they remembered! The vocabulary in there is pretty tough. You know, they learned what "bipedal" and "quadrupedal" were, and I'm like, “OK, wait. ‘bi’ is 2 and ‘quad’ is 4. OK. I had to keep doing that for a while. And they can tell you, “Well a quadruped walks on 4 legs and a biped walks on 2 legs.” Well, how do you know? “Well, because you look at the tracks! You know, the bipeds go like this and the quadrupeds go like that.” Cool! [student learning in science] (L1-17:22)

Unfortunately, although she was enthusiastic about what she experienced, she recognized that having enough time was a challenge and concern for her at this point. In working with her intern, she found that she wanted to try many interesting ideas for experiments and experiences in science. However, she felt that many of them were bounded by time constraints. She would let her intern do these things, however, they would often run out of time to complete. So, she
tried to integrate science into her literature groups and social studies activities. She described her attempts at doing this and the learning that she observed in her students as a result as follows:

Science has been the one that has been really hard because you tend to do things that.... I have a limited amount of time for science [challenge to change; time] and we have one afternoon where we have a big chunk and we either get a parent to come in or you know we do something as hands-on as we can get it or we break it up into a couple activities and I think one time I even looked at, and sometimes we do it as part of our literature groups. I had a visitor here for a day, and I was like, "How do you feel about bird feet?" They're ok. All right, well, can we rotate them through your center and have them look at the bird feet and do the observation and talk about, you know, how they think, you know, which foot goes with which bird based on what the bird needs it for? Which is really kind of cool because again you're looking at that, I'm not telling you this is an owl, this is a goose, this is a whatever - you're saying, well, this one has webbed toes, so that must be the goose [student learning in science]. So, this one has really long claws, that must be the owl. It's cool watching them talk like that! (L1-40:13)

Lynne was, as she described it, “hooked” and wanted to be able to teach science in this manner all of the time. She saw a need to improve her science teaching practices, but wasn’t quite sure how to go about doing this. Lynne’s first attempt at implementing inquiry-based science into her classroom came when she used the Dinosaur Addendum that was developed by other teachers in the district to use in place of the regular prehistoric life curricular unit. Having taught that unit in previous years and the addendum this past year, she felt strongly that her students benefitted much more from the inquiry-based structure of the addendum. She said,

They do better when you can get them really involved in doing stuff, that's why I think the Dinosaur addendum was so successful with them because most of them bought into it and really got into what was going on. (L1-36:37)

Her beliefs about science teaching took on a focus of reform-oriented teaching practices as they related to an inquiry orientation toward science teaching and learning. She described,

Oh yeah, I think they learned way more than what they typically would have because they actually learned things that I won't say were directly connected to Dinosaurs. That sounds kind of stupid because well, yeah, everything you learned is about dinosaurs, but they learned it by doing it. They learned it by figuring out what the tracks are telling you and trying to look at how they're walking and what
size they were. I think they learned better and more than they have in the other ways I've taught it [the prehistoric life unit]. [lesson modification toward reform] (L1-48:10)

These reflections moved to the forefront in her thinking about her own science teaching. Lynne focused her mathematics teaching on questioning her students and helping them to learn the math through their own discoveries (evidence), understanding, and explanations, and found that this same practice worked in science. She began to use a lens of inquiry to teach her science lessons and over the last few months of the school year, Lynne became more comfortable and experimented with new science teaching practices. With each new science unit that was being taught (one unit per quarter), she and her intern focused on trying new strategies for inquiry-based science teaching. They experimented with the use of observation journals during their Animal Unit, focusing on teaching the students to use their observations as their evidence for learning. The pair also developed something that they called “stumpers” as a way to help students in their ability to distinguish groups of animals based on their observable characteristics. By adding more meaningful activities and experiences for the students as well as changing the way she approached her science teaching, Lynne noticed significant changes in the learning of her students.

One of the papers we had the kids do was kind of like a summary, “What have you learned about your mystery dinosaur? What is your evidence?” Because we had, I had typed up the first one and Heather said, ”You forgot about evidence.” So, we went back and added a column for evidence. [lesson modification toward reform; evidence] Well, bipedal, quadruped, “Well, how does it walk, what kind of legs?” Bipedal. “How do you know?” Looking at the tracks… So, I was really impressed with that. [student learning in science] (L1-17:22)

By modifying her practice, adding the “evidence” piece to allow her students the opportunity to explain what they learned and incorporating questioning skills to support, Lynne recognized that her students not only could tell her what they learned, but could also explain their understanding
of how they knew their answer. In her previous practice, she reported that she would not have
known to provide experiences to support explanation building.

Analyzing Lynne’s story, it was apparent that she was in the middle of her change
process. She recognized the importance and relevance of reform-oriented science and was
willing to try almost anything that would benefit the learning of her students. With that change
came many highs as well as many lows, but Lynne reported that self-reflection was necessary in
order to make modifications to her practice. She was growing and changing toward using more
reform-oriented teaching methods, and through trial and error, and perhaps through more
opportunities to work with interns and faculty in science education, she planned to continue
doing what she believed was best for her students’ learning. Her only conflict to change was the
limited time that she had to try to make changes to her curriculum. She said,

So, I think it would be helpful for someone in the PDS program… to look at some
of the inquiry projects, particularly those based on science and see which ones are
based on science curriculum that the district teaches and then really sit down and
look at those, like the Dinosaur addendum, to see you know, do these cover the
concept that needs to be covered and/or are they a better way of teaching than
what we have? Because, you know, I'd be willing to try some of those things, but
I just didn't have the time this year to do it myself. [challenge to change; time]
(L1-33:39)

Lynne’s reported challenge was not uncommon. Other mentor teachers struggled with this same
conflict. Lynne was excited about her learning, but frustrated by not feeling as though she had
enough time in her schedule to make the necessary changes. She reported that she made small
but significant changes in her science teaching practices to be more reflective of scientific
inquiry, but would also like to see others involved in the PDS program take on that task.

5.11.4 Story of Practice – Two Years Later

In the two years since the original interview with Lynne when she reported about her
struggles and successes in changing the way that she taught science, Lynne made science her
focus for personal growth and development. She recently completed a PDS course in science education during the fall semester 2006. She expressed her frustration with some of the district science units for many years (one in particular) and was thinking about how to make positive changes for some time. She discussed her frustration with this unit at length in her original interview because she had just finished teaching it during that school year. She was aggravated and disturbed by the lack of inquiry, feeling that the topic was too broad and did not reflect an understanding of the concepts. Students were doing most of their learning through pictures and through books, and not through their experiences with phenomena. Lynne wanted this unit to move from a more teacher-directed unit, to a student-directed unit.

When she saw that these changes weren’t being made quickly enough, she reported that she decided to do something about it herself. During her fall semester science education course, Lynne and a teaching colleague that also took the course focused their reform efforts on the science unit “The Wonderful World of Nature.” She described how she learned how to use the *NSES* (2000) Essential Features of Classroom Inquiry to guide her lesson design. She stated,

> We’re trying to look at how do you bring inquiry into a primary classroom? It’s not very easy! We used that table a lot from the book that I can’t remember the name of it (Table 2.6) and [we realized] that not every lesson is not going to fall on the inquiry end of it, but what we decided to look at was how far along that table can primary lessons be and we figured anything was better than being way over in the one column. [lesson modification toward reform] Even if you couldn’t get to the other column, you could at least get somewhere past where you were. So Jen and I [collaboration; teaching colleagues working together] decided that we would look at the animal unit since we were both kind of frustrated with the way it was written. And nothing had been done since you were here 2 years ago. And that’s where we decided we could make it more inquiry-based. (L2-04:22)

This unit focused primarily on animals and the animal kingdom, which Lynne found to be very fact-based. She wanted to modify it in order to get the children more involved by incorporating
reform-oriented teaching methods that were inquiry based. She was frustrated by her boundaries, but was focused on rooting this unit in inquiry despite those curricular boundaries. She said,

For me there are a couple reasons: One is that we are bound by the curriculum and a lot of the inquiry really far on the table is “let the students explore what they want to and we provide the materials and provide the background…” but we don’t have the training. We have a curriculum that binds us to, we have to study these things and we may not have necessarily the support or the materials to do what needs to be done at a primary level. [dissatisfaction; lack of support] But I think the curriculum is the big one because it has to be in that window of stuff that we have to do, so we just kept that in mind when we were looking at what we wanted to do and say, “Well this one aspect is not going to be very far along [the inquiry table] because we are providing the things you have to study”, but we can do that in a way that makes it more interesting – hopefully. (L2-06:52)

She went on to say,

…but what I think is hard and why I took the class in the fall is we still have the same curriculum, we still have the same set of standards or expectations, outcomes whatever - how do I take what’s there, on my own, and flip it around so that its more inquiry based for our classroom students? [teacher reflection on practice] (L2-10:05)

Lynne’s process of change was accelerated by the fact that she became involved in a higher-level science course that compelled her to problematize her practice as an elementary science teacher. This in turn caused her to reexamine her science lessons and the teaching practices that she was using to work with her students on a daily basis. Subsequently, she started to think about every unit that she taught in second grade from a different perspective and her frustration was heightened. As she explained in the following excerpt from her second interview, after rewriting the nature unit, she began to examine her unit on “Seasons” and recognized gaping holes in the learning process for her students. She explained,

Not only that, but again it’s forcing you to sit and think about your practice which is one reason why I really like the PDS classes because they tend to do that you know we, I can’t remember when in the course at some point we were supposed to look at the current unit and figure out ways to make it more inquiry based. [teacher reflection on practice] (L2-18:23)

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Lynne’s reflection on her practice led her to think about science concepts differently. In her first interview, Lynne briefly discussed her frustration with how to teach the seasons unit in an inquiry-based manner. At that time, she did not know how it could be done. However, after taking her course, Lynne discussed how she had learned that there are valuable reform-oriented teaching methods that she could use, and did use with her students to develop more inquiry-based lessons. She described,

Seasons! Got nothing here! But you know we did talk about temp probes and how you can see if you wear a pair of mittens that the temperature is different than when you’re not wearing mittens like when you are holding an ice cube that was cool [lesson modification toward reform] and I have never thought about – I thought, “Seasons”, chuck it, I didn’t see the value of doing anything with seasons because they already know everything that I could possibly teach, there was no new material that I could go over that I could find. So we did do that. In fact, my intern did a couple of those lessons with them to look at seeing how temps change when you’re wearing the stuff you wear in the winter and when you’re not and she said they were so excited to do that and they thought that was really neat watching how the things change [student excitement toward science] and I went, “Ok. So there was something that I could do with seasons that was more than just in the fall the leaves fall off the trees, winter it snows, spring plants begin to bud and summer animals have babies.” Yeah! (L2-18:23)

Finally, for Lynne, during the two years that she continued as a PDS mentor teacher, she became focused on her science teaching practices and making science meaningful for her students. She met this challenge with both frustration and achievement and expressed her intent to continue making changes to her practice in the years to come.

That’s why I’m looking forward to seeing what happens in the next couple years. I mean granted we still have to teach in the next few years and try to find ways to make what we teach until they change things more interesting, more inquiry based for the students, but I can’t help thinking, I’m hoping that you know when they get in to revising the curriculum that they try to do it more on Table 2.6 and less out of the book, you know, it’s - I don’t know what’s going to happen, but if not, I guess I’ll be doing it myself! (L2-21:12)
CHAPTER 6: ASSERTIONS AND DISCUSSION

Change is inevitable…Growth is intentional

6.1 Introduction

As described in Chapter Five, eleven study participants provided unique stories of practice in regard to the ways that they think about and teach science in their elementary classrooms. An examination of data for these participants demonstrated numerous commonalities and differences in regard to reform-oriented science teaching practices and as a result, seven assertions emerged from the data analysis.

The following seven assertions help to describe and answer the research questions outlined in the study. These assertions are based on what the mentor teachers reported about the changes that they made in their teaching practices toward reform-oriented methods and the processes involved throughout their change stories. Table 6.1 provides an overview of each assertion and the research question to which they are linked.

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Assertions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How do mentor teachers describe their science teaching practices and how they have changed as a result of participation in PDS?</td>
<td>Refer to Chapter Five – Participants’ Stories of Practice – Stories of Change</td>
</tr>
<tr>
<td>a. In what ways do PDS mentor teachers’ descriptions of practice reflect contemporary reform ideas and practices in science education?</td>
<td><strong>Assertion #1</strong>: Mentor teachers utilized reform-oriented science teaching methods in the classroom and viewed former didactic teaching methods as ineffective procedures for teaching and learning science.</td>
</tr>
<tr>
<td>b. To what extent do mentor teachers’ stories emphasize technical aspects of teaching versus epistemological changes in their thinking and knowledge?</td>
<td><strong>Assertion #2</strong>: Mentor teachers demonstrated a shift from the use of generic inquiry teaching strategies in the classroom to the use of science-specific inquiry teaching strategies and as such demonstrated a more profound view of science teaching and learning.</td>
</tr>
<tr>
<td>c. How is student learning in science reflected in teachers’ stories of practice?</td>
<td><strong>Assertion #3</strong>: Mentor teachers acknowledged an increase in student interest and excitement toward participation in science as a result of their shift from traditional teaching methods to reform-oriented science teaching methods. <strong>Assertion #4</strong>: Mentor teachers reported that science-focused discourse and reform-oriented inquiry science experiences contributed to deeper understanding and more meaningful student learning in science.</td>
</tr>
<tr>
<td>2. What is the relationship between the levels and types of reform-oriented science teaching?</td>
<td><strong>Assertion #5</strong>: Mentor teachers who engaged in science-</td>
</tr>
</tbody>
</table>
of involvement in PDS to change in thinking about and practices of teaching science? specific professional development opportunities were more likely to change their practice to more reform-oriented approaches than mentor teachers who did not engage in science-specific opportunities. **Assertion #6:** Mentor teachers reported that collaboration within a community of practice mediated a change toward reform-oriented science teaching practices.

3. What is the depth of commitment that mentors convey about changes in science teaching practices? **Assertion #7:** Mentor teachers who adopted and implemented evidence-based science teaching practices into their repertoire reported a strong commitment to their continued practice using reform-oriented science teaching methods.

Table 6.1 Assertions by Research Question

### 6.2 Assertions, Evidence and Discussion

Each assertion is presented using the following format: 1) Assertion; 2) Description; 3) Evidence; and 4) Discussion. The following table provides a description of the function of each component in the format.

<table>
<thead>
<tr>
<th>Assertion Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assertion</td>
<td>Provides a relationship derived from all eleven participants</td>
</tr>
<tr>
<td>Description</td>
<td>Provides a brief description of the assertion</td>
</tr>
<tr>
<td>Evidence</td>
<td>Provides multiple data points in the form of quotes that were utilized in Chapter 5: Participants Stories of Practice and Stories of Change. These quotes attest to the validity of the assertion.</td>
</tr>
<tr>
<td>Discussion</td>
<td>Provides a context for the assertion using available literature. Also addresses how the assertion contributes to the literature.</td>
</tr>
</tbody>
</table>

Table 6.2 Description of Assertion Format and Components (modified from Barreto-Espino, 2009)

### 6.2.1 Assertion One

Research Question: In what ways do PDS mentor teachers’ descriptions of practice reflect contemporary reform ideas and practices in science education?
Assertion: Mentor teachers utilized reform-oriented science teaching methods in the classroom and viewed former didactic teaching methods as ineffective procedures for teaching and learning science.

6.2.1.1 Description

A diversity of approaches to teaching science has been utilized in classrooms across the country over the past decades. These approaches range from traditional (didactic) approaches that focus on the presentation of knowledge by the teacher through lectures and teacher demonstrations rather than on the understanding of that knowledge by the audience to more constructivist-type approaches that account for prior knowledge and other aspects of student-centered learning.

In order to accurately describe the reported teaching practices of each participant, the researcher used the science teaching standard guidelines and the professional development standard guidelines set forth by the NRC (1996, 2000) as a measure of comparison to participants’ self-reported and described experiences of personal change in science teaching practices. These standards provided a benchmark to what were considered to be best practices in the classroom and were used as a set of structured guidelines regarding best practices. The original interview questions were not specifically structured around these standards, and as a result, some aspects of the standards were not necessarily revealed within the stories of practice. As each story of practice unfolded, many of the various features of the standards were revealed, making this a logical criteria choice for comparison.

Using views from these standards, as well as current information regarding essential features of classroom inquiry (NRC, 2000), a rubric (Appendix I) was designed as a method to help differentiate among reported teaching practices on a scale of zero to four. On this scale, a
score of zero represented very traditional, non-inquiry based practices in the classroom while a score of four represented very refined reform-oriented practices in the classroom. Based on examination of each participant’s self-reported story of practice prior to formal involvement as a mentor teacher within the PDS program in the district, his/her science teaching practices were placed along the continuum. Additionally, based on each teacher’s description of his/her practice as a result of involvement with the PDS as a mentor teacher, current teaching practices were also categorized and positioned on the continuum for each participant at the time of the original interview and again two years post-interview. This information was then compiled and arranged in Table 6.3.

Throughout this research, participants described their transformation as teachers based on their science teaching practices and how, following through the pattern of either didactic or basic hands-on activities through the realm of using inquiry as the basis for teaching science changed as a result of their experiences through the PDS.

<table>
<thead>
<tr>
<th>Rubric Scale</th>
<th>Level 0</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of Science Teaching Practice</td>
<td>Traditional Teaching Practices: Teaching by Showing or Telling</td>
<td>Activity-Based Teaching Practices: Teaching by Doing (Major focus on hands-on activities)</td>
<td>Nonspecific Inquiry-Based Teaching Practices: Teaching by Doing (Hands-on/Minds-on Science – focus is shifting to include inquiry-building skills)</td>
<td>Inquiry-Based Teaching Practices: (Beginning to think/talk about the use of evidence and explanation throughout science experiences)</td>
<td>Reform-Oriented Science Teaching Practices: (Strong focus on evidence and explanation throughout science experiences)</td>
</tr>
<tr>
<td>Participant Placement Pre-PDS</td>
<td>Lana</td>
<td>Greg</td>
<td>Paul</td>
<td>Lynne</td>
<td>Shelley</td>
</tr>
<tr>
<td>Participant Placement as a result of PDS involvement – After Interview 1</td>
<td>Lana</td>
<td>Greg</td>
<td>Paul</td>
<td>Lynne</td>
<td>Elizabeth</td>
</tr>
<tr>
<td>Participant Placement as a result of PDS involvement 2 years later – After Interview 2</td>
<td></td>
<td>Greg</td>
<td>Paul</td>
<td>Lynne</td>
<td>Elizabeth</td>
</tr>
</tbody>
</table>

Table 6.3 Levels of Inquiry Use: Participant Placement on Science Teaching Rubric Based on Stories of Practice. Information contained in this rubric is based on mentor teachers’ self-reports of their science teaching practices prior to and during involvement with the Professional Development School collaboration. Some categorical descriptions are adapted from NRC 1996/2000 Table 2.6 Essential Features of Classroom Inquiry.
The evidence to follow corresponds with Table 6.3.

6.2.1.2 Evidence

Prior to PDS

Prior to their PDS involvement, each of the participating mentor teachers had been teaching at the elementary level for at least ten years and as such, all were considered to be seasoned educators. Based on each mentor’s description of his/her science classroom, the teaching practices of ten participants were determined to be equivalent to a Level 1, being very hands-on and activity-based. One study participant described this fact-based, concrete hands-on activity enhanced practice of teaching elementary science prior to the partnership with PDS as “facts and crafts.”

“…what I called…“facts and crafts.” You know, teach a little fact, do a little craft. That’s what we did. (J1-04:42)

This information was found to be consistent with information that was gathered about the science curriculum in the school district curriculum requirements at that point in time. For instance, the school district used grade-level curriculum units that encouraged the implementation of many hands-on activities into the daily lessons to support the teaching and learning of science content or facts. Mentor teachers reported using the suggested hands-on activities and these methods were viewed by the school district as effective strategies to reinforce the content information being taught in the science units. As Marla explained:

…because in the past, science had been, you know, we had science units very much like we had social studies units. So, in our unit planning we would say, "Oh, all right, we're working on Medieval" as our social studies theme and ‘Simple Machines’ as our science theme. And everyone would bring their science unit that had been written by a group of teachers and our curriculum specialist and we'd kind of go through the main topics. And everything was pretty much written down for you [emphasis added]. Here's lesson number one or concept number one and here are some ideas to teach concept number one. Here's concept number two and again here are some things or some ideas to teach concept number two.
So, I think, I was really open to any kind of science change because science in the past had been so frustrating. (Ma1-02:31)

Hands-on teaching was differentiated from lectures and demonstrations by the central criterion that students interacted with materials to make observations or to complete a task. A typical science lesson, as described by several participants, consisted of reading and reviewing science material from a textbook, followed by a fun, hands-on activity chosen to reinforce the concept that was just taught. This method of teaching science was popularized throughout the 1980s and early 1990s and as such was used in the development of district curricular units. Nearly all of the teachers in this study were using this or a similar method in their elementary classrooms as their primary means of teaching science prior to their involvement in the PDS, and as Marla explained in the above quote, she, as well as many other teachers in the district, were ready for a change.

In contrast to the ten teachers who taught using mostly hands-on activities, one teacher was classified as a Level 0 on the rubric. This directly reflected her report of using mostly traditional methods of teaching science (e.g. lecture, textbook, worksheets) in her classroom, and using hands-on activities very minimally.

Following Initial PDS Involvement

As the PDS collaboration took hold in the school district, PDS interns entered the classrooms and had the task of implementing science in a different manner as a result of their own learning of science teaching methods in their science methods course. As interns modeled new science teaching practices, new ways of thinking about and teaching science were reportedly sparked in the elementary classrooms (Badiali et al., 2011). Students were being asked to do more than complete simple craft-like activities in science. Students were given direct experiences with natural phenomena that provoked curiosity and thinking. Guided by an inquiry
orientation throughout the PDS, mentor teachers were introduced to inquiry-based science through their interns and many of them reported that they chose to adapt their teaching style and practices as a result. According to their stories of practice, several mentor teachers showed development toward using more reform-oriented teaching methods in their science classrooms. Table 6.3 is a reflection of their “movement” along a continuum toward more reform-oriented teaching practices.

During the first interview, mentor teachers were asked to describe their current teaching practices in science as a result of being involved in the PDS. Just as with the descriptions of practice prior to PDS involvement, these stories were analyzed and teaching practice was classified based on the rubric. Although one teacher, Lana, continued to implement numerous traditional didactic teaching practices and therefore did not “move” on the rubric until the time of her two-year post-interview, the remaining ten participants showed growth and change toward more reform-oriented science teaching practices. Of the ten teachers who were at a Level 1, five progressed to a Level 2 on the rubric as a result of their PDS involvement. Level 2 teaching reflected reports of having adopted an inquiry orientation toward teaching in a general sense and using general inquiry skills such as questioning as a tool in their science teaching. These mentor teachers were in the early developmental stages of viewing science as more than a body of facts and were beginning to incorporate more student-centered practices in the classroom.

Three of the ten mentor teachers progressed to a Level 3 as a result of their initial PDS involvement. Level 3 on the rubric is reflective of being in a slightly more advanced developmental stage of reform, in which science is beginning to be viewed as slightly different from other curricular areas. Teachers who progressed to this level recognized the importance of using not just generic teaching strategies, such as a KWL chart (Ogle, 1986), but were able to
establish an understanding of the need for a more science-specific strategy, an adaptation of the KWL such as a KLEW chart (explained in detail as a scientific argument mapping strategy in Assertion Two). These teachers were beginning to understand the importance of evidence and explanation in learning science, but did not always use it on a consistent basis to guide experiences in the classroom.

Finally, the stories of the remaining two participants reflected growth to Level 4 on the rubric. Level 4 is reflective of being at a highly advanced stage of reform, in which science teaching is viewed through a lens of evidence and explanation on a consistent basis in most experiences provided to students.

Most notably, all but one teacher reported a change in former views of science teaching. Their stories of practice reflected change from former didactic methods. As Bobbie, a teacher who had progressed from Level 1 to Level 2 on the chart explained,

How it [teaching science] used to be, "Oh, this is such a cute idea and this activity is going to be so much fun!" And you want it to be enjoyable for the kids, but now it's deeper than that. You know, what really are the children getting at? What is this telling us about how the children are responding to whatever science unit that we're doing? And I think that has evolved as it's become more commonplace to be thinking in a more inquiry way. (B1-27:26)

At the time of this initial interview, some mentor teachers had been involved with the PDS for as little as two years while some had been involved for seven years. Interestingly, all but one participant had discarded their previous ideas about how to teach science effectively and embraced an understanding of the significance of teaching children using reform-oriented methods. Julie, a mentor teacher who progressed from Level 1 to Level 4 on the rubric, described how science in her elementary classroom transformed from her basic hands-on approach of “facts and crafts” to implementing reform-oriented strategies:
So, it [science] is more observable. So, also making science more appropriate for our students in that these are things they can physically see, or like those life science things, and observe, and notice, and document. Or for science stuff like the magnets, or light and sound, where they can physically design experiments and those kinds of things. So I think that's really changed. And [I am] a more confident science teacher. (J1-35:30)

Julie was not alone in her description of her changed science teaching practices as a result of her PDS involvement. Shelley, who had developed her practice to Level 3, also discussed the significance of incorporating reform-oriented strategies such as questioning, observation, and explanation into her daily science teaching routine. She first described the importance of explanation building:

And the way we do it now is more… just like science, science is the same way. Did that float? Yes, why? Why do you think? Why did this float and this not float? Compare these things. You know, what is the same about them? What's different about them? It's not, “yes, this floated”, not “this didn't, finished.” Yeah - it's the explanation… the thought process, the discussion, the noisiness in the room that makes it powerful, not that they got the right answer. And I say to my students all the time, the answer to me is the least important part. It's the explanation and your thought about it. (S1-24:10)

Then she went on to describe the importance of in-depth questioning and student discourse in the classroom. She said,

And even, you know, raising their hand, one person gives an answer, then I want ten more people to give their answer, or their explanation, and in science, if they have a partner, I want them to discuss it and be able to tell what their partner's idea was to me, not what their idea was. Because primary kids are so, you know have blinders on, they see it their way, and if you force them to have a conversation and present the other person's perspective, then they're learning that, they're thinking about that. (S1-24:10)

Later in her interview, Shelley described how these reform-oriented strategies had crossed the curriculum into her other classroom subjects as well:

I don't know that the other way [of teaching] is "wrong", it's just, well, knowing education, it all travels in circles and you revisit. I think the way that we teach science is showing up a whole lot more in the way that we teach everything else now, too. In that, experiment, let's draw, let's predict, let's draw conclusions, let's
discuss why we think this is the answer. And that was more of a science, that's what you did when you did 'science' in that half hour block of time that you set aside for science, and now it's a piece of math, and now it's a piece of even the way we read books. You know, look at the front cover, what do you think is going to happen in this book? Why do you think that? Now, look at the pictures and see if there's any evidence in there that confirms why you thought that this was going to happen. And that's, you're seeing that inquiry-based science across the board now. (S1-38:43)

In addition to Shelley’s communication regarding her changed practice, Karen talked about how the use of reform-oriented strategies in science pushed her students to think in different ways than they had before when it came to “doing science.” She reported,

So, I think for the kids to have to write about what they've learned, is also an important processing thing for kids, getting them to reflect, draw a picture, label it, whatever…. It can push their thinking. (K1-24:35)

Mentor teachers talked about their change in practice in a way that reflected confidence and self-assurance. Each mentor reported on his/her self-improvement as a science teacher as well as his/her confidence and affirmation in adopting reform methods. As Julie clarified,

Well, certainly personally I feel like, or professionally, I guess, I feel like I'm a much better science teacher. I'm becoming very comfortable with questioning. I feel I'm getting much better at asking those questions to get my students to think. So that part [utilizing inquiry strategies], I think, has helped. (J1-33:47)

As a result of her self-assuredness, Julie’s confidence in her abilities grew. She said,

I question what I'm told to teach more now, and if I don't like the way something is laid out, I'll look for a different way to do it. For instance, we have to teach this underwater life unit, which was always about the ocean and the different parts of the ocean, and we're about as far from the ocean as you can get! So, for Margaret and I it was like, “Well this just doesn't make sense anymore. What can we do to make these concepts more [understandable]?” So, we went to Connie and [she] gave us some ideas, and we completely changed the way we taught that unit. (J1-33:47)

As Julie’s own confidence grew, she reported on how learning how to make these changes then gave her the confidence to extend her learning and new knowledge with others in her district. She explained,
And now… I'm on this science committee for the district thinking about making changes in the primary science units, and we're looking at those STC [Science and Technology Concepts] books… So, it's more observable [for the children]. Also, [it's] making science more appropriate for our students in that these are things they can physically see… and observe, and notice, and document. Or for web science stuff like the magnets, or light and sound, where they can physically design experiments and those kinds of things. So I think that's really changed.

(J1-33:47)

Julie’s role on the science committee allowed her to work with and learn from others about ways to change the district science curriculum to reflect more reform-oriented teaching and learning. As these experiences built and affirmed her confidence in her own abilities and knowledge, the PDS as an organization afforded her the opportunity to take that knowledge and those experiences and share them in an even larger community. She talked about extending her experiences beyond her own school district to state and national conferences on both science education and professional development school communities. She stated,

…being a more confident science teacher. I've also had the opportunities to go to conferences and to present my work with inquiry and science, which I never [was able to do before]. I mean, to get up and speak in front of people about what I'm doing is affirming, but also pretty rewarding. I have people come up to me and say, “Wow, here's my card. Email me about that project.” It's really exciting!

(J1-33:47)

As Julie’s affirmation of her change in practice came from her peers, Shelley’s affirmation came from the changes that she witnessed in her children. She said,

Watching what the interns were learning and how they were bringing that into the classroom and how the students reacted to that. And how, the piece that the interns do that I think allowed me to change my practice was the pre-assessment, the post-assessment, what did you learn, how do you speak about it? That is very powerful because the kids are learning. And we never test primary kids on how many facts do you remember about or anything like that, but just the way they could speak about what they were learning and the excitement that they brought to it. And when is Miss So-and-So going to do another lesson? And it's really… just was a really powerful thing, not just to watch the interns, but to watch the students. And so, it really gets me thinking, you know, this works, this is good. They're excited about it, and they're learning, how can I change the next
piece of this unit, or the next lesson that we typically did this way or that way?  
(S1-32:21)

This affirmation, both at the personal level and the level of the student contributed to each teacher’s story of change. Therefore, after initial involvement as PDS mentor teachers, no matter how many years each participant had served, ten of the eleven participants had adopted an inquiry orientation in regard to science teaching practices. Additionally, all ten of these participants reported a strong conviction to the merits of adopting an inquiry orientation in science and the significance of using reform-oriented methods on a consistent basis in the elementary classroom.

Two Years Post-Interview

Two years following these initial interviews, study participants were interviewed for a second time in order to follow-up on each teacher’s progress and practice of teaching science. One of the main reasons for this second interview was to determine if each participant’s science teaching practices would remain consistent with former descriptions. For each of the ten participants who initially reported discounting former didactic teaching methods in favor of adopting an inquiry orientation and using reform-oriented methods, they reported that they continued to use these methods to teach science. The benefit of not falling back on traditional methods of teaching science was important to these mentor teachers. As Greg stated:

The more you can get them involved in something – doing rather than just talking or showing – that is important.  (G2-15:44)

Furthermore, Lana, the one participant who remained skeptical of using these inquiry methods after her first two years as a mentor teacher recognized the impact that these small changes in her teaching could have on her students in science. She explained the difficulty that she had in
letting go of her traditional methods, but went on to discuss in depth her ability to now recognize
the impact that it has made in her teaching philosophy. She said,

It has taken me to actually to almost bite my tongue, to grit my teeth and to let it
happen knowing that I need to stop sometimes measuring students’ success by
them being able to answer my questions. And looking at the questions they ask.
And honestly, the first time it happened, I really did have to just almost tell
myself to shut my mouth and to let it happen… And after it happened a few times,
I’m fine… But then when I really looked at it, I never really saw the pendulum in
inquiry. I’ve been here for 20 years. It’s really not a curriculum. It’s really not a
teaching style. It’s really a philosophy of learning, in my opinion and it makes
the most sense to be in science but truthfully it’s in every subject. (La2-06:25)

In summary, although some of the participants developed their science teaching practices
to a higher level on the rubric, one fact remained - every one of the eleven mentor teachers
involved in this study utilized reform-oriented science teaching methods such as student-focused
questioning, observation and explanation in his/her classroom and continued to view didactic
teaching methods as ineffective. Each mentor progressed from levels on the rubric that did not
involve using inquiry as a basis for teaching (Levels 0 and 1) to levels that utilized reform-
oriented methods on a varying scale (Levels 2, 3, 4) while simultaneously having an inquiry
orientation toward science teaching. Additionally, each participant reported with certainty that
former traditional methods of teaching science were ineffective for teaching and learning science.
Margaret summed it up best when she described her experiences of being a mentor teacher and
how her dedication to utilizing reform-oriented science teaching methods could affect others:

[I was] pretty green at the beginning and really needed somebody to talk to about
it. But the more you work with somebody, [the more] you feel empowered… To
me it’s like affecting the next generation of teachers, so why not? To keep
moving forward and asking and looking… Time and energy? How can you not
give that to the passion of teaching? Where do you draw the line? What we want
is to keep them moving forward in their scientific thinking. (M2-24:46)
It was not always an easy process, but one that participants expressed as both necessary and iterative. Learning to take on the challenge of thinking and teaching differently, as Julie reported, reflected the accounts of every participant. She said,

Well and I think, too, it’s just such a different way of thinking… I think you have to experience it to see that it does work. I think it’s scary for people especially if you didn’t learn that way. And you are uncomfortable with science to begin with and you are uncomfortable with the unknown. Because you really have to be ok with saying, “Well we might get there, we might not.” And you have to be comfortable with questioning and I think that’s something hard for a lot of people, me included. I think we just get better at it but I sometimes don’t feel like I’m all the way there yet. (J2-17:24)

6.2.1.3 Discussion

A constructivist viewpoint suggests that learning occurs when you question your own preconceived ideas and that the best way for this to occur is through exposure to experiences you cannot reconcile readily in your own mind with the understandings and experiences available to you. One such method of doing this in a science classroom is through the use of hands-on activities. Hands-on teaching is a very popular and very basic method of teaching science that was popularized throughout the 1980s and early 1990s. By definition, hands-on science is defined as “any science lab activity that allows the student to handle, manipulate or observe a scientific process” (Lumpe & Oliver, 1991, p. 345). Hands-on science teaching is perhaps the first and most basic building block on the steps to teaching science through inquiry. Unfortunately, without proper follow-up, hands-on activities in science can become disjointed and lack the connection to the next steps in learning that connects activity with understanding.

In practice, inquiry science often occurs on a continuum (Jarrett, 1997) and includes not only hands-on opportunities for children to engage in the practice of science through activities and experiences, but also importantly allows for the building of opportunities to connect meaning through those activities. Inquiry is the agent of constructivism, allowing for those connections to
be made for children to develop their own questions about phenomena and to seek their own answers to those questions.

According to the NRC (2000), one approach to teaching science, which remains common today, focuses on teachers providing their students with sets of science facts and with technical words to describe those facts. Science classes of this type treat education as if it was “preparation for a quiz show or a game of trivial pursuit” (p. xii). These didactic methods of teaching science are teacher-focused and unfortunately ineffective. Despite children’s natural fascination with exploration in science, for many years the teaching of science consisted of attempts to skillfully impart scientific knowledge to children. Still today, teachers of elementary science typically perceive their job as directly related to the amount of scientific content to which they can expose children with the belief that science is only factual in nature, or conversely, there is a lack of attention to content altogether. Regrettably, elementary teachers often feel inadequately prepared to teach science and therefore revert to traditional right and wrong fact-based teaching methods. Many teachers find it difficult to change how they teach science because they learned science in ways that are very different from inquiry methods (Loucks-Horsley et al., 2003). Current literature confirms the assertion that traditional forms of teaching science through these didactic processes and unfocused hands-on activities are ineffective in the elementary science classroom.

Fortunately, teaching science in the elementary grades can be designed “for all students to develop critical basic knowledge and basic skills, interests, and habits of mind that will lead to productive efforts to learn and understand the subject more deeply in later grades” (NRC, 2007, p. 34). Research supports the assertion that using inquiry methods to teach science are the most effective and meaningful ways of helping children learn scientifically (NRC, 2000). Competent
teachers encourage children to wonder, to ask questions, to explore possible answers to those questions and to construct their own evidence-based explanations.

As teachers recognize the effects their change in practice has on the students in the classroom, they are more likely to continue those practices. For example, as Loucks-Horsley and colleagues (2003) explain,

> As teachers begin to see science teaching as less a matter of knowledge transfer and more an activity in which knowledge is generated through making sense of or understanding content, they begin to see their own role as teacher changing from a direct conveyor of knowledge to a guide helping students develop their own meaning from experiences. (pp. 195-196)

Inquiry science teaching approaches encourage learners to observe, ask questions and formulate explanations based on their own curiosity. When teachers adopt these strategies as teaching methods in their classrooms, not only do students feel more motivated to learn science (NRC, 2000) but they also retain a connection to and engagement in their own learning of science. Teachers who have embraced the complexity of teaching using this lens of inquiry tend to accept this pedagogical change and are less likely to revert to former practices because of the achievement that they observe in their students.

As Loucks-Horsley et al. (2003) reported, most research indicates that it can take several years (3-5) for teachers to fully implement a new practice or program. This was supported by the evidence in this study. After at least two years, but not more than seven years, all but one of the study participants reported an increased use of reform-oriented science teaching strategies in the classroom. For the remaining participant, it took her four years of participation in the PDS before she accepted the legitimacy of these practices as part of her daily routine and philosophy in teaching science.
In addition, evidence from participants’ self-reports in light of the literature confirms that teachers paid attention to implementation for several years in order to progress from an early focus on management to a later focus on measuring student learning (Loucks-Horsley et al., 2003). All participants in this study have progressed in their science teaching approaches to where each is teaching using at least basic reform-oriented approaches toward science teaching. However, not every one of these participants has adopted the use of science-specific inquiry approaches on a consistent basis. Assertion Two of this study examines this idea more closely to determine how or why some teachers have moved toward a shift from generic inquiry approaches to the use of more science-specific strategies.

6.2.2 Assertion Two

Research Question: To what extent do mentor teachers’ stories emphasize technical aspects of teaching versus epistemological changes in their thinking and knowledge?

Assertion: Mentor teachers demonstrated a shift from the use of generic inquiry teaching strategies in the science classroom to the use of science-specific inquiry teaching strategies and as such demonstrated a more profound view of science teaching and learning.

6.2.2.1 Description

Assertion one captured how participants, as a result of their involvement within the PDS community as mentor teachers, changed their teaching practices from traditional to inquiry-based in the science classroom. Assertion Two reports in greater detail on the finding that, in addition to the general inquiry-based shift in pedagogical practices, many of the teachers in the current study reported the significance of utilizing two very science-specific strategies that they employed in their daily routine of teaching science – (1) KLEW charts, and (2) science talks.
These science-specific strategies allowed mentor teachers to better understand the difference between basic inquiry skills and reform-oriented science practices in the classroom. As a result of the nature of KLEW charts and science talks in making student knowledge public, mentor teachers reported better understanding of science concepts not only for their students but also for themselves.

Mentor teachers in the current study, as stated in this assertion, demonstrated a shift from the use of generic inquiry teaching strategies to the use of these two science-specific inquiry-teaching strategies. Through the PDS partnership and professional development opportunities, mentor teachers learned about and implemented these strategies into their teaching repertoires.

6.2.2.2 Evidence

Following is evidence that supports the assertion that participants have not only recognized KLEW charts and science talks as critical and unique to the science curriculum, but have adopted these strategies as routine in their classrooms.

KLEW Charts

A KLEW Chart is an adaptation of the traditional KWL Chart, an instructional technique designed by Ogle (1986). In the traditional KWL, teachers activate students’ prior knowledge by asking them what they already Know. Then students (usually collaborating as a classroom unit) set goals specifying what they Want to learn. After taking part in classroom readings or short activities, the students discuss what they have Learned. KWL graphic organizers are designed for use with any school subject and are not necessarily subject-specific. Alternatively, KLEW Charts are subject-specific and were modified and designed expressly for use in the science classroom (Hershberger, Zembal-Saul & Starr 2006) as an instructional strategy used to support argument construction in science lessons as learners negotiate coherence among claims and
evidence and consider alternative ideas. It was developed by a university science education faculty member and mentor teacher within the specific PDS that this research has taken place. KLEW stands for Know, Learning, Evidence, and Wondering. Students articulate their prior knowledge (i.e. what they Know or think they know), the claims they are negotiating (i.e. what they are Learning), the Evidence upon which claims are based, and the new testable questions they are interested in pursuing (i.e. their Wonderings) (Zembal-Saul, 2009, p. 696). This adaptation differs from the traditional KWL because it emphasizes the importance of constructing claims from evidence. Additionally, it encourages students to conduct further investigations based on their questions about phenomena.

KWL (Know-Want to Know-Learned) charts have been promoted as a reading comprehension strategy for many years. Initially, all of the mentor teachers reported on use of KWL charts in the classroom as a basic inquiry strategy used in subject areas such as Reading, Social Studies, Language Arts and Science. Elizabeth explained in the following quote how she used KWL in a superficial fashion as a fixed method to write children’s ideas down on paper. She chose which topics she felt she could really discuss with the children based on her own beliefs about what children did and didn’t know already about a science topic. She reported,

Well, I've always done those KWL charts. I mean, that was always part of what we would do, but it's a little bit different now [with KLEW]. I don't know that I would have done those for as many things [science topics] as I do now. You know, like if I really didn't think that the kids would [know much]. For example, [the concept of] “day and night.” I don't think that I would have expected any kids to know or maybe one or two to know about what was day or night, so I wouldn't even bother [doing a KWL] because I'd think, "Well, they don't know, so why go there?" But now I do more topics. I will just see, just to kind of get a feeling for what is it that they do think. Because I knew they didn't necessarily know, but I didn't know what they did [emphasis added] think. So that kind of helps you to see where you know exactly what level they're on and a lot of it is very fantasy. They just have a very fantasy-based knowledge of a lot of the things that are going on, you know? And now I will do that. I mean, I might have said, "What do you know about insects?" because I would figure that they would know
something about insects, but I might not have asked, "Well, why do you think there's day and night?" or something more of a complex kind of idea. (E1-41:28)

Elizabeth’s use of KWL charts in the classroom was not unique. Many of the participants reported sporadic use of KWL, and interestingly, its use was reported more as a graphic organizer or way of organizing the responses given by students instead of a method of probing into student thinking or understanding of a science concept. As Greg reported, using KLEW charts added a change to his science teaching vocabulary to probe for that understanding from the time when he just used KWL charts in his teaching. He stated,

The more you can get them involved in something – “doing” rather than just talking or showing – that is important. And certainly, trying to incorporate their questions and their wondering in the whole process because we usually start every science unit doing KLEW charts. Like what do they already know and what do they think they know. We talk a lot about what is your evidence. And that is certainly a piece that wasn’t there before the interns [PDS]. I don’t remember using that vocabulary [prior to PDS]. (G2-15:44)

Furthermore, at the time of their initial interviews, many mentor teachers were just learning about how best to use the charts and were often beginning to understand how they were “different” from KWL. As a result of PDSs strong focus on the development and use of the KLEW chart (Know-Learned-Evidence-Wondering) as an explanation mapping strategy for the science classroom, more teachers began to use them more consistently and teachers recognized the relevance and the important connections their students were making in their learning. By modifying the KWL to include a component labeled “evidence”, teachers were compelled to ask the students to explain how or why they knew that piece of information that they were sharing with the class. Karen recognized the importance that focusing on evidence added to the learning process of her children.

Another thing that the science course [teaches]...that the interns always bring back [is] the KLEW chart. K-L-E-W. And I had always learned it as KWL. But, I like the thing! I like the evidence idea, what's your evidence? And my interns
have been really good about that. So we always get a great big piece of bulletin board paper that might stretch the width of two of those book shelves and you know, he, that's what Mike did this year, he had 4, you know the 4 parts to it, and in the very beginning it's just really a nice way to see what they do know about the topic. But as he goes along he worked really hard to get the kids [thinking]. And my other interns have done the same thing. What's your evidence? What's your proof that, of what we've learned? And I think that whole idea is really important in science, not that you've seen something or that you can tell a fact, but what's your evidence for it? So, to me, that's a really nice little piece that that's been important in science in my room since... I've had interns. (K1-21:20)

This recognition of the significance of adding the “evidence piece” to the use of the chart was consistent among all of the participants. Focus on evidence in conjunction with a strong focus in student wonderings was important to each participant’s change process. Julie believed that it was this change in focus that helped her science teaching become more student-driven and relevant to her students’ understanding of science concepts. She described,

Well, definitely [I now use] the KLEW chart. Yes, and also thinking about doing more student-driven science. Using, like with the magnet unit, using their wonderings to propel the unit more than the content that the district says you have to teach. And using the idea of using that evidence, and making them back up their claims with the evidence is very powerful. I had used KWL before, but not with this KLEW thing, and not focusing more on their wonderings. (J1-14:13)

Each participant expressed his/her success with using the KLEW chart in the science classroom, especially for its more detailed focus on student ideas about science concepts and use as a learning tool rather than simply a graphic organizer. Interestingly, despite its popularity with mentor teachers, implementation of the KLEW chart was not always an easy process for transition into regular usage. Using a KLEW chart challenged even the most seasoned teachers at times and for many took years to adapt to their own comfort level. As Shelley explained,

That is something that every year, the interns do it year after year after year [KLEW charts]. I don't do it quite that formally. What I find in my own personal teaching is that going back to that chart is a challenge for me. So, the chart itself is not as useful as the idea. So, and then having a conversation with someone else and explaining it. You know, “what did you learn” is not where it ends. “How do you know?” - that is where it ends. But I don't do a very good job of compiling
everything we learned about a particular topic at the end, and that's what I think the KLEW chart gives you is that compilation - that “Okay, now look at it all together.” That, I think, is powerful. (S1-26:13)

Regardless of the amount time or effort it might have taken for each participant to determine its usefulness, every participant used it in his/her classroom to some degree and consistently reported that it has not only helped him/her become a better science teacher, but it has aided in the development of students as learners of science. As Shelley stated above, it helped her students to explain their answers more clearly. Some participants, like Karen, found its usefulness in the process of gathering information from the children to guide their wonderings about science topics, something that she had never done before in science class:

You know, you miss so much of what the kids know or want to know that maybe it’s related but not mainstream. But… I just think it's so great to pick the kids brains on things. This is what they know, and this is what they want [emphasis added] to know. (K1-23:28)

Still others discovered the importance of not only asking their students what they knew about a science concept, but to help them learn to explain why or how they knew it. By extending their questioning of the children, Margaret and Julie reported the development of a more complete understanding of what they knew about their students, and felt that their students were able to think metacognitively.

As the students worked, we walked around watching and listening. We learned that one way we could get to their wonderings was by listening for their surprises. When Charlie was surprised that the magnet stuck to the metal table, but not the metal chair, we helped him turn that statement into the wondering: Do magnets stick to all metals? When Jessica noticed that she could make a paper clip stick through a book, we helped her turn that into the wondering: What can magnets “stick” through? (Excerpt from Magnets: Attracting Student Wonderings)

Thus, use of KLEW charts as a science-specific strategy was common among participants as a tool that has become a routine fixture in their classrooms. This shift from the use of generic
KWL charts as graphic organizers for ideas in the classroom proved to be instrumental in the change process for mentor teachers on their paths toward more reform-oriented science teaching. Paul may have summed this idea up most concisely when he stated the following during his interview:

[I think science] curriculum should just be a series of questions, you know, instead of objectives and activities, just a series of questions that you explore with the kids and some of the questions can be the kids' questions...We do a lot of stuff with KWL charts and I'm kind of ignoring them. We do a KWL chart, we put it up, it looks nice, and then we go do a prescribed lesson that's in the manual instead of paying attention to what the kids could be asking. So, I'm not sure that the kids are really good at asking the questions or knowing what it is because they're kind of used to - they're kind of on a welfare system - you know, ok, we play this KWL game with all of our teachers and we'll sit and ask some questions and they'll put the chart up in the room and we'll never - we never revisit the chart or we never answer our own questions. So, I'm trying to with all the other things that I teach, trying to make it more inquiry, what I think inquiry science would be [with the KLEW charts]. (P1-19:34)

In conclusion, KLEW charts as an instructional process to help learners articulate claims and link them with supporting evidence in order to provide justification for their claims (Zembal-Saul, 2009) are an integral part of a reform-oriented science classroom. As Marla summarized,

I think one thing that inquiry has taught me is we had always done KWL charts, you know. I like the introduction of the "evidence" - support your reasoning. That's huge. Don't just tell me, “This is what I think.” “Well, why?” [Being able to] support your reasoning is huge... I think it's learning that is so genuine that it just becomes part of who they are and the way they deal with information in the future. I mean, it's really neat when you have a kid say, "Well, what's the evidence, what's your evidence for that?" Oh, ok, that tells you that they understand the whole process. Which is really exciting! (Ma1-33:19)

Science Talk

Another science-specific teaching strategy that was utilized by mentor teachers was the concept of science talk. As is the case with KLEW charts, science talks are also subject-specific. While every mentor teacher talked about the importance of discourse in the inquiry-based classroom, the use of science talk in their science classrooms was described as a unique or
specific tool for aiding in the understanding of science concepts. According to the NRC (1996) talk in a science classroom (or what this research refers to as science talk) is a vehicle that allows students to engage in discourse that prompts for critical thinking while eliciting the use of evidence in formulating explanations. Formal and informal science talk focus on the same purpose, to engage students in meaning-making discourse practices. In the case of this research, science talk often went hand-in-hand with the implementation of KLEW charts in the classroom. Mentor teachers in this study viewed this as a critical aspect in the process of teaching science. As Julie discussed,

I think that [science talk] is critical. I think there are so many people out there who have a lot of misinformation as to what inquiry science is. Some people think it is just students asking questions, so [some people think] it’s all based on student questions, which it isn’t. Or some people think it’s just hands-on, well, they’re doing things. So I think they miss that evidence, to me that’s the key, collecting data, providing evidence. That’s really what inquiry is – using that [evidence] to answer the questions. (J2-24:39)

Prior to involvement in PDS and learning about science talks, mentor teachers often engaged students in talk that viewed the sharing of results as the main outcome focus of a science lesson. To tie in with KWL charts, for example, students often shared what they learned about a science concept, but teachers rarely asked students to elaborate on their understanding of that learning (i.e. asking students how or why to probe for comprehension or interpretation).

As with the implementation of KLEW charts into the classrooms, it took a few years of practice for several mentor teachers to learn how to effectively integrate more sophisticated methods of talk into science instruction. As novices, many mentor teachers’ described their integration of science talks in the classroom much like Elizabeth described the way her interns practiced it. Often mentors were learning right along with their interns. She described:

I think it is interesting to hear the interns in the very beginning when they first do their science talk with the whole group and they’ll say, "They really seem to know
a lot." But then they've only called on the 5 or 6 kids who really know a lot. So I say, "Why don't you try calling on some of the kids who don't have their hands raised." Say, "We're not going to raise hands today." Just call on everybody or random people and you'll get a very different view of what the kids know. That's important for them [the interns] to see because they do tend to call on the kids with their hands raised and they're the ones who know probably more, unless there are those random kids out there who still don't know but they still they never get discouraged with things. (E1-42:49)

Practicing discourse through a teacher-centered generic approach gave teachers a one-sided view of what children in the classroom did or did not know. Use of talk in classrooms in this manner lacked both depth and a connection to the meaning-making process and in the end could not be considered true science talk as it was more of a question/answer session masquerading behind the label of “science talk” because the students were talking about science topics. As Julie reinforced, meaningful use of science talk takes time and effort to implement correctly.

The importance of having mentors who are comfortable is [critical]… it’s so much easier to put our four little stations and do that and be done with it. It’s hard to have a science talk and you forget that that’s the key to it. The stations, the lessons, the experiments, they’re fun but unless you can pull it together in a science talk kids don’t really get as much out of it. (J2-24:39)

Often teachers reported that authentic science talk in elementary classrooms began by involving the students in teacher-led discussion where the students engaged in rich discourse about science concepts. Marla talked about the reaction of her students to her early science talks. She said, Oh, they love[d] it! Because they're the ones then sharing their discoveries with you and then there's this rich discussion - "Well, I'm not sure that that's true" - and suddenly you have a buy in by more of the kids because it's not just here is a paper, here is the steps for the experiment, tell me what you find and tell me by writing several sentences. It's a discovery and everyone is involved and excited about it and they’re jumping out of their skin trying to tell you what they have found and the evidence that they have that supports their findings. (Ma1-31:48)

However, as mentor teachers learned to engage students in science talk, they came to consider it to encompass more than asking the students questions and expecting them to simply answer those questions. As mentor teachers became more sophisticated in their practices, students also
became more comfortable with sharing their ideas and reasoning with each other and began to challenge each other’s ideas. As Julie described,

The students get more and more excited – they begin to think about – like evidence becomes easier for them. You know, “what’s evidence? What do you mean by that?” …and you still get one or two that say that, they are getting used to saying, being able to say, “well I know that because…” (J2-08:30)

Margaret agreed with Julie. She said,

Well, they [the students] have excellent wonderings. And if we really hear what they're saying, and I know that we have an objective, and it's kind of in that science talk… I mean, where are we going to take that wondering? How are we going to get that evidence? It’s in [the science talk]. (M1-07:02)

This quote attests to the idea that although there was no definition of the right way to conduct a science talk. Over time, the descriptions of implementation revealed a more highly developed discourse practice. For example, as Shelley reported on her use of science talk in the classroom:

Yes, definitely, that's definitely a science talk. And I mean I will do them in different ways depending on what we've learned. I might have 5 different kids explain something to the whole group or I might say, turn to your neighbor and share your idea, or I might - it depends on what it is and how we do it. So they take different forms, but science doesn't end when the experiment is finished. You have to have the science talk in order to [bring it together]. (S1-27:34)

Margaret also shared how her growth in the use of science talk focused specifically on allowing herself to not only listen more closely to the children and but to also accept their explanations without being judgmental. She described this self-learning process in the following description of her students’ learning during a science experiment on germs. She described,

But then the idea that I've grown on is, “What did they learn?” This kid put, "If you put dirt on a piece of bread, you will get a lot of mold." Now, I wouldn't have thought that should be the answer, but that's what he learned. I thought that was pretty cool. And, let's see, some of these are pretty easy to read. This little girl I thought was cool, too. She said that "you should wash your hands to be healthy, and if you're healthy you feel good." Now, I didn't help them with these, that's what they drew... I mean, it came from our Science Talk, we had a science talk and from that science talk then they went back and wrote this. And, I think what
I've learned from inquiry is that letting the children come up with their own answers is pretty important, and I thought that was pretty important. (M1-11:54)

Finally, Paul made a valid point as he described the significance of engaging students in meaningful science talk in the classroom for the purpose of gaining sound knowledge of what students in the classroom do and do not understand about a science concept. He explained,

The kids will do anything and you can make it look like we're doing calculus, or you can make it look like we're doing an advanced science kind of thing, but what do they really get out of it? You listen to "kid talk" and listen to what they are getting out of it, it's not always what you as an adult think. (P1-22:11)

Science talks served as an important function for Paul in that by listening carefully to his students’ ideas, he could identify their current ideas and understanding of the phenomenon being studied more so than assessing in more traditional ways. Margaret’s description of a situation when she thought all of her students grasped a concept about magnets but learned that they actually did not know the concept supports Paul’s generalization about not always knowing what our students understand without an effective science talk. She described,

And that's the thing... they've answered their question, they're o.k. and they don't want to play. They're done playing with it. But [this other group of] children were still into kind of playing, and I thought they [all] had the answer that they [the magnets] flip because of the poles, but then we went to the science talk and there was only part of the children who could answer that. And after that I thought, “Gee, they've done it enough times.” But then, they hadn't done it enough times... when you think about what they've learned, and what their evidences are and then you go back and you see if they have any more questions... To teach science this way is risky because we don't have any outcome, you don't know, I mean you have to do your own assessment - what have they learned? It's time consuming to do it this way. And it takes a lot of energy to get those science talks going, to hear what kids want to say and to set it up. (M1-23:15)

So, science talk as a specific inquiry strategy in the classroom became an important part of the routine of science lessons for participants. Science talks made students’ thinking public, which then allowed teachers to identify current ideas of science concepts under study. Focusing on
questioning students about what they were wondering as well as what students thought they knew and understood about science concepts allowed for improved knowledge for the mentor teacher in the classroom as well.

6.2.2.3 Discussion

Teaching science in the elementary school is an ongoing inquiry into students’ ideas about the natural world. In order to guide this inquiry, teachers must be able to recognize and understand their students’ ideas about scientific concepts. Unfortunately, authentic discussion happens infrequently in the science classroom (Winokur & Worth, 2006). According to recent studies by the NRC, it is reported that most of the talk in the science classroom comes from the teachers and this talk seems to be “oriented primarily toward persuading students of the validity of the scientific worldview” (Ogborn, Kress, Martins, & McGillicuddy, 1996, as cited in NRC, 2007, p. 187).

KLEW charts and science talk are two science-specific teaching strategies that go hand-in-hand to tackle the issue of authentic discussion in the elementary science classroom. The nature and structure of the KLEW chart, with the addition of the “evidence” section of the chart, compels teachers to get children talking about science with the teacher and with other students in a way that is quite different from traditional methods of talk in the classroom. Through the use of these two compatible science-specific teaching strategies, participants within this study have matured beyond merely sharing observations to an approach that encompasses the use of talk for supporting the development of scientific explanations and the co-construction of meaning about science ideas.

Science lends itself to analytical thinking, and the use of KLEW charts and science talks by mentor teachers in this study supported this type of learning. KLEW charts and science talks
are very similar strategies in the fact that they encourage talk among students for two main purposes or goals: (1) to help children construct scientific explanations from evidence; and as a result (2) to help the teacher gain a deeper understanding of what his/her students are thinking by listening to their responses or ideas about science concepts. In this research study, most teachers used science talks in combination with their existing science programs and typically organized them around questions the students asked. There were numerous structures for implementing science talks in the classroom such as using them at the beginning and at the end of a science unit, or utilizing talk throughout a unit by recording students’ ideas and questions on chart paper. Although there was no “right” or universal method to how or when talk was used in the classroom, teachers’ goals remained constant.

The nature of a KLEW chart makes it necessary for teachers to lead discussion beyond the question/answer/question approach to talk in the classroom. Science talks are a form of discussion in which students talk with both the teacher and with one another openly and respectfully in an exploratory fashion about their ideas and questions about scientific concepts (Winokur & Worth, 2006). KLEW charts are revisited and discussed daily, or at least whenever the science concept is being taught in the classroom. Students frame their thinking based on what they know or think they know about a science concept and evidence gained from experimentation, talk or research. This generates new wonderings, which in turn leads to new ideas, thus perpetuating the learning cycle throughout the inquiry process.

In elementary school science, discourse in the science classroom is critical because it encourages interdependency among students and promotes many different forms of communication (NRC, 1996). Formal or informal science talks are a time for students to think out loud together, including even those students who may struggle with reading, writing, and/or
In science discussions, students generate meaning from the classroom talk, or what
mentor teachers in this study called science talk. According to Gagnon and Abell (2007), this
type of talk is characterized by student spontaneity – comparing, expanding, and revising the
ideas of others as well as offering tentative explanations.

Teachers also take on a different role during science talks. “True Dialogue” occurs
“when teachers ask questions to which they do not presume to already know the ‘correct answer’”
(Lemke, 1990, as cited in Gagnon & Abell, 2007, p. 55). Generally speaking, the teachers’ goal
is then to listen to students’ ideas and develop a reflective stance toward them (Winokur &
Worth, 2006). Compared to more generalized question/answer sessions in a science classroom,
science talks allow students the opportunity to engage in many aspects of scientific literacy. As
students engage in this kind of talk, not only do they learn how to present and explain their ideas
to others, but they also learn how to make evidence-based arguments, answer challenging
questions persuasively, revise their thinking in the face of counter evidence, and clarify their own
thinking by talking to others (Rosebery & Hudicourt-Barnes, 2006).

Science talks create a space that allows all students to participate in the ongoing
intellectual work of the class, in ways that are scientifically meaningful. When
this happens, everyone learns, including teachers. (p. 317)

Where Does Epistemology Fit In?

The research question around which this assertion was developed asked about the extent
to which mentor teachers’ stories emphasized technical aspects of teaching versus
epistemological changes in their thinking and knowledge. The above assertion provides an
answer to the first part of this question. As their stories were analyzed, mentor teachers in the
current study, as stated in the assertion, demonstrated a shift from the use of generic inquiry
teaching strategies in the science classroom to the use of science-specific inquiry teaching
strategies. This was representative of changes that were made to technical aspects of teachers’ practice. Teachers changed their practice to include specific strategies to support student learning in science.

Teachers often struggle in their attempts to implement practices such as science talks in classrooms (Gee, 2005; Winokur, Worth, & Heller-Winokur, 2009) as they recognize challenges in promoting and enacting science discourse in the classrooms. Harris and Rooks (2010) affirm that complex science instruction that engages students in these types of science learning strategies requires that teachers need to take on a new role in shaping how learning unfolds in classrooms that are focused on inquiry. Therefore, one could make an assumption that because these mentor teachers reported making these changes to reflect science instruction that engaged students in the strands of scientific practices as recommended by Duschl and colleagues (NRC, 2007) that their views of the nature of science may have changed as they enacted such practices. However, making such an assumption would be an inference and not an assertion based on these particular stories of practice.

Teachers’ use of more science specific strategies did reflect changes that they were making toward using and understanding the significance of and difference between general inquiry methods and those with a specific science focus. This reflected a change in their pedagogical practices and as such, their epistemological views of student learning in science, not necessarily their views of the nature of science. Teachers who utilized these science-specific strategies in their classrooms were able to recognize the significance of the connection to evidence and explanation as an integral part of their students’ learning in science. These technical aspects of teaching are believed to have afforded teachers a way to engage their
students in the active construction of science ideas and explanations, therefore enhancing their ability to inquire.

An excerpt from Marla’s interview supports the idea of epistemological change in the way she understands how student learning was enhanced by her changed practice. She reported,

Oh, they love[d] it! Because they're the ones then sharing their discoveries with you and then there's this rich discussion - "Well, I'm not sure that that's true" - and suddenly you have a buy in by more of the kids because it's not just here is a paper, here is the steps for the experiment, tell me what you find and tell me by writing several sentences. It's a discovery and everyone is involved and excited about it and they're jumping out of their skin trying to tell you what they have found and the evidence that they have that supports their findings. (Ma1-31:48)

The reaction of her students affirmed Marla’s practice, which supported her belief that these strategies and reformed science teaching practices in the classroom were effective. She went on to say,

I think one thing that inquiry has taught me is we had always done KWL charts, you know. I like the introduction of the "evidence" - support your reasoning. That's huge. Don't just tell me, "This is what I think.” “Well, why?” [Being able to] support your reasoning is huge… I think it's learning that is so genuine that it just becomes part of who they are and the way they deal with information in the future. I mean, it's really neat when you have a kid say, "Well, what's the evidence, what's your evidence for that?" Oh, ok, that tells you that they understand the whole process. Which is really exciting! (Ma1-33:19)

In their review of the literature, McDonald and Songer (2008) explain that the “explicit and implicit conceptualizing teachers do about science and pedagogy sets the foundation for the classroom discourse, and by extension, students’ learning” (p. 975). Using a lens of classroom practice situated within a community of learners requires a focus on the activity of the community and in particular the discourse of the classroom. Managing inquiry-based classrooms is complex, requiring that teachers attend to students, materials, tasks, ideas, as well as the social context that shapes the overall climate of the learning environment (Harris & Rooks, 2010). Using Margaret’s report about the connection between discourse and learning in the classroom
supports her change in practice as it is connected to her change in understanding how students learn and the complex nature of implementing talk. She said,

But then the idea that I've grown on is, “What did they learn?” This kid put, "If you put dirt on a piece of bread, you will get a lot of mold." Now, I wouldn't have thought that should be the answer, but that's what he learned. I thought that was pretty cool. And, let's see, some of these are pretty easy to read. This little girl I thought was cool, too. She said that "you should wash your hands to be healthy, and if you're healthy you feel good." Now, I didn't help them with these, that's what they drew... I mean, it came from our Science Talk, we had a science talk and from that science talk then they went back and wrote this. And, I think what I've learned from inquiry is that letting the children come up with their own answers is pretty important. (M1-11:54)

Mentor teachers’ observations and understanding of student learning may suggest a link to their knowledge that learning has occurred as a direct result of their implementation of science-specific learning strategies. This is reflective of epistemological changes in the way teachers understand learning, however, it is not connected to their views of the nature of science. Put another way, the mentor teachers in this study did not report on their personal views of science as a way of knowing (Abell & Smith, 1994; Brickhouse, 1990; Lederman, 1992, 1999). Thus, more in-depth investigation into the structure and specific talk practices within scientific discourse communities in these elementary classrooms and more targeted questioning about teachers’ beliefs about how these practices relate to their understanding of the nature of science would be beneficial to aid in the understanding of how and why teachers transitioned to the use of science-specific strategies. Nevertheless, as a result of this research, a connection can be made between changes in teachers’ practices and epistemological changes in their understanding of students’ science learning.

6.2.3 Assertion Three

Research Question: How is student learning in science reflected in teachers’ stories of practice?
Assertion: Mentor teachers acknowledged an increase in student interest and excitement toward participation in science as a result of their shift from traditional teaching methods to reform-oriented science teaching methods.

6.2.3.1 Description

One of the predominant commonalities in mentor teachers’ stories of practice was the enthusiasm with which each teacher talked about the changes that each had witnessed in students’ behaviors when it came to doing science in the classroom. Every participant was both excited and enthusiastic to share not only his/her own story of practice, but to also divulge details about the changes that they were seeing in students as a result of these changes in teaching practices. In every case, teachers described a type of excitement, not just toward science class in general, but toward science *learning* that was very different from what any of them had witnessed prior to their adoption of inquiry science teaching practices in their classrooms.

Mentor teachers consistently reported that they felt that students had become invested in their own learning experiences, more readily participated in classroom experiences, and looked forward to science class each time it was on the daily schedule. This attitude of interest and excitement toward learning, as observed first-hand by each mentor teacher, helped teachers to recognize the importance of teaching science using reform-oriented teaching methods.

6.2.3.2 Evidence

Each participant in this study pointed out that science was the classroom subject that nearly every elementary student described as being his/her “favorite.” Other curricular subjects like reading, math, and social studies, although liked by some, teachers explained, were not at the “top of the list” of favorite school subjects for their students as consistently as science. For example, as Julie stated,
It [science] brings them into school. You know, we have to teach them to read and to write and to do math, but what gets them wanting to come back the next day? It's science. (J1-30:25)

Interestingly, student excitement about science was not necessarily as prevalent prior to each teacher’s involvement in the PDS. Mentor teachers described the excitement among students toward science as something that prior to PDS was often unpredictable, observed mostly when the students were engaged in an activity or craft. Teachers incorporated hands-on activities whenever possible, but the curriculum was still more teacher-directed and less learner-centered. As Julie continued,

So we had developed what we thought was pretty good science for kindergarten at the time… and every week they'd have a new little experiment or something. But it was fairly teacher-directed - it was hands-on, but it was fairly teacher-directed… but I really, I was told what to teach, so I couldn't design my own. (J1-08:17)

The students reportedly enjoyed the hands-on activities in science class, however, when the activities were over, the excitement seemed to also cease. When teachers went back to the textbook to reinforce the concepts, the practice of lecture and memorization stifled students’ interest in science concepts. As Karen elaborated, teachers limited not only themselves but also their students when teaching science following these traditional rules:

So, I have got some really good strong thinkers in my class this year and you know, you limit yourself so much if you take a curriculum guide and you say, “Well, I need to do this, this, this, this and this.” (K1-23:28)

Subsequently, as mentor teachers became involved in the PDS, they began to see new and innovative approaches to science teaching modeled by the interns in their classes (Badiali et al., 2011). With these pedagogical changes, they also noticed changes in the behaviors of their students. Students reportedly showed an attitude change toward science that involved both interest and excitement that had not necessarily been noticed by these teachers before. As both
interns and mentors implemented reform-oriented teaching practices, the students became excited about science class each day. They were eager to engage in science activities and get involved in the on-going development of their own science learning. As Shelly wrote,

Science is a favorite subject of many [of my] students. If they see science on the daily schedule in the morning they can hardly wait for that time of day! They are begging to know what we are going to do and how we are going to do it. They learn more because they are part of the experience designing process. We are directly working to answer the questions that they [emphasis added] have at the outset of the unit. (S2: final email)

Some mentor teachers discovered this newfound excitement toward science as an unexpected, but welcome result of their change in practice. As Karen stated,

I think kids love science and I think we teachers may not [have] always known that, but I think kids love science! And if you ask them, you'd probably get most kids [to] now raise their hands and say they like science! (K1-50:37)

Another recognized outcome of the change toward using more reform-oriented methods in science classes was the motivation of students to continue their science learning outside of their classroom. As Shelly said,

[Before PDS] we could start a new unit and you know, a month into a unit, unless I sent a newsletter home, parents didn't have any idea what we were studying. And I do send newsletters home, so they [parents] do. But, we start a new unit now, and, right now it's Underwater Life… and day two of the new unit, ten kids have shells in their hands that they can't wait to share! It's just, they're so excited about it that I don't have to say, "Tell your parents." They go home and can't wait to find things - you know, beanie babies and pictures, and, you know things that may or may not [be connected], but they're so excited about what we're learning that they can't wait to learn more and to tell their parents about it and to bring things in so that they can share what they know. (S1-08:24)

As Shelly stated, parents also recognized these changes in their children. As teachers’ reform-oriented teaching practices became more established, they often made connections across the curriculum. Karen pointed out that more and more parents acknowledged these changes in their child’s learning.
So, I think I've spent probably more time on trying to find a way to make language arts interesting by doing science, because kids love science. I mean, it is probably the favorite part, they learn so much - parents now always say at conferences, "Wow, they know so much about animals, and animals in winter, and animals in the pond..." you know, all these different things, but because we try to do that, at least in this school. I don't know that they do that in other schools... But, science is the core, you know, of the whole year. They just love it, yeah! (M1-50:51)

As other mentors described, not only were students simply more excited about science and more engaged in the process, but they also felt that students had become more sophisticated in their views of science as something more than just a collection of fun activities. As Julie said,

[One thing that has changed] well, certainly, is that science is always one of their favorite parts of the day. When they see science on the board, 2 to 1 they are excited. I've seen, and it's hard because I'm in 1st grade, so if I had been teaching 3rd grade and you could see it [earlier on], like Kate [third grade teacher] who has kids now that have been through science for a few years with inquiry science. She sees a difference in the kinds of questions that they are asking and the evidence that they are providing. I don't really see that because I don't get students who have really been through years of it, so what I see as the year goes on [is that] the students get more and more excited, they begin to think about, like evidence becomes easier for them [to identify]... and they are getting used to saying, being able to say, "Well I know that because..." Today we were just planning our science conference and they were writing down their scripts. They were planning their scripts for what they are going to say, so that I see as the year goes on I see more of a change from the beginning of the year to the end of the year than I do from year to year to year. (J2-07:50)

For Julie, and others, they noticed that as students’ interest in science increased as a result of their excitement and motivation, so, it seemed, did their understanding of the process of doing science. As Margaret described in the following statement, she often found her first-graders ready to “jump out of their skin” just to talk about science discoveries in the classroom:

Oh, they love it [using inquiry-based methods in the classroom] because they're the ones then sharing their discoveries with you! And then there's this rich discussion, "Well, I'm not sure that that's true", and suddenly you have a buy in by more of the kids because it's not just, “Here is a paper, here [are] the steps for the experiment, tell me what you find and tell me by writing several sentences.” It's a discovery and everyone is involved and excited about it and they’re jumping out
of their skin trying to tell you what they have found and the evidence that they have that supports their findings. (M1-31:48)

Mentor teachers reflected on the observation that excitement toward science, coupled with this new outlook of student-ownership of their own learning, empowered the students in such a way that they continued to become more motivated to learn. As Karen described the simple activity of using student-created work instead of just pictures from textbooks during her dinosaur unit, she explained,

The kids were really excited about [dinosaurs] because [they] had scanned in…their dinosaur picture and some of the writing that they'd done and the lesson revolved around that. So when the kids saw their own work up there, they were especially excited about that. (K1-11:26)

Margaret reinforced this concept when she described the following example of an inquiry-based series of lessons on the human heart that she implemented in her classroom. She said,

[The heart investigation] was one of the ways that one of the little boys that I dearly love, that motivated [emphasis added] him to read and write - science. I mean, science was, you know, it wasn't reading, it wasn't math, it was science [emphasis added] that did that. (M1-30:39)

Finally, Julie pointed out that as a result of the changes that she made in her science teaching practices, the children responded by showing their excitement and enthusiasm through words and actions. Additionally, and unexpectedly, in a curricular area that by nature is usually dominated by males, Julie observed that these reformed practices encouraged a love of science in her female students as well. She said,

Oh, my kids love science! That's their favorite part of the day. And when we have our closing circle and we sit, and [talk about] what went well today, if it's not lunch or recess, it's basically science. But they love [emphasis added] whenever science is on the board for the day. They're excited about what we're doing. And I have students saying now, “I want to be a scientist!” And that didn't really happen very often prior to this. So that's very exciting…and not just the boys, which is extra-exciting. (J1-31:10)
At the conclusion of her interview, Julie not only summed up her thoughts about her first graders and their attitudes about science, but she captured the thoughts and observations of each of the study participants regarding their own classrooms. She said,

I don’t have to motivate my students to do science here anymore… they just love it! (J2-04:52)

6.2.3.3 Discussion

According to a recent study conducted by the Alliance for Childhood, children spend much less time learning through play and exploration, and a lot more time sitting still, listening to teachers lecture, or being tested (Miller & Almon, 2009). What role then does excitement and motivation toward learning play in the schematics of classroom learning? According to the participants in this research study, having students who are engaged in their learning experiences through excitement about the topic or motivation toward learning about the concept play a strong role in helping those students to want to do science.

In How People Learn: Brain, Mind, Experience, and School (NRC, 2000), Bransford, Brown and Cocking posit that new ideas about ways to facilitate learning – and about who is most capable of learning – can powerfully affect the quality of people’s lives. Additionally, research on learning suggests that there are new ways to introduce students to a traditional subjects such as science, and that “these new approaches make it possible for the majority of individuals to develop a deep understanding of important subject matter” (p. 6). Research over the past decade, along with two major national reform efforts, has cultivated new standards in science education that both support and describe in detail these best practices in science education. Curriculum guidelines and teaching methods have been well established that facilitate science learning in the elementary classroom. The challenges of learning for today’s
world then require both disciplined study and problem solving from even the earliest grades (NRC, 2000).

In order to meet these challenges, “learners must be motivated to pay attention, complete assignments, and engage in thinking” (NRC, 2000, p. 280). Children are natural observers and therefore naturally inquisitive. This curiosity about how the world works makes engaging children in science relatively easy (NRC, 2000), but what makes it difficult is doing this in a meaningful way. For this reason, providing science instruction that encourages and supports interest, excitement and motivation in learners is critical to sustaining reform-oriented change in elementary science classrooms.

6.2.4 Assertion Four

**Research Question:** How is student learning in science reflected in teachers’ stories of practice?

**Assertion:** Mentor teachers reported that science-focused discourse and reform-oriented inquiry science experiences contributed to deeper understanding and more meaningful student learning in science.

6.2.4.1 Description

_Talking about_ science concepts and _doing_ science were two of the most common practices consistently mentioned by study participants as playing vital roles in the learning process of their students. Although it was not the original intent of this study to analyze the depth or sophistication of each participants use of discourse practices or methods of hands-on inquiry experiences (as each participant was at a different level of development of their science teaching skills), it became necessary to convey the significance of these practices at their differing levels of use among teachers and students since each participant reported the relevance
of these practices in their classroom. Teachers attributed science-focused discourse and inquiry science experiences to the learning changes that they believed were taking place in their science classrooms – learning that mentor teachers felt was becoming more meaningful, relevant and noticeable in the students through each teacher’s personal observation and understanding through their stories of practice.

For the purposes of this research study and for this assertion, science-focused discourse was broadly defined as any usage of teacher-student or student-student conversation in the science classroom. Many mentor teachers used the term “science talk” to describe such interactions, although this term was also very broadly used. Some science talks were very sophisticated and formal in nature, while others were informal and unstructured. However, the discourse practices that mentor teachers described were much different from traditional teacher-student interactions in the classroom as discourse was used as a vehicle to not only elicit answers, but also for children to explain their thinking about science concepts that they were learning. In addition, reform-oriented inquiry experiences were defined for this assertion as using the guidelines set forth by the National Research Council (2000). As mentioned earlier, each mentor teacher was at a different stage in his/her development as a reform-oriented science teacher and therefore described these experiences differently. Interestingly, what made these experiences different than what these teachers had been doing with science in their classrooms prior to their PDS involvement focused around several commonalities, the first being that science experiences in the classrooms were no longer disconnected, teacher-directed or created, or sporadic. Reform-oriented inquiry experiences provided by each mentor teacher were based on student wonderings and were most often co-created between teacher and student in order to
obtain the most authentic learning experiences possible for the children. Students were engaged in concrete activities, using relevant materials, over a prolonged period of investigation.

On most every teaching occasion, science-focused discourse and reform-oriented inquiry experiences were taught in combination in each science lesson because they had become such a natural combination not only for student learning, but for teacher assessment and understanding of student learning as well. Each participant reported on the implications that the particular use of these two strategies had for improving student learning in his/her science classroom. Evidence to support this assertion follows.

6.2.4.2 Evidence

Throughout the course of this research analysis, it was recognized that as mentor teachers discussed student learning in science, their stories of practice focused on two main teaching approaches that were consistently used with the students: science-focused discourse practices and providing reform-oriented inquiry-based experiences and how these new methods have affected student learning in the classroom. Evidence to support these findings begins by providing examples from mentor teachers of how they have changed the use of discourse in their classrooms over their years of involvement in PDS. Secondly, evidence to support mentor teachers’ use of reform-oriented inquiry experiences for students in the science classroom is presented through examples of hands-on activities and science-specific strategies and the effects of these reform-oriented methods used in elementary classrooms.

Science-Focused Discourse

The following conversation took place in a first grade classroom following an inquiry science experience using bar magnets:

Our first grade students were seated in a circle ready to share during our science talk.
“I could make Erin’s magnet jump with my magnet,” was the first response.
“Tell us more about it,” we replied.
“You have to use the bar magnets and find the two sides that don’t like each other, and when you do, you can make the other magnet jump.”
“You used the bar magnets, but do you think we could do that with other magnets?” we asked. A chorus of “yeses,” “no’s” and “maybes” filled the room.
“Should we add that to our wonderings?” we asked.
And so: Do all magnets have sides that “like” and don’t “like” each other? was added to our list of wonderings that we would test.

Excerpt from “Magnets: Attracting Student Wonderings” Paper presented at the 2004 PDS Inquiry Conference by two study participants, Julie and Margaret.

An examination of participants’ self-reports revealed that mentor teachers in this study viewed science-focused discourse as an essential component that contributed to students’ understanding in science. Although some mentor teachers in this study used formal, structured “science talks” as illustrated above as a strategy for eliciting thinking and responses from their students, other participants used informal, unstructured opportunities for discussion of science topics with their students. Most often, however, mentor teachers used a combination of both formal and informal strategies. Importantly, every mentor teacher participant recognized and reported the significance of science-focused discourse (formal and informal) and its role in strengthening the learning process for students in their classrooms.

At the outset, one of the most important approaches recognized by classroom teachers of science was to first provide students with a safe and encouraging environment in which to share ideas and thoughts about science concepts. As Margaret described,

And I thought, “Wow, if you're not given that opportunity [to talk], not encouraged, and said yuck to stuff like that in science, ugh.” The whole idea of asking the questions… they have a lot of things to ask. And I wonder if that isn't somewhat how children get turned off to science as well. I mean, if you have a mom and a dad in a family, are they too busy to talk about it? Are they interested in it? Do they encourage non-fiction books? Do they ever watch Discovery channel? And there are certain kids who are inclined, I can name them in my
Margaret felt strongly that taking the first step into talking about science, both formally and informally, helped her students to begin to open up, share their ideas, and “get turned on” to science. Other mentor teachers acknowledged that this strategy of simply talking with students about science ideas, although difficult at times for them as teachers to do, was not difficult for most students, and most mentors reported that students “loved to share their stories and ideas whenever possible.” It was initially very challenging and eye-opening for many mentor teachers who, before actually sitting down and talking with their students, thought that they both knew and understood much of what children already knew about the science topics that they were teaching. For example, as Lynne shared, she was astounded at the ease with which her students talked about what she thought were “complex” science terms that she stated she would not have previously introduced to their vocabulary in second grade. She explained,

And, so that [concept] I think was a little bit hard, but yet, they talked about it, they know what endothermic and ectothermic are... I remember reading somewhere, try not to use the terms "warm-blooded" and "cold-blooded" because it has a misconception. And, hopefully most of our kids said, “Well, what did that mean?” Well, it regulates it's own body temperature. I'm like, 2nd graders know what that is? That's really cool. Yet that's not something I thought could happen. (L1-17:23)

Lynne recognized that by allowing her students to talk amongst each other and with her, and by listening to them reason through their thoughts and ideas instead of simply “telling” them the answers, they were able to both describe and understand a science concept that she would not have previously believed they could.

Similarly, by allowing her students to talk openly, Shelly recognized that prior to her PDS involvement and her growing understanding as a teacher of the importance of science talk
in the classroom, she would not even have allowed her students to talk about or even try out certain ideas in the classroom. By encouraging her students to share their ideas through science-focused discourse, and allowing her students the freedom to make choices about their own learning experiences, Shelly discovered that her students were capable of tackling tasks and problems that she previously would have either ignored or created herself. She said,

My students come up with the most bizarre ideas of how to solve a problem! I've learned through class meeting that you keep a stone face, [that] every idea is a good one, you write them all down, you let them [emphasis added] choose. I find sometimes that these ideas that they've come up with, that I would never in my wildest dreams not only have thought of, but, ten years ago would never have even let them try, sometimes work the best. (S1-20:48)

This example showed how change has affected both Shelly’s views of her students and how they think as well as how she teaches in the classroom. By engaging her students in science talk, she observed that they were able to apply information to their own lives and situations and therefore able to make meaning from it.

In addition to the importance of, as one mentor described, “getting over the hump” of just letting the students do more talking in the classroom, it was also noted that by shifting the focus away from teacher-directed activities and providing opportunities for both teacher and students to engage in science-focused discourse throughout a science lesson, mentor teachers discovered that students were not only more engaged in their own learning, but seemed to have a deeper understanding of that learning. For example, as Margaret described an investigation in which her students participated involving hand washing, she explained how the simple acts of both listening and talking played in the learning experiences of her first-graders. She said,

So, this time, when we did it [the unit on hygiene], it was great because we kind of brought up the idea of hand washing and why should you wash your hands. And they gave us the reasons, you know, you really need to [wash your hands]. And I have never had a kid, it was so cool, I said, “So what are these things that are on your hands? Well, they're germs.” I mean, and some kid, of course, you
know, you get the different thinking, said “Microorganisms.” I said, "What?!” I said, “What is that?” They said, “Well, they're germy things, they can cause stuff, you know, germs.” And he said, “Well, it's like when you have a boo-boo on your…” I mean this kid was [talking about] a microorganism and then he talks like a boo-boo “…and then you get a boo-boo on your knee and if you touch it you can get germs in you, you can get sick from stuff like that.” Or how else did they use the word "germs"? From, you know, wiping your nose and things like that. So they really knew… And so this one kid said, "Well, I think we should use wet wipes." And I thought, “Ok, why not?” I mean, so in my mind, I had set it up hoping they'd ask the right questions so we'd go a certain way, but they brought in their own information… we then decided that we would do it on the bread. And what would happen to the bread? And they said, "These microorganisms that cause germs or you to get sick, would cause mold." Now don't ask me how they knew that, but… the one kid said, “It causes mold” and somebody then said "Oh yeah, I've seen mold." I mean, the conversation went, “Yeah, if you leave bread around too long, it will get moldy.” But then they were really interested in what the dirt would do to the bread. And they really had great questions that they [emphasis added] came up with, but it came from them. (M1-07:02)

This example of providing the children with time to talk and focused discourse allowed Margaret to learn more about her students’ thinking than if she were to have just designed and set-up a teacher-directed hand-washing activity for the children. As she described throughout this quote, the students were not only talking to her about their own ideas, but they were sharing ideas among themselves and talking through what they knew about how to conduct a fair investigation. Through one small experience such as this, Margaret was able to assess both prior knowledge of her students and their ideas about how to carry out a fair test, all with simple guidance from her own questioning of them, listening to their responses, and allowing time for students to respond and talk together.

As she continued to describe this particular hand-washing investigation, she continued to describe what she witnessed the children learning through their experiences and the amazement that she felt as a result. As students gathered and collected evidence, she recorded their findings on a KLEW chart that was hung in the room. As students described not only what they learned,
but also explained their learning to her, she was astonished by their interpretations and understanding of the meaning behind what they learned. As she presented and explained the KLEW chart during her interview, she described,

[Looking at the evidence chart that the students created] It's all good [emphasis added] evidence. They compared it to the other groups. The dirty hands group put them up and they compared. And [the students determined that] washing your hands is important for removing germs that make you sick because the dirty hands group had the moldiest bread. The washing hands group had the least. So they [emphasis] drew that conclusion. The bread was moldiest when you do not wash your hands. It's because they saw [emphasis added] it. I saw the mold on the bread. And the wet wipe napkin caused white mold - that was the funniest thing. But they said, “I've never seen that before and I know it is mold because I saw it!”
(M1-11:08)

Again, as Margaret continued to illustrate this one particular hand-washing investigation, she described it as one of the defining moments in her development as a science teacher. She was intrigued and surprised by the types of things that her students learned as a result of the inquiry-based investigation. Her perception of student learning was deeply affected by the types of responses that her students provided, as they were not always necessarily the typical answers that she expected. On the contrary, they were much more in-depth and reflective of first-graders’ understanding and interpretation of the science content. She said,

But then the idea that I've grown on is, “What did they learn?” This kid put, "If you put dirt on a piece of bread, you will get a lot of mold." Now, I wouldn't have thought that should be the answer, but that's what he learned. I thought that was pretty cool. And, let's see, some of these are pretty easy to read [reading the KLEW chart]. This little girl I thought was cool, too. She said that, "You should wash your hands to be healthy, and if you're healthy you feel good." Now, I didn't help them with these, that's what they drew... I mean it came from our Science Talk. We had a science talk and from that science talk then they went back and wrote this. And, I think what I've learned from inquiry is that letting the children come up with their own answers is pretty important, and I thought that was pretty important. (M1-11:54)

In addition to Margaret’s example of the importance of science-focused discourse on student learning, Julie shared her reflections on how she has adapted her use of talk in the
classroom. In an excerpt from a paper that she co-authored with Margaret for their district inquiry conference, Julie described the role that science-focused discourse played in her students’ learning of science. She wrote,

We also learned that as we questioned and listened to our students, we pushed and helped them to clarify their thinking. This led to deeper understanding of content. This was evident after an exchange with Susan and Jim. We spent an entire class period around the wondering “What sticks to a magnet?” Susan and Jim were in a quandary because their magnets stuck to one metal bell, but not another. Jim said he thought that some magnets stick to some metal and other magnets stick to other metals. We brought them a collection of magnets. They tried and discovered that all the magnets stuck to one bell and none stuck to the other. When asked, ‘Now, what do you think,’” Susan questioned, “Are there different kinds of metals?” Jim informed her that there were. Her face lit up and she replied, “I get it! Some kinds of metals stick to magnets and other kinds don’t.” Given the time to test this wondering with multiple trials, the students were able to make a claim and support it with evidence. We were confident that they understood the concept because we had taken the time to listen and find a way to clarify their thinking. The ‘ah-ha” for us as teachers was that in the past our students could say that magnets stick to some metal and not others, but we never took the time to hear their explanations of why this was, which could have been filled with misconceptions. (Excerpt from Magnets: Attracting Student Wonderings)

By taking time to focus discourse in science classrooms and to listen to children as they reason through their understanding, not only does the evidence support the testimony that mentor teachers have gained a deeper understanding of what and how students are learning in science, but it also supports the report that the learning that has taken place in their science classrooms is more meaningful to their students as well.

Reform-Oriented Inquiry Experiences

In addition to and in combination with science-focused discourse, mentor teachers reported that reform-oriented inquiry experiences played a significant role in the development of student learning in science. These science experiences were more than just “hands-on activities”. They incorporated numerous science-specific strategies (discussed in Assertion
Two), and involved the students through the use of questions that they (the students) often had about certain phenomena. These reform-oriented inquiry experiences were much more child-centered and student-generated than they had been prior to their work as mentor teachers within the PDS.

Learning how to transition from prior methods of science teaching to involving students through scientific inquiry provided an initial challenge for many of the mentor teachers. Although it was often a difficult task at first, each participant reported that the benefits far outweighed the challenges. Shelley described her frustration as follows:

But how can I provide the opportunities for the students to discover these things? Because I was finding that you could talk until you're blue in the face about how a fossil is formed and the layers of the earth and some of them get it, and some of them have no deeper understanding, [in fact] they're probably even more confused than they ever were, because it's so abstract. There's no way they can understand how many years it took to do. You know, they just can't, they're too young, it's beyond them. But to do an experiment where I've provided the structure and they're building the layers and adding the fossils in as I'm talking and giving them [guidance]. But they're seeing it, they're feeling it, they're discovering something abstract in a very concrete way. I find that a whole lot more of them have an understanding. (S1-08:34)

Once Shelley realized that her second grade students needed concrete experiences in science through which they could use all of their senses to discover the science concept, she also became conscious of the fact that they were learning in a different and more meaningful way. Margaret described this learning as being “genuine” when she explained,

I think it's learning that is so genuine that it just becomes part of who they are and the way they deal with information in the future. I mean, it's really neat when you have a kid say, "Well, what's the evidence, what's your evidence for that?" Oh, ok, that tells you that they understand the whole process, which is really exciting! (M1-33:19)

Greg agreed and he supported the idea that students needed to be engaged with both materials and other students in the classroom when participating in science. He said,
Well, I think that they certainly learn a lot more with anything that they are actually doing. (G1-22:13)

Furthermore, Karen added that the value of allowing students to take time to engage in the simple task of observing things around them was a pedagogical change that she made and now used on a regular basis in her classroom. She said,

So by the time it was all said and done the kids could talk about the similarities and differences from one animal category to another based on their observations...[using] their evidence. Exactly. So, that was another example of just a change in, I'd never done that before... like watching that rabbit. If you watch the rabbit, the nose never stops twitching. You know, their nose is constantly going and the whiskers are constantly going and the kids, of course, they do pay attention, and they got a lot out of these observations, just a lot. You know, they can talk about how the animal moves. Does the animal go like this when it walks, or does it jump, hop or whatever? And so it was just the comparisons by the time we got to the last animal category. You know, they had a wealth of knowledge. (K1-30:57)

Karen felt that by allowing children the time to do what they instinctively would do outside of the classroom, they felt a connection to their own learning and perhaps, in this example, learned more about rabbits than they might have from just reading a story or looking at pictures in the classroom. The children experienced time spent just following the animal while observing its daily habits and actions, thus leading to clearer understanding and a deeper knowledge base about rabbits and their behaviors.

Likewise, Lynne explained the value of using real objects for the students to observe as they learned about animal characteristics in her classroom. She described,

I had a visitor here for a day, and I was like, "How do you feel about bird feet?" She said, “They're ok.” So, [I said] “All right, well, can we rotate them through your center and have them look at the bird feet and do the observation and talk about how they think which foot goes with which bird based on what the bird needs it for?” Which is really kind of cool because again you're looking at that. I'm not telling you this is an owl, this is a goose, this is a whatever. [The students are] saying, “Well, this one has webbed toes, so that must be the goose. This one has really long claws, that must be the owl.” It's cool watching them talk like that. (L1-40:13)
Additionally for Lynne, she described one of her first experiences with teaching using reform-oriented inquiry experiences as one that opened her eyes to the impact of providing these inquiry experiences to her students instead of just doing hands-on activities in the classroom. One of the first things that she taught in her second grade classroom during her first year as a mentor teacher was the district Dinosaur Addendum (a modification to a district curricular unit on prehistoric life created to enhance the use of reform-oriented science methods in the classroom). Julie described the addendum as follows:

So then, it's [our dinosaur unit] very engaging. So the students actually learn more than just dinosaur names, and what they ate and stuff. They really come to understand them as animals and understand what it means to be a carnivore and what their skull would look like and what their teeth might look like. (J1-06:29)

Lynne’s experience with the district Dinosaur Addendum convinced her right from the start that her students not only learned more about studying prehistoric life but were also engaged in and committed to their learning in a more meaningful way than they had been prior. She was excited about the things that she witnessed happening in her classroom. She said,

It [the modified dinosaur unit] was [emphasis added] our science program, and I was astounded at some of the discoveries that the kids not only made but they remembered! The vocabulary in there is pretty tough. You know, they learned what "bipedal" and "quadrupedal" were, and I'm like, “OK, wait. ‘bi’ is 2 and ‘quad’ is 4. OK. I had to keep doing that for a while. And they can tell you, "Well a quadruped walks on 4 legs and a biped walks on 2 legs." Well, how do you know? “Well, because you look at the tracks! You know, the bipeds go like this and the quadrupeds go like that.” Cool! (L1-17:22)

As Lynne described her use of the addendum in her classroom, she explained how she was astounded by the things that the students not only learned but what they retained as a result of their engagement in the experiences. She stated,

I think they learned way more than what they typically would have [by engaging in the investigations] because they actually learned things that I won't say were directly connected to Dinosaurs. That sounds kind of stupid because well, yeah, everything you learned is about dinosaurs, but they learned it by doing it. They
learned it by figuring out what the tracks are telling you and trying to look at how they're walking and what size they were… But, I think they learned better and more than they have in the other ways I've taught it. (L1-48:10)

Even though she struggled at times not to revert back to her old methods of teaching this unit through lecture, reading, and memorization, she reportedly understood the importance of being able to provide her students with opportunities to engage in experiences in order to more fully comprehend the science concepts. As she toiled over how to better provide her students with a concrete example of how to understand the science concepts of stereovision and monovision in dinosaurs, she reached out to the PDS community for ideas instead of falling back on old methods. She talked about that hands-on experience excitedly:

The stereovision-monovision was a little bit harder because it was harder for them to experience it. And one of the interns…came up with a really good experiment to get them to experience it. She took paper bags and cut some with stereovision, which had the holes up here, and had the kids walk around and look at things and then she cut the holes on the side, and that's monovision because, well for us, you can only look out one side at a time, you can't see right in front of you. And so it gave them a better sense of what that looks like. (L1-17:23)

For Lynne, as well as for each of the other participants in the study, the significance of offering inquiry science experiences on a daily basis in the classroom was crucial to the learning of each child. As Lynne summarized her experience with the Dinosaur Addendum:

They (the students) do better when you can get them really involved in doing stuff, that's why I think the Dinosaur addendum was so successful with them because most of them bought into it and really got into what was going on. (L1-36:37)

A final example of how reform-oriented inquiry experiences benefited the elementary students came from Julie when she was asked to elaborate on a comment that she made during her interview about using sound probes in the classroom during her “Sound and Light” unit. She described the effect on her students as follows:

Yes, it helped them [to understand the concept of sound]! [We were] watching [the wavelengths] and we did snapshots. So we were able to print them out. So it
wasn't just watching it and then having it disappear, we actually made copies of them, so after they did it and they watched them, then they could look at them and really analyze, as much as first-graders can analyze the differences in the waves. So I thought it was very, I mean first-graders, for them to be able to visualize something is always good... Well when you can see the waves - I mean they can't visualize yet. Abstract thinking is not there. So when you put it on the computer and they can see the waves, they no longer have to visualize it in their brains, it's there.  (J1-24:14)

Reform-oriented science experiences played a critical role in the development of the students in each mentor teachers’ elementary classroom. By offering opportunities for the students to engage with phenomena, abstract science concepts were made concrete and understandable for the children. This pattern was recognized and reported by all eleven participants in the study.

In conclusion, an excerpt from the teacher inquiry paper written by Julie and Margaret supports the assertion that for these eleven PDS mentor teachers and their students, science-focused discourse and reform-oriented inquiry experiences led to deeper understanding and more meaningful student learning in their science classrooms.

Every science lesson was followed by a science talk. This was our opportunity to come together as a class and share what we learned. It was at these science talks that students made their claims to address our wonderings, and supported their claims using the evidence they gathered through their experiments. This environment encouraged them to learn from one another and strengthen their understandings of the concepts, (National Research Council, 2000). These talks were also an important time for the students to share what they noticed or were surprised by. While investigating the wondering: *Are some parts of the magnet stronger than others?*, some of the students made chains of paper clips on different parts of the magnets. Michael noticed that when he took the magnet away, the paper clips seemed to still stick together. He brought this to the science talk and demonstrated it for the class. The “oohs” that followed indicated that although some of his classmates had seen the same thing, many others hadn’t and were eager to try it. We then asked if anyone saw this happen with any other materials. When it was clear that no one had, we asked if they thought they could make it work with other things. This led to the class wondering: *Can you turn other things into magnets?*  It was important for us to have the materials on hand during these science talks. It was usually easier for the students to show than to tell. By showing the whole class what they noticed, everyone could share the surprise and together we could frame the wonderings into testable questions.

*Excerpt from “Magnets: Attracting Student Wonderings” Paper presented at the 2004 PDS Inquiry Conference by two study participants, Julie and Margaret.*
6.2.4.3 Discussion

Assessment of student learning is an integral part of the learning process (Shepard, Hammerness, Darling-Hammond, & Rust, 2005), involving an understanding of the uses of both formative and summative assessment practices in the classroom. Summative assessment practices often allow for teachers to follow traditional paths of evaluating students through the processes of assigning grades to measure for student proficiency while formative assessment practices are generally used during the instructional process in order to improve teaching or learning through the use of such tools as rubrics, observation and discourse. Although summative assessment practices were neither evaluated nor discussed by participants in this research study, the mentor teachers that participated in this research study used their knowledge and experience of formative assessment practices to report on their own observations of student learning in the science classroom. Through informal formative assessment practices classified as “on-the-fly” and “planned-for” assessment (NRC, 2007), instruction went a step beyond traditional classroom interactions by probing for understanding and meaning-making. Mentor teacher participants acquired information on a continuing and informal basis, such as in the course of daily classroom talk and inquiry activities, permitting teachers to use information from such experiences to guide instruction and assess “students’ conceptions, mental models, strategies, language use, or communication skills” (p. 281). These observations and examinations of student behavior in the classroom strongly supported participants’ use of the science-specific teaching strategies of discourse and inquiry practices by strengthening student understanding in science.
Talk is a vehicle that allows students to engage in discourse that prompts for critical thinking while eliciting the use of evidence in formulating explanations (NRC, 1996). It is through social interactions that discourse occurs (Gee, 2005) therefore allowing students to master the acquisition of science concepts. As summarized by Duschl and colleagues (NRC, 2007), discourse and classroom discussion are “key to supporting learning in science” (p. 251). They go on to assert that students need encouragement and guidance in the classroom in order to articulate their ideas and recognize that explanation rather than facts is the goal of scientific enterprise. As a result, the social interaction played out through science talk in the classroom is integral to both scientific practice and productive science learning. Relevant science education literature states that, “socially supported interactions can strengthen children’s ability to learn with understanding” (NRC, 2001 as cited in NRC, 2007, p. 265).

Mentor teacher participants in the current study appreciated the value of using science talk, both formal and informal, in their classrooms as meaningful and necessary methods to both engage children in learning as well as to measure understanding, familiarity, and appreciation both of and for science concepts and practices. In consensus, the significance of talk in the elementary science classroom, as studied by others in the field (e.g. Driver, Asoko, Leach, Mortimer, & Scott, 1994; NRC, 2007; Ogborn et al., 1996), is agreed to be fundamental to the process of doing and thinking about science and is considered to be central in developing understanding of scientific concepts and practices.

Additionally, evidence from instructional research suggests that students can in fact engage in science as practice in meaningful ways (NRC, 2007). For over 20 years, studies have shown that teaching science as inquiry leads to positive attitudes towards science (Shymansky, Kyle, & Alport, 1983). Inquiry practices in elementary science classrooms look much different
from traditional methods, engaging students in the active construction of ideas and explanations and enhancing their opportunities to develop the abilities of doing science (NRC, 1996). In this study, mentor teacher participants did not report on strict, measurable learning in the form of grades and answers on tests (summative assessment), but rather through their stories of practice, reported on the changes in attitudes toward doing science and outcomes of understanding scientific concepts through classroom discourse and observation. These changes were seen as a direct result of using inquiry science teaching practices in the classroom.

In conclusion, participant’s attention to both science-focused discourse and reform-oriented inquiry science experiences in the classroom and how each relates to observations of student learning was encouraging. Although this study did not investigate student learning directly, mentor teachers reported that the use of these reform methods was making a difference in their classroom learning environments. As Duschl and colleagues (NRC, 2007) argue that “students learn science by actively engaging in the practices of science” (p. 251), supporting the evidence put forward through this assertion. Teaching science as practice includes carefully constructed support and instruction that is central to scientific practice. However, as is also mentioned by Duschl and colleagues (NRC, 2007), managing classroom discourse interactions and appropriate inquiry science teaching practices are not easily facilitated, requiring professional development for participating teachers. The structure of the PDS environment and introduction to scientific talk and inquiry science teaching practices through student interns offered unstructured opportunities for adaptation of such methods. Continuing this study into more specific measures of student learning through increased teacher professional development opportunities incorporating scientific discourse and practices would be a natural and beneficial continuation of this assertion.
6.2.5 Assertion Five

Research Question: What is the relationship between the levels and types of involvement in PDS to change in thinking about and practices of teaching science?

Assertion: Mentor teachers who engaged in science-specific professional development opportunities were more likely to change their practice to more reform-oriented approaches than mentor teachers who did not engage in science-specific opportunities.

6.2.5.1 Description

Assertions one and two provided an in-depth look at the self-reported teaching practices of participants and how each mentor teacher moved on a continuum from either traditional or hands-on methods of science teaching toward more reform-oriented practices as a result of their participation in the PDS collaborative. As data was analyzed, it was observed that study participants reported changes to their teaching practices. Naturally, the question that followed was, “To what were these changes attributed?”

6.2.5.2 Evidence

In order to best describe the assertion that engagement in science-specific professional development opportunities is reflective of change toward more reform-oriented science teaching practices than is length of time involved in more generalized experiences, evidence from each of the eleven participants listed above has been grouped according to similarities in their stories. In each case, the mentor teacher’s practice was addressed using the lens of science-specific professional development opportunities and how they have/have not affected his/her practice.

The evidence for this assertion was based on placement/movement on the Participant Placement Rubric (Table 6.3). The first group of evidence focused on Lana, a mentor teacher who did not engage in any science-specific professional development but who did move from a
zero to a two on the rubric and the reasons supporting her movement. The second group addressed the practice of Greg, Karen, Elizabeth, and Bobbie. These four mentor teachers were all grouped at a level two after their initial interview and showed no movement on the rubric between interviews one and two. The third group focused on Marla, Paul and Shelley, three mentor teachers who were initially grouped “higher” on the rubric than those in group two, but who did not reposition on the rubric following their second interview. The fourth group focused on evidence from Julie and Margaret, two veteran teachers who were initially placed at a four on the rubric and how their actions revealed an even deeper understanding of reform oriented practices two years later and why. Finally, the fifth group focused on Lynne’s practice and her movement on the rubric from a two to a three based on engagement in science-specific professional development.

Group 1: Lana

At the time of her first interview, Lana was a nineteen-year veteran fifth grade teacher and was working with only her second intern. She was selected for participation in the study based on her response on the impact survey where she stated that she felt that she had changed, her science teaching practice as a result of her involvement in the PDS. As she completed her first interview and related her story of practice, it was determined that she, in fact, had made very little change to her practice. Although she was beginning to talk about different science strategies and inquiry processes that she noticed her intern using in the classroom, she was hesitant to “jump on the bandwagon” to adopt any of these practices or to make any significant changes to her own practice. In fact, as she described her science teaching, it was revealed that she was using many traditional teaching practices such as lectures, cookbook-type labs and occasional activities to support learning. Although she frequently commented that she
considered her teaching practices to be very open and discovery-based for her students, her descriptions of teaching clearly revealed that her style was very teacher-directed and limited to structured, pre-packaged lessons, which left little room for student inquiry. Although she allowed her intern to utilize reform-oriented practices that she was learning about in her science methods course in her daily science lessons, Lana herself was not using these strategies when she was teaching the class. Therefore, she could talk about the strategies in a somewhat informed manner, but was not making use of them in her daily teaching routine.

At this point in her PDS participation, Lana’s only experience with reform-oriented science had come from her interactions with her two interns. The teaching ideas and strategies that she described continued to be very traditional in nature and only included some inquiry science teaching strategies (e.g., in-depth questioning) when she was working specifically with her intern. These factors placed her at a zero on the placement rubric upon completion of her first interview.

Interestingly, at the time of her second interview two years later, Lana made a noteworthy comment at the very beginning of her interview. She stated,

I need to tell you that although I told you that I was a teacher who taught using inquiry when we talked last, I might have said before that I was conceptual in my ideas about science and I wasn’t probably, I truly wasn’t… But the irony is that I thought my beliefs were always there, but obviously my activities that I did, even with what I thought were the beliefs, did not support those beliefs. (La2-09:44)

Over those two years, as Lana described her more current teaching practices, it became clear that although she had not taken great strides in her development, she had made some progress toward the use of reform oriented science teaching practices. Even though she still didn’t like to use the word “inquiry” to describe her practice, she recognized her growth in her understanding of how
to properly use inquiry science teaching practices in the elementary classroom and the importance of doing so. As she described,

It [my teaching] hasn’t changed dramatically, honestly. I think the thing that used to be there that’s gone, or I shouldn’t say it’s gone, it’s been altered, changed or modified. There used to be much more of a reliance on accountability for *myself* [emphasis added] and that accountability was a lot of lab journals, a lot of data collection that was then used to maybe support, defend or refute a hypothesis that we came up with. I think now it’s changed to this: I think there is a much more of a reliance on posing a situation to the children, discussing avenues that they could take to, I’m not going to use the word inquire, but to wonder on various subjects and how *they* [emphasis added] could go about finding the material that can again, support, refute or whatever, their ideas. I think that’s where it’s changed... It has taken me to actually, to almost bite my tongue, to grit my teeth and to let it happen knowing that I need to stop sometimes measuring students’ success by them being able to answer *my* [emphasis added] questions and looking at the questions they ask. (La2-03:40)

Lana’s description of her practice caused her placement on the rubric to move from a zero to a two based on the details of her changes.

So, how did she get there? How did Lana learn about these reform-oriented teaching methods and gain a better understanding of inquiry science teaching as her foundation? For Lana, these changes were made as a result of her interactions with her intern. She did not engage in any science-specific professional development opportunity over the course of her four years as a mentor teacher, yet she still was able to make some small, yet significant changes in her beliefs about how science should be taught and began to put those beliefs into practice. Her years of experience as a mentor began to build a foundation, however, it also became clear throughout her story of practice that she still struggled with aspects of how best to implement these methods. Time and again she questioned the relevance and implications of making these changes.

I still worry about those kids. I’d like to see them do more but if they have a question and it’s posed in such a way then it’s going to be difficult [for them]. For me, I’ve got to be ok with it and to much more look at the process and not at the outcome and it’s been hard. I still struggle with my own accountability, I truly do with these kids, because ultimately I’m held accountable. (La2-06:25)
Lana remained frustrated with not knowing how to “make it all work together” as she described. She had moved beyond being self-oriented in her thinking (How is this affecting me?) to becoming more task-oriented in her thinking processes (How do I do it?). She was focused on how to make the new strategies work in her classroom without becoming completely overwhelmed by small details. She was learning to let go of her command of the science lessons and to make her science experiences more meaningful for her students. This was a very big step for Lana over the course of those two years and she also recognized the importance of seeking outside resources in science. She said,

No, [I’ve taken] nothing specifically in science, although I might like to. I’m still doing the math work… The irony to me is, my thoughts in conceptual math have really not wavered since beginning my graduate work and when I really look at what I’m doing now in science it’s starting to mirror my beliefs in math. (La2-09:44).

As she stated, she did not participate in any science courses or other opportunities, but has had extensive professional development in mathematics over the past ten years. She often pointed out the connections that she was beginning to make between her beliefs and practices in math to what she was experiencing in science. This connection to change in science as it is related to her involvement with an intern can be described by the initial study from this research (Badiali et. al., 2011). However, without further evidence, it is unknown at this point if or how science-specific professional development would affect Lana’s change process throughout her time as a mentor teacher in the PDS.

**Group 2: Greg, Karen, Elizabeth and Bobbie**

These four mentor teachers were grouped together at a score of two on the Participant Placement Rubric based on their original stories of practice. They shared many commonalities among their stories and talked about their science practices as inquiry-based by providing
numerous hands-on experiences for their students to help reinforce science concepts. However, as each described his/her classroom to the researcher, their stories revealed that even though they were utilizing many aspects of inquiry science teaching in their classrooms, they rarely discussed the use of science-specific inquiry strategies in order to maximize their students’ learning experiences. These teachers were still in the learning phase of how to implement science strategies that were introduced to them by their interns in the classroom.

Each participant had worked with at least five interns over the years. Just as was the case with Lana, for these teachers, it was determined that nearly all of their growth and development in the area of science came from their interactions with their interns. As Karen discussed,

Ah, well, I would say it's, well, I've never actually taken any of the courses offered for teachers in the science area here, you know, with PDS. I've never taken any of those. So whatever I get is either through my intern or sometimes we have school district in-services, which we had recently, we had one that Connie led that was about using these monitors that are hooked for, it had to do with the light and sound unit, actually, to hook them up to the computers and you would get these programs. (K1-38:13)

Interactions with interns played a significant role in the initial change of mentor teachers. As Karen continued to describe, these opportunities to learn first-hand from watching their interns was critical to that process. She said,

Definitely, yes it does, that does [emphasis added] make a difference. And I think perhaps that would be a direction for the science people in the PDS would be to have more of those kinds of things for other mentors to do because a lot of us don't know anything about something and if we are simply handed a piece of paper, well, you know. How often are we going to take the time to learn it if we don't see how cool it was? (K1-40:21)

As additional support for this assertion, these mentor teachers were able to recognize that personal growth in their science teaching reached a point where, although each continued to learn in the classroom from their work with interns, if they were to gain a deeper understanding of the processes of reform science teaching they would need to engage in more formal
professional development. Elizabeth’s story was one example of this. She elaborated at least two times in her interview about how she enjoyed learning new ways to improve or change her practice. She implied that she perhaps had a predisposition toward change, but in order to affect a more meaningful change in her teaching, she would have to engage in more formal inquiry into her science teaching. She said,

I think changing my practice to make it better is something I'm always trying to do. So each year I usually try to, I pick something that I want to focus on. And even though I've never done an official inquiry project where I've written [something] up and I've presented it, every year I pick one or two things that I want to focus on and I read about it and I do, I collect data and I do things with my kids and I notice the differences and I you know, take note of that and then the next year I add something different. And so, but a lot of that's come from the PDS, like a lot of the way of actually, now that I think about it, I mean I always had little things that I changed, but the big questions now, a lot of them came from inquiry classes I took and journals I kept and questions I had and wonderings I had about things that I was doing in these journals that I would later on the next year, say, "Well, I'm just going to make that a full-blown project, and maybe I'll write it up and do it as an inquiry project," but I never do. But I learn so much from it. (E1-45:24)

Several times during her interview as she reflected on her practice, Elizabeth recognized the importance of professional development that is specific to science teaching. As she stated,

So they [the PDS interns] have really been how I learned at all about this because I've not taken any PDS science courses yet, so any of the little bit of learning that I've done about science and how to teach science differently has really come from an intern and their projects that they do and when they're teaching science, they're trying to incorporate all of that. So, it probably would be really good for me to take some actual science course from Connie to get more understanding of it, too. (E1-30:19)

As the interview progressed and Elizabeth talked more and more about her science teaching methods, she continued to return to the thought that it was important for her to take the “next steps” in learning more about reform-oriented science teaching practices. She revealed,

I think with the science, I think probably I'd like to be able learn more about inquiry and how you know, probably take a course from Connie [university science education PDS faculty]. A couple courses she's taught I've not been able
to take at the times that she taught them, but I'd like to actually learn more about it because I think sometimes when I get information from my interns, they're still struggling with understanding what it exactly is and I probably would get a better view of it from Connie or somebody who's teaching it, or Kate, yeah, Kate [teaching colleague] is fabulous. But that probably would be a helpful thing for me then to be able to focus more on science as a way of teaching science in more of an inquiry-based. (E1-59:24)

Unfortunately, due to family issues, Elizabeth was unable to take any courses during the two-year period between interviews and therefore did not report any changes in her practice. However, the importance of this evidence lies in the information that Elizabeth recognized a need for science-specific professional development in order to enhance her personal development as an effective teacher of science.

Additionally, although Greg’s approach of turning his science class over to his intern very early in the school year has put him in a secondary position in the classroom, he pointed out the importance of the fact that in order to become a “better mentor” he needed to engage in professional development that was more specific to science:

I haven't [taken any science courses] through PDS. No, I've had some health issues... I would like to, in the future, now that I'm... back on track again I will consider next summer possibly doing something. And I haven't done any of Connie's things. I took one of Jon's courses on Creating a Social Environment in the Classroom a couple of years ago, but nothing [in science]. (G1-10:37)

Thoughts such as these were common across these four participants. Yes, these participants changed the way that they were teaching science over the course of many years of being involved in the PDS, but they were still lacking a deep understanding of specific reform-oriented practices in science and continued to implement many generic strategies while only beginning to touch on some science-specific aspects of teaching. Perhaps engagement in science-specific professional development or other outside science experiences would promote a more sophisticated understanding of how best to implement reform strategies in the classroom.
However, at this time, because these mentor teachers have not engaged in any such experiences, this assumption can only be gauged based on findings from the other groups within this study.

**Group 3: Marla, Paul and Shelley**

Marla, Paul and Shelley were three veteran mentor teachers each of whom had worked with interns for no less than three years. All three mentors were categorized as a “three” on the rubric after analysis of their initial stories of practice and all three shared the unique aspect of having served as PDAs (professional development associates) with the PDS for at least two additional years. PDAs are teachers working within the PDS who take leave from their classrooms for one to two years to act as liaisons between the school and the university and educators within the community. In this capacity, as teaching colleagues and educators, they are more readily available and accessible to mentor teachers and interns who contribute their assistance or expertise in certain curricular areas.

Marla, Paul, and Shelley modeled many aspects of inquiry science teaching practices in their classrooms and their stories reflected a deeper understanding of the importance of focusing student learning in science. They used science-specific teaching strategies in their classrooms and more often discussed how the use of these strategies impacted the learning of the children more consistently than those participants in Group two.

Just as the participants in Group two had described, these three teachers attributed much of their initial learning in the science classroom to their experiences in working with their intern. As Shelley stated,

Watching what the interns were learning and how they were bringing that into the classroom and how the students reacted to that. And how, the piece that the interns do that I think allowed me to change my practice was the pre-assessment, the post-assessment, what did you learn, how do you speak about it? That is very powerful because they're, because the kids are learning. … it just was a really powerful thing, not just to watch the interns, but to watch the students. And so, it
really gets me thinking, you know, this works, this is good. They're excited about it, and they're learning, how can I change the next piece of this unit, or the next lesson that we typically did this way or that way? (S1-32:21)

Working with interns in the classroom provided that initial movement across the continuum for the three participants in this group based on previous research findings (Badiali et al., 2011). However, as Marla, Paul and Shelley indicated during the initial interview, this new outlook encouraged each of them to pursue a different avenue within the PDS. Each of these teachers left the classroom for two years to become a PDA in the district. This meant that each served as a liaison between interns and the university faculty, which included guiding interns through the process of teaching, co-teaching in classrooms, reflecting on current research and practice, as well as working closely with the PDS team to ensure the success of each intern as well as the collaborative.

Marla, who served as a PDA for two years, counted her experiences during that time period to have greatly affected her overall practice. The following quote captures this claim, as was also supported by both Paul and Shelley regarding their PDA experiences as well:

Oh, that's huge [the PDA experience]. And that opportunity to still be involved with children in education at different levels and become an observer again was just an awful like a free college education at a different level. The opportunity to observe teachers, the opportunity to observe interns and students, the opportunity to really reflect upon your own practice and beliefs, oh my. And then, the difference in discussion that as a PDA you actually really think and talk about the theory behind things, pedagogy, but teachers are so immersed in the minutia of the day that you don't often have that opportunity to step back and view the whole. (Ma1-37:21)

Importantly, being a PDA not only affected overall teaching practice among these three mentors, but it impacted each of them in the area of science specifically. After spending two years working with many interns in the area of science, and also having numerous opportunities to spend extended amounts of time observing and interacting in colleague’s classrooms, these three
mentors sought to continue their personal growth and education in the area of science once they returned to their own classrooms. All three engaged in some type of science-specific professional development following their two-year PDA experience.

Marla’s story reflected the importance of being able to recognize the critical need for science-specific professional development. She was a thirty-three year teaching veteran who was eager to discuss the importance of both peer collaboration around science topics and science-specific coursework as major contributors to her change in science teaching. Marla often alluded to the importance of the roles that both formal and informal science-specific professional development played in her change. One specific example of informal science professional development that she shared pointed out the importance of peer collaboration:

I think the other thing that this kind of collegial group provides is almost a peer coaching model of sorts in that a group of teachers would meet after school and say, "How are we going to do this? You know, how are we going to deal with the simple machines?" …we would think about it together, somebody would try it, and then…[we would] say, “Well, this kind of worked for me, but this really didn't work and next time I think we ought to do it this way.” …But with the new model of people getting together in these kinds of collegial groups, and also, interns are constantly in the classroom and just spurring you on, too. Watching their teaching and trying to be the best that you can as a teacher educator, as a model for them and you're working together and trying that. But if I tried simple machines rotations in my room and some things worked and some things didn't, chances are, after school I'm going to talk to Jamie who's right down the hall from me and we're going to talk through it and when she does it next week or in the next couple days, she's going factor in my experience and tweak her lesson a little bit so, it's the group working together and changing and modifying the lessons as you go. (Ma1-12:21)

Marla went on to share the important role that more formal, science-specific professional development played in her change toward more reform-oriented practices. She said,

The other piece that really helped me with science education and the inquiry stance into the realm of every day for the teachers in our district is the fact that there were summer courses that were offered that were tailored specifically to our needs. Think about your own education, and when was the last time a university said to you, "What would you like to learn?" You know, let's look at your own
curriculum, let's look at your needs [emphasis added]. How can we design a course that fits your needs? You know, how many times has that happened to you? (Ma1-19:14)

This idea of personal attention to needs was something that was extremely significant to Marla. It not only helped her to deal with her skepticism toward the program, but also affected her on a very personal level. This helped her to make a personal connection to the new practices in science. She continued by saying,

…often times education, unfortunately at many different levels, is like a one-size-fits-all. When I went to Penn State many years ago, when we were still using a chisel and a stone, but anyway, when I went to Penn State, there were courses that I took and I sat in a room with 300 other kids, or 150 kids. It wasn't until the last two years that I was in classes that were smaller, but there was something in every class that added to my general knowledge. But in no time in the four years that I was there did someone say to me, "What questions do you have about your own education and what would you like to learn?" It was very prescribed - you're going to take this, you're going to take this, you're going to take this. In many ways, in-service opportunities in a school district are much the same way. It's something that happens to [emphasis added] you, it doesn't happen with [emphasis added] you. But this was a really fantastic opportunity to go to a science class in the summer and have somebody say, "What do you want to learn?" How can we take your curriculum and think about it and present it in a different way?" And again, you're in a room full of people who are sharing your exact experiences with this district and with the curriculum, and again you have this collegial group forming. At times, I felt a stronger connection to the mentors. (Ma1-19:14)

Marla took advantage of several summer course offerings in science through the university PDS collaboration. These courses enhanced the collegiality that she believed was integral to her change process. She stated,

I took several of those summer science classes because it gave you the opportunity in the summer time, which is kind of a reflective time anyway, and a down time to really think about your teaching, think about the curriculum, think about the changes you wanted to make and then, in addition to that, you had a support system. People saying, "Well, what if we did this? How about if we do this?" and "Let's try this!" That makes all the difference in the world. (Ma1-28:02)

She continued to express her feelings about the significance of such opportunities. She said,
I think that to me was huge to be able to meet in the summer with teachers in the district who are dealing with the same curriculum and saying, "Where are you finding this information?" Because information changes, whether it's science information or social studies information, information changes and you always want to be, you know, current with what you know and what you're presenting and that's, in a, especially in a community like this, everybody's an expert in something...So, you want to make sure that your knowledge is current and you're solid in what you know, and those summer science classes, and also the opportunity to pick up the telephone or to email someone and say, "you know, I'm having trouble with this, with Bernoulli's principles of flight. Help me out here." And bingo, there it was! (Ma1-28:02)

These opportunities for science-specific inquiry into her own practice were critical to the change process for Marla. Not only did they allow her to connect with her colleagues and what they were doing in science, but it also gave her a better understanding of both content and pedagogy as it related to science teaching. Shelley, too, recognized the importance of understanding science to a greater degree and to pursue professional development opportunities. She discussed her involvement in the PDS community as follows:

I've done about all of it. I was a PDA, I was on the course-creation team for Classroom Learning Environments, I've taken the inquiry course several times and done an inquiry project. (S1-40:33)

She has engaged in numerous inquiry-based opportunities through the PDS collaborative. However, Shelley was unique in that although she did not engage in a specific science professional development course through the PDS, she began her college career studying nuclear engineering, science and math. She pointed out several times during the interview that her natural passion for science has caused her to pursue personal professional development in science through science resources such as journals, books, and science websites in order to help her to connect theory to practice.

Paul’s story was similar to Marla’s, but also a bit unique. Paul began his pre-PDS journey as a hands-on, process skill type teacher, placing him as a “one” on the rubric. His
experiences as both a mentor and a PDA afforded him the opportunity to reflect on his practice and to make changes to the way that he taught science in his classroom, moving him from a “one” to a “three” on the scale at the time of the first interview based on his self-report. Paul consistently described his personal need to have time to self-reflect and to do, in his words, “whatever it takes” to learn how to do the best job of teaching science.

An argument is that anybody starting a new thing probably needs it [some sort of professional development]. You know, you're twenty, I'm fifty-two, and the first time I study a phenomenon I thought, “We need to have some hands-on and minds-on kind of activity of thinking about this stuff or ideas.” Annenberg has lots of courses you can take, maybe with other teachers. That's one of my dreams is to take courses with maybe Kate and some other teachers, maybe have the university person come in as a consultant or something. Keep us from complaining about the school district and get us moving in the classes, yeah! (P1-42:01)

What made Paul slightly different from other participants in this group was that he actively pursued outside opportunities for professional development that were not necessarily offered by the PDS. In the above quote, he mentioned the Annenberg series of science videos he accessed online and used as a personal means of professional development in science (and other areas). Additionally, Paul contacted Leah, a science education faculty member, and invited her to come to his classroom, critique his science teaching, and help him to design and implement science lessons that incorporated more inquiry strategies.

Leah [science education mentor] has had me think about that a little bit. Is inquiry always generated by the kids or can it be one of the questions I have for them? I guess it could be. But I'd like it to be a little more democratic than it is right now. You know, I still think that despite the fact that I'm trying to do inquiry kinds of things, I've made a lot of progress with being a teacher. (P1-19:34)

This personalized science-specific professional development, Paul described, was what effected the biggest change in his science teaching practices.
For Marla, Shelley and Paul, there was not much change in their stories of practice after two years had passed. As each was asked to describe his/her science practices two years later, each story paralleled practices from two years prior and each mentor discovered that they weren’t doing too many things differently. Marla was not focusing on science as she continued in the district as a reading support specialist. Paul was still struggling with how to connect his beliefs about how science should be taught to the actual science curriculum that he was responsible for teaching, and Shelley has continued to mentor and refine her practice. As she wrote,

I feel like the "new ideas" are not as frequent as they have been in the past. Some of this is because our units have not changed and the ideas that were created earlier in the PDS have stayed primarily the same… I have been involved in PDS for what seems like a million years. It has been seven or eight - gee I will have to think back. I have had at least five interns and was a PDA for two years. I have continued to be involved with CLE courses in the summer but have not taken anything directly related to science. (S2: final email)

Shelley’s story of practice remained virtually unchanged from her initial interview, as she reported no engagement in any form of science-specific professional development. Like Paul, she discussed continuing to work closely with her intern and getting better at implementing such science-specific strategies as the KLEW chart, using student wonderings to guide her teaching, and refining her pedagogy in the science classroom.

For these three participants, their strengths as elementary science teachers have been attributed not only to their personal motivation to learn more about science teaching practices, but also on their involvement in science-specific professional development opportunities, both in and outside of the PDS environment.

*Group 4: Margaret and Julie*
Margaret and Julie were two mentor teachers that had been working together for nearly two decades and as such, together tackled the issue of how to most effectively teach science in their classrooms. They admittedly put science at the top of their list of favorite subjects to teach and used this motivation to refine their practice on a daily basis. Their movement along the Participant Placement Rubric (Table 6.3) placed them both at a four on the scale following their first interview. Although they continued to acknowledge that they were, in their words, “always learning” and “never claim[ed] to be perfect” in how they teach science, their practice reflected nearly all of the standards of reform-oriented teaching methods that focused on scientific inquiry at the forefront of each lesson, investigation or unit that they developed.

When asked specifically what it was that sparked their motivation in science teaching, like all others in the study, they recognized the initial importance that their work as mentors working with interns played in their growth and change. For both Margaret and Julie, it was the new ideas and practices that the intern brought to their attention that sparked their curiosity and interest in learning more about reform methods in science teaching. Julie stated,

Then I just met Connie through [my intern], and got involved with thinking about science differently through [my intern]… But I didn't take [science] classes until after that year. It started with Carol and her interest in science, and her work with Connie and what she brought to the classroom, and me not being very happy with our science curriculum. I mean, I knew there was something wrong with it, but I didn't know quite enough how to change it myself… So it was kind of a combination. And then meeting Connie and actually getting to work with Connie and take some classes with Connie, and that's kind of what brought it about. (J1-01:58)

The first year of mentoring also started their first formal inquiry into their practice as both Margaret and Julie engaged in a teacher research project that resulted in the development of an addendum to a district curriculum unit on Prehistoric Life. Not only had they created, developed, implemented/field tested, and studied this document, but they formally presented
their research at the district PDS inquiry conference, sharing their product and findings with colleagues. Julie shared,

Then that year, I had to chair the Dinosaur unit for our team, which was a dinosaur. And Connie actually was instrumental in helping me, and that became my inquiry project. And Margaret and our two interns helped me rewrite this unit and make it a very inquiry-based unit on paleontology. And I haven't looked back. And now I know what cutting-edge science looks like. (J1-01:58)

Unlike other participants in the study, Margaret and Julie’s engagement in a formal, science-specific teacher inquiry project enhanced their knowledge and allowed them to continue to pursue innovative avenues for science teaching over the next several years. As both mentor teachers acknowledged the influence of their interns and this inquiry project as their starting point, they also attributed their continued learning and more in-depth understanding of both science content and pedagogical methods to science-specific professional development opportunities. As Margaret stated,

Truthfully, I mean, it was education. When you think about it, Connie was the one who began us thinking about this kind of stuff. So that the idea was sparked and I took a course and yes, she was a teacher, but I was with other professionals who were really interested in it. And then, I think, not only finding out about it, but it spurs that interest or that desire. I mean, I like science, so it pulls that desire to say, where else can I go with this and there are books. … So, learning from not only the literature but learning from being presented with them. But then the most powerful thing I can do is talk to people. If I sit around with Kate and Julie, it's like Ta-da! Wow! (M1-17:59)

Margaret elaborated on the importance that coursework played in helping her to make connections between her past experiences in the classroom and her desire and willingness to try new things in the science classroom. She said,

You know what's interesting? Is not only that I have taken coursework because it spurred me to do that, and it's spurred me to do more collaborative and open. I mean, I'm an open kind of individual anyhow, to be more open… And if I wouldn't have had some of the background from the coursework that I was [taking]… But it came from my experience… and then I think the education pulled those thoughts [together]. (M1-22:52)
Julie’s story supported these same claims. She recognized that having an intern was an important stepping stone on her road to change toward reform-oriented science teaching, however, when she was asked during her second interview, “If all you had ever done was worked with interns, do you think you would be where you are today?” Julie’s response was an emphatic, “No.” She explained that the personal professional development opportunities that focused specifically around science content and pedagogy were even more critical in her change process. She said,

First of all, it’s that experiencing the learning in an inquiry way. When you take the science course, Connie does practice what she preaches so you are immersed in inquiry science. You can see it working and you get excited about it yourself and then you can see, “Oh, well this is what happens to students, they get excited!” I think its feeling it from the participant point of view and then watching somebody who’s really good at it teach it. She’s a wonderful kind of role model so you can say, “Oh wow!” Just learning from watching her teach and then having her support as I tried to do things. Because we took the courses she has always been there to help and to talk to… And I think it helps to experience it. If I was just experiencing it from having an intern it’s a whole different story because first of all I wouldn’t be as comfortable with inquiry. I certainly have always been someone who lets my intern do what they have to do. I don’t know if I would have been as comfortable to jump in and help or to offer ideas because I wouldn’t know as much about it. And I don’t think an intern is in a position to teach a mentor because they are just learning. You can work through it together, but I think it’s completely different. It encompasses many aspects - really understanding children and understanding management things and understanding lesson progression and all those kinds of things – and really understanding the [science] curriculum, too. (J2-19:12)

Another aspect of professional development in which Julie and Margaret engaged was working on the science curriculum committee. As a result of their increased confidence in their science teaching abilities, they felt comfortable enough to assist in the process of adapting the science curriculum for the entire district in moving toward more reform-oriented practices. Julie stated,

Well, certainly personally I feel like, or professionally, I guess I feel like I'm a much better science teacher. I'm becoming very comfortable with questioning. I feel I'm getting much better at asking those questions to get my students to think.
So that part, I think, has helped. I question what I'm told to teach more now, and if I don't like the way something is laid out, I'll look for a different way to do it. For instance, we have to teach this underwater life unit, which was always about the ocean and the different parts of the ocean. And we're about as far from the ocean as you can get! So like, for Margaret and I it was like, well this just doesn't make sense anymore. What can we do to make these concepts? So we went to Connie and Connie gave us some ideas, and we completely changed the way we taught that unit. And now I'm on this science committee for the district, thinking about making changes in the primary science units, and we're looking at that STC, those STC books. And one of them, the unit is very much like what we've been doing now, a couple of times, with our underwater life unit, creating these pond communities. And we've been doing it now, the last 2 times we taught this unit. So, we are hoping to help make these connections. (J1-33:47)

Finally, it is important to note that Margaret and Julie continued to engage in science-specific professional development opportunities (e.g., science curriculum committee) prior to the second interview. They each remained at a level of four on the Participant Placement Rubric. Julie, however, had the unique opportunity to engage in a different level of science-specific professional development between interviews. She was offered a teaching position with the university to assist and co-teach the PDS elementary science methods course during the previous fall semester. She worked closely with Connie, the PDS science education faculty, and Kate, a third-grade teaching colleague in her building. No other participant in this study had an opportunity such as this to experience the formal teaching of education students in the methods of reform-oriented teaching practices. Julie described how this affected her both personally and professionally.

Well, I helped Connie, which was a big, big change for me. Helping her teach the PDS [elementary science methods] course was really rewarding. You know, whenever you teach something you always learn from it. So, not only learning from working with Connie and Kate, but then from having to think about how to teach a group of young people. That was pretty exciting for me. (J2-01:37)

Julie and Margaret both have committed much time and energy into developing their science practice and seeking out both formal and informal professional development opportunities in
science. They remain exceptional teachers of science who both understand and effectively model reform-oriented science teaching practices at all times in their classrooms as a result of their time and effort supported by science-specific professional development experiences.

I think that anybody taking those [science professional development] courses if they really throw themselves in, if they take them because they are interested in growing, they’re going to grow and they are going to learn a lot. And it was fun seeing Connie and Kate every week and really talking science very week. Imagine what that would do for you. So that was very exciting. (J2-23:22)

**Group 5: Lynne**

Lynne’s story followed a similar path to that of Margaret and Julie in that her experience with science-specific professional development catapulted her to a deeper understanding of reform-oriented science teaching practices. Lynne was a fifteen-year teaching veteran at the time of her first interview. She had only recently gotten involved with the PDS when the program expanded to her school. She served her first year as a PDA and when she returned to the classroom, she became a mentor teacher. She was working with only her second intern at the time of the first interview. Lynne’s self-description of her teaching practices placed her in the “two” category on the rubric. Her story reflected a movement toward the use of inquiry in the science classroom, however, she was not using reform methods exclusively and she consistently talked about her struggle with trying to make sense of how these new ideas fit in with her beliefs and practices toward science teaching. She attributed her learning to her observations of other classrooms during her time spent as a PDA, and from experiences with her intern, but, as she described below, continued to struggle with how to truly make meaning of what she was doing in the classroom.

To some extent my science teaching, I think, is finally really starting to change because of my sabbatical year and last year and this year I kept hearing about evidence, evidence, evidence, they have to provide evidence. And I'm like well how the heck do you get 2nd graders to do that? My intern this year was able to
show me some ways to do that... We've done some of those kinds of things, but I don't think that without, like the in-service we had or without a mini-course that directly connects it to the units that I'm going to remember. Until it becomes a habit, it's hard to remember to use the language, or you know, remember not to tell them, but to ask them, "Well, what do you think? You tell me." Ugh. (L1-9:07)

Lynne wanted to make changes to her science units to make them more inquiry-based, but she toiled over the process of completing that task. Issues such as time, experience, and commitment interfered with her desire to implement changes quickly and effectively now that she was becoming familiar with new strategies and teaching methods.

Well, I spent 4 weeks before this unit started trying to figure out a different way to teach other than a week on mammals, a week on fish, a week on birds, a week on insects, a week on amphibians, and a week on reptiles or whatever I left out. And, I couldn't do it. I didn't have enough time... Because, you know, I'd be willing to try some of those things, but I just didn't have the time this year to do it myself and because I hadn't chosen that as an inquiry project, I couldn't get that ready in the middle of doing my own inquiry which was on my classroom community, and you just, you can't do everything at once... Again, if I don't practice it, I'm not going to use it. (L1-33:39)

As she pointed to issues that she felt interfered with her ability to effectively develop science lessons that reflected her beliefs about best practices, she pointed out that the one major factor she felt would facilitate this process would be to engage in personal professional development opportunities. She said,

I'd like to take classes! I'm very busy... it's just been really hard to get that in. And I feel bad about that because I do enjoy science and I do think it's a lot of fun and I have a husband who is a meteorologist so you know we get into a lot of discussions on that. It'll just have to wait until I can get there... and a two-hour in-service doesn't quite do it. (L1-56:08)

Upon completion of her first interview, Lynne expressed a feeling of frustration. She was excited about her new outlook toward science, yet frustrated that it “wasn’t as easy as it looks.” When contacted two years later, she was eager to share many aspects of her growth in science. Lynne’s frustration with her science curriculum had prompted her to make the time and take a
graduate level science education course at the university with Connie, the university PDS science educator.

What I think is hard and why I took the class in the fall is we still have the same curriculum, we still have the same set of standards or expectations, outcomes whatever. How do I take what’s there, on my own, and flip it around so that its more inquiry based for our classroom students? (L2-10:05)

The focus of this course was to investigate current science units taught in the district and to make modifications to make them more inquiry-based. She elaborated,

Since I find the PDS classes so valuable, I have been taking them off and on as my schedule fits. In fact, I decided to take another one this fall—in Science Ed! We looked at how to bring more inquiry into our practice, and what that might look like at a primary level. Another teacher and I have decided we would like to tackle a primary science unit that we teach in the last quarter of the year. This unit is "The Wonderful World of Nature" which means we cover six animal categories and much about plants. I have been dissatisfied with this unit since I started teaching it many years ago, because it is “too broad” and not "deep enough". We are supposed to teach what makes an animal an amphibian, for example, and compare it to other types of animals. We cover amphibians, birds, fish, insects, mammals and reptiles! Jen and I had to complete three lessons for our class that were more inquiry-based, as well as provide some background information. (L2-email)

As Lynne described her project, it became apparent that she was describing the same unit that she had struggled with during her first interview. Participation in this course supported her growth and the development of her practice to both include and understand more about reform-oriented science teaching practices. Lynne provided copies of her revised lessons from the course for the researcher to examine. These modifications reflected a more advanced level of understanding of inquiry and included implementation of all of the essential features of classroom inquiry (NRC, 2000).

I think taking the course forced us in some ways to look at it and say, “Ok, we know that it can be done, how are we going to do it?” And especially the challenge because of what we looked at, where we were told, in some ways it’s really hard to do it with factual information, to do it with animals and biology, but then we turned around and said, “But we want to do it we’ll find a way!” But that
gave us the motivation to do it you know, knowing that it was going to be difficult but wanting even more in some ways to be able to do that so that we can have something that’s more inquiry-based… Not only that, but again it’s forcing you to sit and think about your practice which is one reason why I really like the PDS classes because they tend to do that… It’s figuring out what is it supposed to look like at this level that’s difficult and that’s where it can be difficult for the teacher to have the time. (L2-17:41)

Finally, for Lynne, she described the significance of how her semester-long experience in a science-specific professional development course affected her change. She stated,

That’s what I think that this fall class was helping me do was to see “What is the difference between learning and having kids discover?”….I think the hands-on is “I have a bunch of stuff for you to do and you go do that and we talk about it” and the inquiry is, “You may still have a bunch of stuff to do, but the question is why are we doing this?” Having the kids see patterns or having them come up with connections… And [if we go in an unplanned direction] which is not where I intended to go I say, “I didn’t get there because they just started making these connections.” That’s what I think is the difference between providing them with the activity and having it be more inquiry. (L2-40:14)

For Lynne, working with an intern was a good start, but not quite enough to help her gain a strong understanding of how inquiry was supposed to look in a science classroom. She felt that it was necessary for her growth to have additional, science-specific professional development that required her to reflect on and analyze her own teaching practices in order to truly make progress toward understanding both how and why she was changing her beliefs and her practice. She did take advantage of a professional development opportunity and her change was reflected in her stories of practice and document analysis to support her work in her science teaching in the classroom following her participation in the science education course.

6.2.5.3 Discussion

Demographic information from study participants showed that mentor teachers involved in the study were from a variety of backgrounds, grade levels, and had differing years of teaching experience. At the time of interview one, the range of teaching experience for mentor teachers
was between fourteen and thirty-three years. Additionally, the range of years of experience working as a mentor teacher with an intern was from one to seven years. Demographic information gathered from the PDS Impact Survey was synthesized in the following chart:

<table>
<thead>
<tr>
<th>Participant</th>
<th># Years Teaching</th>
<th>Current Grade Level</th>
<th># Years Working With PDS Intern</th>
<th># Years Working With PDS Planning Teams</th>
<th># of Times Engaging in Teacher Inquiry</th>
<th># of Times Participating in PD Courses or Workshops</th>
<th>Type PD Courses or Workshops</th>
<th>Other Types of Involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Julie</td>
<td>25</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>4</td>
<td>8</td>
<td>Inquiry (3); Science (1); Technology (1); Social Studies (1); Classroom Learning Environments (3)</td>
<td>Reading intern applications; Interviewing interns; Attendance at conferences</td>
</tr>
<tr>
<td>Margaret</td>
<td>30</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>Classroom Learning Environments; Peer coaching - KLEW chart [development]; Worked with university faculty; Prehistoric Life Teacher Inquiry (3); Mentoring; Summer-Responsive Classroom; PDS Movement Course</td>
<td>Reading intern applications (6); Interviewing interns; Hosting intern in partner classroom (3); Attendance at conferences; contributed to research</td>
</tr>
<tr>
<td>Lynne</td>
<td>15</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>Teacher Inquiry (3); Mentoring; Classroom Learning Environments; Science</td>
<td>Sabbatical – participated in Math Education &amp; Social Studies Education expansion teams; PDA meetings; Reading intern applications; Interviewing interns; Hosting intern in partner classroom</td>
</tr>
<tr>
<td>Elizabeth</td>
<td>14</td>
<td>K</td>
<td>5</td>
<td>x</td>
<td>x</td>
<td>5</td>
<td>Teacher Inquiry Course; Teacher Mentor Course; Inquiry</td>
<td>Reviewing intern applications; Interviewing interns</td>
</tr>
<tr>
<td>Paul</td>
<td>26</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>Reading intern applications; Math</td>
<td>Reading intern applications; Interviewing interns; PDA</td>
</tr>
<tr>
<td>Greg</td>
<td>21</td>
<td>2</td>
<td>7</td>
<td>x</td>
<td>1</td>
<td>5</td>
<td>Instructor for PDS Workshop</td>
<td>Reading intern applications; Interviewing interns; Hosting intern in partner classroom</td>
</tr>
<tr>
<td>Marla</td>
<td>33</td>
<td>Learning Support</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>Many</td>
<td>Science Summer Course</td>
<td>Review of intern applications (7yrs); PDA (2yrs); Attendance at PDS Conferences</td>
</tr>
<tr>
<td>Shelly</td>
<td>19</td>
<td>½ split</td>
<td>4</td>
<td>7</td>
<td>&quot;All of the time&quot; (twice formally)</td>
<td>7</td>
<td>Reading intern applications; Interviewing interns; Hosting intern in partner classroom; PDA</td>
<td>Reading intern applications; Interviewing interns; PDA</td>
</tr>
<tr>
<td>Karen</td>
<td>21</td>
<td>2</td>
<td>6</td>
<td>7</td>
<td>3</td>
<td>7</td>
<td>Classroom Learning Environment Participant and Presenter</td>
<td>Reading intern applications; Interviewing interns; Hosting intern in partner classroom</td>
</tr>
<tr>
<td>Bobbie</td>
<td>31</td>
<td>K</td>
<td>7</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>&quot;7 years Inquiry Conference attendance; Attended 2 PDS conferences; Contributed to PhD research 2 times; Reading intern applications; Interviewing interns&quot;</td>
<td>x</td>
</tr>
<tr>
<td>Lana</td>
<td>19</td>
<td>5</td>
<td>1</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>Reading intern applications; Interviewing interns</td>
<td>x</td>
</tr>
</tbody>
</table>

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As these data were gathered and analyzed, no significant connections could be found between categories. Information from this chart was then compared to information in Table 6.3. As can be seen in the following chart (Table 6.5), there was no significant connection to be found between years of teaching experience and placement on rubric. Additionally, there was a slight association found between years working with a PDS intern and participant placement on rubric. For the two teachers who had the least mentoring experience, their placement was on the lower end of the rubric scale. This phenomenon was investigated more thoroughly through interview analysis. However, for the remaining teachers, experience as a mentor placed them anywhere between two and four on the scale, placements that did not follow any specific pattern of length of time working with interns.

A significant connection was found between science-specific professional development and its relationship with mentor teachers’ placement on the rubric. For each of the teachers that engaged in at least one science-specific summer course, inquiry project, or other outside science learning experience, as a result of his/her self-report, placement on the rubric (Table 6.3) reflected at least a three or four, higher than participants that did not engage in science-specific professional development experiences. These results demonstrated that teachers such as Margaret and Julie were implementing numerous reform-oriented practices in their science classrooms and reflected a strong conviction for teaching science in this manner.

<table>
<thead>
<tr>
<th>Mentor Teacher</th>
<th>Years Teaching Experience</th>
<th>Years Working with PDS Intern</th>
<th>Reported Science-Specific PD (prior to Interview 1)</th>
<th>Placement on Rubric (after Interview 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lana</td>
<td>21</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Greg*</td>
<td>23</td>
<td>9</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Elizabeth</td>
<td>16</td>
<td>6</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Bobbie</td>
<td>33</td>
<td>9</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>
This pattern in the data was recognized but not reported at the time of the publication that resulted from the initial research (Badiali et al., 2011) as the results of the study primarily focused on the influence of PDS interns in the science classroom environment. However, two years after the initial data were collected, the researcher was positioned to conduct another round of interviews. Knowing that there was a possible link between the science-specific professional development and reform oriented teaching practices, it was critical to again focus on stories of teaching practice and information regarding professional development opportunities. At the time of the second interview, each mentor teacher was teaching the same science units that he/she had been teaching two years prior. Teachers were again asked to describe their practice and were specifically asked if they had been involved in any additional, science-specific professional development. Based on their self-reports, each participant was again placed on the rubric scale and this information can be found in Table 6.3. A synthesized version of information from Table 6.3 and Table 6.5 is shown in Table 6.6.
Although each teacher’s shift toward inquiry-based science teaching practice was unique in many ways, there was one commonality among those teachers who showed movement on the continuum. This commonality, revealed through analysis, was the type of professional development in which these teacher had been involved. More specifically, patterns in the data confirmed that for those mentor teachers whose practice had reflected strong evidence for placing them at a “four” on the rubric, there was only one common factor that was shared between each participant. This factor was science-specific professional development. Teachers who had been involved in extensive formal professional development in science, in the form of coursework, formal teacher research into their own science teaching, or in the form of other types of science-specific experiences outside of their own classroom, were found to describe their science teaching practices in a more sophisticated manner than other participants in the study.

As reported by Buczynski and Hansen (2010), in order for any professional development to be effective, teachers must put into practice their professional development experiences. It was supported that working closely with an intern did provide clear opportunities for growth and change toward reform-oriented science teaching practices, as was supported by every participant’s story of change. Additionally, these science experiences with an intern marked a critical juncture in the process of change for every mentor teacher. As mentioned previously, this information was presented in an earlier document based on data from this study (Badiali et al., 2011). However, this factor alone did not provide a mentor teacher with the abilities or understanding necessary to teach science as inquiry with the greatest degree of implementation. Roughly speaking, working with an intern can be considered a springboard into trying new ideas.
and beginning to build new experiences, but working with interns will only get you “so far” down the path toward reform. In order for mentor teachers to develop a more refined level of understanding of how best to implement reform oriented practices into their daily classroom environments, they need some form of science-specific professional development. These experiences can come in the form of coursework, workshops, committee work, teacher inquiry or other similar opportunities. In addition, teachers need specific instruction on teaching strategies and theories behind using them. In addition to this, they need to both observe examples of these strategies in use and be afforded opportunities to practice those strategies themselves (Loucks-Horsley et al., 2003; Quick, Holtzman, and Chaney (2009).

Most elementary teachers in the U.S. are not sufficiently prepared to teach science subject matter, and they often lack the confidence to teach science regularly (Lee, Adamson, Maerten-Rivera, Lewis, Thorton, & LeRoy, 2008; Tilgner, 1990). This is problematic because the teachers who are most in need of professional development are those who do not necessarily have sound pedagogical content knowledge of the subject matter and do not have ready access to science-specific professional development opportunities (Buczynski & Hansen, 2010). The NRC (1996) states that “reforming science education requires substantive changes in how science is taught, which requires equally substantive change in professional development practices at all levels” (p. 5). According to the NRC (2007), in order to move toward instruction that is consistent with current trends in science education reform, teachers will need “substantial, ongoing, and systemic supports for their own learning” (p. 306). However, comprehensive professional development for educators has generally been a neglected or shallow component of school reform efforts for the past twenty years (Speck & Knipe, 2001). It is believed that while teachers typically need substantial professional development in a given area (close to fifty hours)
to improve their skills and their students’ learning, most professional development opportunities in the U.S. are much shorter (Darling-Hammond et al., 2009)

Teaching is “the act of organizing and shaping learning experiences for students” (Loucks-Horsely, 2003, p. 37). In order to do this effectively, it is thought that teachers ultimately need to be proficient in their content areas, understand how students learn, and have a wide range of instructional strategies to facilitate that learning in the classroom (NCTM, 2000; NRC, 2001). In order to meet the needs of teachers to increase their abilities to teach science in ways that are consistent with national standards and state frameworks, it is important to have available professional development opportunities that help teachers to develop a deep understanding of the nature of the science discipline.

Recent research efforts describe what effective professional development should look like for elementary teachers of science (Loucks-Horsley, 2003; NRC, 1996; NRC, 2000; NRC, 2007). It is agreed upon that opportunities need to provide sufficient time, structure and support in order to be effective. As Loucks-Horsley and colleagues (2003) explain the process of change in educational settings, and more specifically in science education, one factor that they emphasize is this: “At different stages in the change process, individuals need different kinds of support and assistance” (p. 48). They go on to emphasize:

It should come as no surprise, then, that when change occurs, it does not happen in one step, but is progressive. Studies of individuals who change their practice over time report that individuals go through stages in how they feel about the change and how knowledgeable and sophisticated they are in using it. The questions that people ask evolve from early questions that are more self-oriented (What is it? How will it affect me?) to questions that are more task-oriented (How do I do it? How can I use these materials effectively? How can I organize myself? Why is it taking so much time?) to questions focused on impact (I this change working for my students? Is there something that will work even better?) (p. 49).
This pattern is recognized and is supported by evidence with this group of eleven mentor teachers on their journeys through the process of change in how they think about and teach science in their elementary classrooms. For these participants, movement across the rubric is reflective of movement through the level of questioning addressed in the above quote. When teachers were first introduced to inquiry-based science, their questions were self-oriented as they began to think about the new ideas. As their interns modeled reform strategies in the classroom and as mentor teachers initially tried these new strategies and methods themselves, they began to focus on the task-oriented factors of the change process. However, in order to transform their practice from a more task-oriented base of inquiry in science lessons to an impact-oriented view of science in the classroom, mentor teachers reflected a need to be challenged to think and act differently through their interactions with science-specific professional development opportunities.

Participants who described their practice in a manner that reflected strong implementation of reform-oriented science teaching skills participated in some form of formal science-specific professional development. This type of professional development allowed each teacher to self-reflect and examine his/her practices and to begin to design and implement original and creative instruction that reflected reform methods. Summer science courses, formal inquiry projects, and/or science planning teams are just a few of the examples of science-specific professional development opportunities in which these participants engaged. Additionally, for participants who did not move forward on the continuum after two years had passed, the findings were the same: none of these mentor teachers participated in any science-specific courses, workshops, or any other type of science-specific professional development opportunities.
This assertion also supports similar research by Bell (2002). She discovered that in-service teachers who had participated in science-specific learning experiences within the context of a professional development school setting indicated that their inquiry-based learning experiences raised their confidence to teach inquiry science. These teachers also indicated intent to teach more science as inquiry.

In conclusion, it was found that through this research and for this group of participants, science-specific professional development opportunities were necessary in order to effect a change in classroom practices that were reflective of a strong understanding of reform-oriented inquiry in science. Without such opportunities, positive changes were made to incorporate more inquiry strategies in the science classroom, however, these changes remained relatively unchanged over time. Therefore, in order for teachers to continue to make progress on their path of change in science teaching, they must be both encouraged to participate and given ample opportunities to engage in experiences that focus on learning and understanding the principles behind what effective science teaching looks like in the elementary classroom through formal and informal science-specific professional development opportunities.

6.2.6 Assertion Six

Research Question: What is the relationship between the levels and types of involvement in PDS to change in thinking about and practices of teaching science?

Assertion: Mentor teachers reported that collaboration within a community of practice mediated a change toward reform-oriented science teaching practices.

6.2.6.1 Description

Based on the original research question, “What is the relationship between the levels and types of involvement in PDS to change in thinking about and practices of teaching science?” data
analysis revealed a strong connection between mentor teachers’ reported changes in science teaching practices with their involvement within their school community. Participants consistently reported on the influence that different members within their teaching community had on affecting their change in both thinking and practice of teaching science in the elementary classroom. Mentor teachers’ self-reports of their change stressed the importance that it was most often the combination of these community members, not one single person or entity in general, that had a significant effect on their process of change. More specifically, these relationships were built around science education and thus were science-specific collaborations, not generic support groups. These science-specific communities of practice played a vital role in the growth and change toward more reform-oriented practices of these elementary mentor teachers. In the following paragraphs, the evidence describes the supportive relationships surrounding science collaborations within the PDS community.

6.2.6.2 Evidence

Communities develop around things that matter to people (e.g., science teaching) and this gives each member a sense of joint enterprise and identity (Wenger, 1998). There were three main science-specific collaborations that mentor teachers identified and reported as being highly supportive of change in their science teaching practices. Those collaborations were identified as support from an intern, support from elementary teaching colleague(s), and support from PDS university faculty.

Support from an intern in the science classroom

For each mentor teacher, his/her primary involvement working with an intern was the first “spark” that initiated thinking about teaching science in a new and/or different manner. As a result of having personally seen and experienced the ways that each intern was being asked to
interpret and try out new science lessons in the classroom as a result of their science methods course, each mentor teacher was challenged to examine his/her method of teaching science. However, as is the case in many traditional student teaching placements, student teachers spend a few weeks in the classroom, teach a few lessons, and then move on either to another placement or toward graduation, leaving the mentor teacher with some new ideas, yet no real method to question or follow-through on those new ideas unless he/she pursues it on his/her own. Alternatively, since these interns spend the entire year in the classroom and their university assignments are linked very closely to the district curriculum and classroom events, the intern and mentor teacher work closely for an extended time period on science lessons.

Often, mentor teachers described their initial reaction to these reform-oriented practices as one of dissatisfaction with their current teaching method. For example:

It started with Carol [PDS intern] and her interest in science, and her work with Connie [university science education faculty] and what she brought to the classroom, and me not being very happy with our science curriculum. I mean, I knew there was something wrong with it, but I didn't know quite enough how to change it myself. (J1-07:31)

This was a common reaction among mentor teachers. Although Julie stated that she had been frustrated with her science teaching prior to working with her first intern, many others reported that they had not even really given much thought to the effectiveness of their science teaching prior to having an intern in the classroom. In these cases, the intern was the catalyst for change if you will, the person that caused the change. As Margaret reflected,

Working with interns has been absolutely phenomenal for me because from their science class, young professionals are coming in with ideas. And I see, hmmm, o.k. - I'm going to put it this way - I see that in my class I learn from the interns. Well, this is what I'm supposed to do? What do you think we can do with this? (M1-22:52)
Shelley elaborated on this, citing the importance of reflection on practice as an added bonus of mentoring an intern.

[With an intern in my room], it was definitely an evolution of what PDS has done for me, in science and in all areas. It has forced me to examine my belief system and why I believe the way I do because I need to help someone else understand why I'm doing things the way I'm doing them. (S1-12:50)

Elizabeth agreed and said,

Because the PDS encourages reflection in classes, I have had lots of opportunity to reflect on my practice and make changes to try to improve my practice. Having an intern is a lot of work, but is really worth the effort for the growth it encourages in me, and the benefits it gives to the children. (E1-21:40)

Even Lana, who repeatedly resisted to acknowledge the intern as the specific person or event that changed her thoughts about teaching science, eventually did recognize that it was the presence of that intern that affected her in a different way and caused her to reflect on her own practice. She said,

She (my intern) herself didn’t (spark anything in me). I mean, she was excellent – she had a lot of ideas. I think, more for me, it was her questions [emphasis added] to me that when I would respond to her would spark my questioning, “Why was I doing something?” (La1-08:39)

During her first interview, Lana really struggled with this idea of having an inexperienced young teacher contribute to her change. She saw her role as mentor as the one who was preparing, teaching, guiding, and not necessarily learning as an added component of the relationship. However, in her interview two years later, after she finished explaining the changes that had been taking place in her science classroom since her last interview, she was asked specifically by the researcher, “How do you think you have gotten to this point in teaching science this way over the last two years? Is it having the intern in your classroom?” Her response was:

That’s a huge part of it…and I think you get comfortable, you get engrained and you get lazy and it’s easy to use those [district curriculum] units. But it really was, in my opinion, knowing what the PDS interns had to do and I had to at least create
the atmosphere to allow that to occur in my classroom which has probably changed it the fastest for me otherwise I’d still be reading about it, thinking I’m doing it, but not doing it. (La2-13:03)

This mentor/mentee relationship allowed each mentor teacher to question his/her beliefs about the way that he/she taught science in the classroom. The classroom teacher may not have immediately started teaching science using these new methods, but they were questioning their own practice and by doing this, each mentor was challenged with a new way of thinking about their science teaching practices. The introduction of the intern into each elementary classroom was a critical juncture in the change process for each mentor teacher (Badiali et al., 2011).

As a result, relationships were formed in the classroom. Instead of being isolated in the classroom and being faced with trying new methods and ideas alone, mentor teachers recognized the importance of having a significant other in the classroom, a partner, with whom they could talk and try out new science practices. As Elizabeth reflected on the importance of working with her interns over the years, she affirmed this idea. She said,

I really feel like I have learned so much about my own practice from having an intern. It’s just so interesting because when you have to teach somebody something, you really have to think about what it is you do and why… and so each intern has taught me something about myself and made a change for me… they have really been how I learned at all about this because I've not taken any PDS science courses yet, so any of the little bit of learning that I've done about science and how to teach science differently has really come from an intern and their projects that they do and when they're teaching science. (E1-30:19)

Margaret reinforced the significance of the support of the intern in her story of practice by saying,

And I have learned, my intern last year was a tremendous questioner…we would really push off each other and she was a tremendous questioner, so I think we learn from them as well, and from their projects and their questions and helping them… and if I'm helping someone else to learn, I learn as well. (M1-22:52)
Greg acknowledged the significance of the previously unrecognized support that simply having another teacher with whom one comes in contact each and every day that challenged him to avoid burnout in his science classroom. He said,

…just the fresh ideas and the excitement that an intern, someone at the beginning of their teaching career brings. It really does rub off when you're around someone like that - when you've taught twenty-two years like I have, you know, sometimes you feel like "Oh, how many more years can I do this?" But being around someone who's eager and like I said, I get lots of good ideas from the interns. (G1-27:15)

As mentor teachers told their stories, not only was the intern reported as the catalyst for change, mentor teachers most commonly began the telling of their personal stories of change with the introduction of the intern. The support that each mentor received from the intern and the confidence that was substantiated started each down the path of looking outside of the four walls of their classroom to others within their community. Marla captured this experience when she stated,

The relationship that a mentor and an intern form lasts, usually, much longer than the year. And that, in a way, is the beginning of the support group… but I think that mentor-intern relationship when it really does [emphasis added] work, is the beginning of a long support system, you know a collegial group that lasts throughout the year. (Ma1-16:11)

Each of these examples highlights participant’s conclusions about the importance of the support that the PDS intern provided for each of them in their change in science teaching practices. Whether the intern was the catalyst or simply a significant other in the classroom, the opportunity to work alongside another teacher on a consistent basis afforded each participant the confidence to pursue new ideas and practices in science.

Support from elementary teaching colleagues

Each participant in this study reported that the intern was his/her first connection to thinking about science in a new or different way. The intern was the first critical juncture in the
change process (Badiali et al., 2011). Some participants worked with interns for a few years before they reached out to others in their community of practice, while other participants began immediately seeking the advice and assistance of their teaching colleagues down the hall or in the next room in teaching science in their classrooms. Julie and Margaret provided an example of two mentor teachers who immediately began working as a collaborative team with their interns in their science classrooms. For example, Julie said,

I think collaboration is so important in all areas of teaching, but especially when you're trying new things. First of all, you've got a synergy of knowledge or ideas. You know, when two people come together you certainly get better than double the amount of ideas. Margaret is really good because she asks good questions that make you think things through. Like I'm a, "Oh yeah, let's try that!" And I don't really think through the whole process. So she'll say, "Well, how are you going to do that? And what are we going to do about this?" And so it really makes you think, and as you think about things and articulate things, it helps work out kinks ahead of time, and that I think is really good. So we plan well together, we have fun, so we can play with science. (J1-09:53)

Julie went on to describe one particular science unit that she and Margaret tackled early on in their collaboration. She described,

Like when [Margaret and I] did this magnet thing, we played around, and looked at the magnets and played with the magnets and learned a little bit more about magnets ourselves, and then brought that to the classroom. There's that kind of collaboration. And then, if things don't go well or if you're scared about something, to have somebody else to share the experience with, who can say, “Well that didn't work for me either”, or “Well I did it this way”. Or if she teaches a lesson before I teach it, I'll go to her and say, "Okay, what happened? What worked, what didn't work?" And she'll do the same thing for me. So that it helps improve your teaching just by talking about pluses and minuses with somebody else. (J1-09:53)

For some of the study participants, the immediateness of these science-specific teaching relationships was very important in their learning process. They could continue to utilize their relationship with their intern, through both teaching and mentoring, however, working with a colleague allowed them the opportunity to focus on those things that a more experienced other
could attend to. As one participant stated, “New teachers have awesome ideas, but often get caught up in the basic classroom management struggles.” Collaborating hand-in-hand with veteran colleagues often helped mentor teachers get down to focusing on more content knowledge in science.

Paul stressed the importance of this idea of working with teaching colleagues who were focused on this shared practice of reform in science classrooms. He said,

John introduced us to, "critical friends" groups, only he calls it "critical inquiry groups" I think. So I'm in a couple of those now. (P1-15:22)

Marla believed that working with colleagues was not always necessary for some teachers. She said,

I don't think it always takes a collegial group, I mean, there are probably people in every building that take a look at this and go "wow!" and can do it on their own. But for some of the rest of us, that group, that collegial group is really important in kind of leaving those feelings of inadequacy in science and also frustration and trying to redesign your science lessons to be more inquiry-based. (Ma1-10:01)

However, she went on to disclose that the strength that a support group, a critical inquiry group, could offer in science was imperative for most mentor teachers. Reaching beyond their classroom walls for support from others involved in making similar changes to their science teaching practices was critical to the change process.

I think the other thing that this kind of collegial group provides is almost a peer coaching model of sorts in that a group of teachers would meet after school and say, "How are we going to do this? You know, how are we going to deal with the simple machines?" And somebody, you know would think about it together, somebody would try it, and then they worked the opportunity to say, well, this kind of worked for me, but this really didn't work and next time I think we ought to do it this way... so that often times the progress that you make one year you forget about until you're well into the unit. But with the new model of people getting together in these kind of collegial groups...but if I tried simple machines rotations in my room and some things worked and some things didn't, chances are, after school I'm going to talk to Jodi [teaching colleague] who's right down the hall from me and we're going to talk through it and when she does it next week or in the next couple days, she's going to factor in my experience and tweek her
lesson a little bit so, it's the group working together and changing and modifying the lessons as you go. (Ma1-12:21)

In addition to having a connection with a critical inquiry group in science education, connection to professional development associates (PDAs) within the community proved to be important as well. Lynne’s accessibility to Kate [PDA] was very important to her on her path toward change in her science teaching practices. She said,

Kate, that's our PDA who's a real science person, too, she's one of the people who teaches science courses - so, she helped plan some lessons that I kind of just watched and listened to, and thought, this is really cool. You know, what are the kids going to learn from this? You know, how are they going to build their understanding of some of the body systems? (L1-09:07)

This accessibility to teaching colleagues, for assistance in the science classroom, whether to watch science lessons, build science lessons together, or just to talk about what worked or didn’t work in the classroom with the children was a common theme for all participants. Those teaching colleagues could be in the form of a classroom teacher across the hall, a colleague who was serving out of the classroom as a PDA, or a group of like-minded individuals within the school (i.e. critical friends group). Lynne summed it up best when she said,

So having someone with the prior knowledge of experiencing it I think helped relieve some of the concerns that some of our people who hadn't really attempted it before had. I didn't have any concerns. I was just really excited. I was just, you know, it was nice to have her there to be able to say, OK, so how did you tackle this one because you had first grade and if you could do it in first grade I know that's appropriate for second grade. So, having either someone who's done it before or having some sort of guideline, information, particularly when you are in the process of changing your thinking I think is very, very helpful. (L1-43:47)

Support from PDS university faculty

In addition to the support that mentor teachers received from having an intern in the classroom and having the opportunity to work with fellow teachers both in their schools and around the district on science education reform methods, each participant discussed the impact
that having continued and consistent support from PDS university faculty made on their change process. Marla provided an example of how this support group was critical in her change process:

There was that support that you could get from the university, slash from the collaborative, the PDS collaborative. But, as more and more people became involved in the PDS, you had a support group within your school, within your division, which also helps you change science...Also, I really liked the support that the PDS brings to science teaching. So, if you had a question, I mean, Connie, especially when the PDS was only 2 or 3 schools, you could see Connie in the building and even if you didn't see her you had formed that relationship with the PDS so you could make a telephone call and say, "I don't understand why this isn't working. You know, tell me, I don't understand the science behind it and I don't understand why this isn't going the way it should be - the lesson." (Ma1-02:31)

For Julie, she continued to reach out to anyone who could help her learn more about using science teaching practices that reflected an inquiry approach. She was first intrigued by her intern’s work in her classroom, which caused her to reach out to her teaching colleague in the room next door, Margaret. As she and Margaret continued to try new methods, they then looked beyond their colleagues to a university science educator that worked within the PDS.

And then, this meeting Connie and actually getting to work with Connie and take some classes with Connie, and that's kind of what brought it [change in science teaching] about. (J1-07:55)

For each participant, it was regularly pointed out to the researcher that it wasn’t simply the opportunity to work with a PDS university liaison within the realm of science education that helped them to foster a change in their practice - it was the trust and mutual respect within this science-specific community of practice that helped each participant to try new practices and to feel safe in doing this. Shelley, a first grade mentor teacher, elaborated on this point quite clearly. She said,

The opportunities that are there for thinking deeper are not just because of my intern, but because I feel that my expertise from being in the classroom is well
respected and valued and Jon is wonderful about that, and Connie is wonderful about that. You know, none of them would ever say they know more than any of us, and so Connie will walk into the classroom and learn something and so the respect on all levels is another reason that I feel allowed to explore why I'm doing things, and change. (S1-14:09)

Science was the curricular area which most of the mentor teachers identified as the one they felt the least qualified to teach prior to their PDS involvement. Therefore, having the opportunity to work with university professors was important in their journey of change in science as the mentor teachers felt that they were getting qualified advice and assistance from professionals in the field on inquiry and science education. This foundation of trust and respect that was established between university PDS faculty and mentor teachers was a vital part of the change process. As Bobbie, a kindergarten teacher who has been involved in the program since its inception stated,

But they've tried just about everything and they listen to everything that the teachers say…So, there is an obvious continued collaboration…But there's always this work between everyone and you always, you don't feel like there's any closed door sessions, in anything that's important and that you're working with in that it's just a sense of trust. (B1-37:07)

These relationships that were formed within this community around the topic of science education were not haphazard or disorganized. They were focused around a common goal - to improve science teaching practices in the elementary classroom to support student learning. Each member worked to contribute to the process. Paul, a fifth grade mentor teacher, felt that this commitment, by all members of the community, was crucial to the success of implementing reform-oriented practices. He said,

It was the PDA meetings where we would sit around, and you worked with the university professors who kind of have the attitude that, well we're going to get this done no matter what. We're going to accomplish this. We're interested in this so we're going to try to make this happen. (P1-08:43)

Marla elaborated on this point when she stated,
Connie was here the other day meeting with a teacher and that's a real benefit to the PDS that enriches everyone - it enriches the children in the classroom, it enriches the teachers' experience, it enriches the intern's experience, and I have to think that as much of an impact as we, as much of an impact as the university has made on us, we have made a similar, a different impact on the university and how they go about teaching prospective teachers. (Ma1-34:05)

Furthermore, Julie, a first grade teacher who has become instrumental as one of the forerunners in the science reform movement in the district worked closely with Connie, the university PDS science education professor, said,

Then that year, I had to chair the Dinosaur unit for our team, which was a dinosaur! And Connie actually was instrumental in helping me, and that became my inquiry project. And Margaret and our two interns helped me rewrite this unit and make it a very inquiry-based unit on paleontology. And I haven't looked back! (J1-01:58)

Margaret also discussed the important role that Connie played in her change process. She said,

I know working with schools we all have our issues to get through when you think about political or administrative or whatever, but instilling the love of what you do - if that can be done, wow! I mean, what I know is that my science teaching changed because of Connie [PDS university faculty]. I've always liked science teaching - I don't know, because you're inquisitive, you like things, you like bugs, you like that, you know - but our curriculum has not always lent itself to time and wonder, I guess. And it was Connie coming in who just helped that along. (M1-02:48)

Mentor teachers reported that this shared respect and commitment to improving the way that science is taught in the elementary classroom was valued within the teaching community and validated their practice as teachers. They felt that they were viewed as professionals within their community and that their thoughts and ideas mattered. Julie, as well as several other study participants, felt that these opportunities to reach to other teachers outside of their district through participation in workshops and conferences was critical to building her confidence in her practice. She reported,
I've also had the opportunities to go to conferences and to present my work with inquiry and science, which I never - I mean to get up and speak in front of people about what I'm doing -- is affirming, but also pretty rewarding. I have people come up to me and say "Wow, here's my card. Email me about that project, it's really exciting." …And actually the PDS is the only way I've gotten to any conferences in the last, oh, five, six years. Any place I've ever been it's because I've gone through PDS. (J1-35:30)

This PDS science community was an essential component to the growth and development of each mentor teacher’s science practice. Mentor teachers reported that without these resources and relationships that their change in science may not have happened. Marla, in pointing out that there are perhaps teachers that don’t need the collegiality, described how those people are a minority in the community and how she felt the collaborative effort was significant to change in her science teaching practices. She said,

I don't think it always takes a collegial group, I mean, there are probably people in every building that take a look at this and go "Wow!" and can do it on their own. But for most of the rest of us, that group, that collegial group is really important in kind of leaving those feelings of inadequacy in science and also frustration and trying to redesign your science lessons to be more inquiry-based behind. (Ma1-10:01)

In these quotes, it is observable that the study participants valued their involvement in the science-specific community of practice and believed that this community played a significant role in their growth and change in practice. Furthermore, without either a formal or informal grouping of like-minded colleagues with whom to share ideas and practices, these changes toward reform-oriented practices may very well have not taken place over the years. All of these examples highlight the importance of a strong support system for change.

6.2.6.3 Discussion

When teacher teams, work groups, and departments function as communities of practice, numerous studies have shown that there are strong, desirable effects on the willingness of faculty members to implement instructional reforms (NRC, 2007). Thus, it was not surprising,
throughout this study, that mentor teachers gravitated toward these types of supportive opportunities in order to learn more about changing their practice.

According to Wenger (1998), a community of practice defines itself along three dimensions:

- **Mutual Engagement**: How the community functions as its members build collaborative relationships and establish norms. Binds members together into a social entity.
- **Joint Enterprise**: What the community is about and how, through their interactions, this shared understanding binds them together. This is continually negotiated by community members.
- **Shared Repertoire**: As part of the practice within the community, a set of communal resources (e.g., routines, artifacts, vocabulary, lessons) that members have developed over time is produced and shared.

The argument made by Jean Lave and Etienne Wagner (1990) nearly two decades ago was that communities of practice are everywhere and that we, as human beings, are generally involved in a number of them throughout different aspects of our lives. Some communities are formal, and some are informal, but what makes them different from a community of interest or a geographical community is that members of a community of practice are involved in a shared practice (Smith, 2003, 2009). In the case of the PDS community involved in this research, it was a formal community of practice wherein the members were brought together by joining in common activities and by what they have learned through their mutual engagement in these activities (Wenger, 1998). In this respect, the PSU-SCASD PDS community involved a shared practice of becoming involved in order to improve and/or reflect upon teaching methods in different areas of the curriculum and to move toward a shared goal of taking an inquiry stance in the elementary teaching classroom. Within this large community, there were many smaller “communities” that focused on different aspects within the large community. Some examples of three such smaller communities of practice therefore focused on classroom learning environments, reading instruction, and science education.
Bryk and Schneider (2002) found that building social trust among faculty contributed to the level of engagement around reform initiatives. In the case of this researcher analysis, there were numerous commonalities or similarities across the stories of practice that reflected a strong connection to working both with and alongside others within the PDS collaboration in order to move toward more reform-oriented teaching practices in science education. Although some of the mentor teachers reported involvement with several others within the community, still others reported on the influence of just one or two individuals. However, as the data revealed, the one thing that became very clear was the fact that none of the mentor teachers acknowledged their growth toward reform-oriented science teaching practices in their science classrooms as a product of their work individually or independent of another person of support.

This type of work in science-specific communities of practice can be considered an important type of teacher professional development, as was described in the previous assertion. Current trends in the research point to the need for elementary teachers to experience sustained science-specific professional development while in service (NRC, 2007). These experiences should be “rooted in the science that teachers teach and should include opportunities to learn about science, about current research on how children learn science, and about how to teach science (p. 7).

Research provides evidence that strong professional learning communities can foster teacher learning and instructional improvement (Borko, 2004). An important approach to enhancing teacher learning is to develop communities of practice. This approach involves building collaborative peer relationships and teachers’ participation in education research and practice (Lave and Wenger, 1990). Research shows that practicing teachers learn from their own practice, through their interactions with other teachers, and from teacher educators in their
schools, in degree programs, and in specific teacher enhancement programs (NRC, 2000). Just as research shows that students learn best in learner-centered environments, so it is with teacher learning. Unfortunately, the efforts to facilitate teacher learning in this way often falls short, instead consisting of required lectures and workshops that are not tailored to the specific needs of the teachers (NRC, 2000).

The majority of teacher learning takes place informally, on a daily basis in the classroom. The relationships that they form among colleagues within their school play a significant role in affecting this learning, and growth. NRC (2007) synthesized literature in the area of professional development and teachers’ opportunities to learn in the recent book *Taking Science to School*. Seven critical features were pointed out that research suggests are well-structured opportunities for teaching learning, two of which were pertinent to supporting the assertion that supportive relationships developed through collaboration within a science-specific community of practice mediate a change toward evidence-based science teaching practices.

The first feature states that well-structured opportunities for teacher learning “include school-based and job-embedded support in which teachers may engage in assessing student work, designing or refining units of study, or observing and reflecting on colleagues’ lessons” (NRC, 2007, p. 307). Loucks-Horsley and colleagues (2003) support the concept of communities of practice as they support the professional development of teachers of math and science. Referred to as “professional networks” by this team of authors, they affirm that participation in the science specific community can be a successful strategy for providing professional development for individual teachers and are “especially effective in reducing isolation among teachers” (p. 151). According to their research, a professional network is “an organized professional community that has a common theme or purpose” (p. 146). Networks provide a forum for interaction with peers
and other parts of the community. In the process, individual teachers gain access to new resources and perspectives and become part of a professional community that examines and reflects on issues related to teaching and learning in science. It was easy to see how these aspects of working within a community of practice was critical to study participants in their growth and change in science teaching as they continually pointed out the benefits of working within this community.

The NRC (2007) further explains that within these professional networks or communities of practice, members work collectively on core tasks that they “learn to execute at increasing levels of proficiency over time, drawing on support and feedback from the group” (p. 308). These tasks involve much more than technical knowledge or skills associated with the reform. They involve deeper understanding and collaboration around the ideas and practices, and in the case of this research, reform oriented teaching practices in elementary classrooms. Furthermore, in order for a community of practice to function effectively, it needs to generate the shared repertoire of ideas as recognized by Wenger (1998). It needs to develop various resources such as tools, documents, routines, and vocabulary that in some way carry this accumulated knowledge of the community (Smith, 2003, 2009). These mentor teachers did all of these things, some to more extent than others, but all were moving along the continuum of reform toward changing practice, changing curriculum, and changing their beliefs about best practices in science.

The research also suggested that well-structured opportunities for teacher learning should emphasize the collective participation of groups of teachers, including opportunities for teachers from the same school, department, or grade level. Working within these groups, teachers need to be engaged in collective work on issues that emerge out of their own efforts. The community
should be able to provide support, encouragement, motivation, and intellectual stimulation (Loucks-Horsley et al., 2003). For those involved in the process of change, which was the case with this research, being involved in a science-specific community of practice provided a “venue for teachers to recognize that they are part of a profession that is also in the process of change” (p. 151) which helped to legitimize these reform efforts and contribute to the validation of practice.

As Roth and Tobin (2002) assert, teachers rarely are provided with opportunities to work at each other’s elbows despite the fact that in many other career fields it is very common that this is how learning arises, and unfortunately, the lack of such opportunity makes it unlikely that changes will occur. They go on to say that teachers “learn tremendously when they co-teach, that is, when they work together with another teacher, at each other’s elbows” (p. 9). Whether mentor teachers’ work consisted of working with PDS interns, colleagues, or university faculty, all of these experiences involved some aspects of co-teaching, an approach that involved individuals teaching and making sense collectively. In learning to teach, and in the case of this study, learning to teach science, there was great value that came from learning by doing. Roth and Tobin (2002) reported on the value that comes from “learning by doing, especially if others are able to co-teach and participate collaboratively. Learning to teach is an ongoing process for any teacher” (p. 44). This notion of co-teaching and collaboration supports the type of work and relationships that were exemplified within this community.

The literature confirms the assertion that it is likely that teachers who have a strong system of support and are engaged in science specific communities of practice will be more successful in their implementation of reform oriented science teaching practices. Professional development is key to supporting effective science teaching practices for all teachers, especially
elementary teachers who generally do not have a strong background in science. The NRC (2007) put forth a recommendation that school systems should ensure that all K-8 teachers experience “sustained science-specific professional development” (p. 296) while in service. Participants in this study were engaged in these types of opportunities as a result of their involvement in PDS and have reported that it is exactly this type of experience that has greatly influenced and affected their change toward reform-oriented science teaching practices.

6.2.7 Assertion Seven

Research Question: What is the depth of commitment that mentors convey about changes in science teaching practices?

Assertion: Teachers who adopted and implemented evidence-based science teaching practices into their repertoire reported a strong commitment to their continued practice using reform-oriented science teaching methods.

6.2.7.1 Description

According to their stories of practice and referring to Table 6.3 from Assertion One (shown again below), it is noted that teachers whose focus on teaching science using inquiry-based teaching practices not only progressed as a result of their initial PDS participation, but that their science teaching practices did not return to former practices after two additional years. In point of fact, every teacher remained committed to their current teaching practices and some progressed toward increased implementation of reform-oriented teaching practices over the course of this study as can be seen in the table below.

<table>
<thead>
<tr>
<th>Rubric Scale</th>
<th>Level 0</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of Science Teaching Practice</td>
<td>Traditional Teaching Practices: Teaching by Showing or Telling</td>
<td>Activity-Based Teaching Practices: Teaching by Doing (Major focus on hands-on activities)</td>
<td>Nonspecific Inquiry-Based Teaching Practices: Teaching by Doing (Hands-on/Minds-on Science – focus is)</td>
<td>Inquiry-Based Teaching Practices: (Beginning to think/talk about the use of evidence and explanation)</td>
<td>Reform-Oriented Science Teaching Practices: (Strong focus on evidence and explanation throughout science)</td>
</tr>
</tbody>
</table>
As revealed through their stories, participants in this study no longer viewed science as a body of facts to be learned. On the contrary, science was viewed as multi-faceted and inquiry was an approach to provide the most natural way to capture students’ understanding about concepts. As mentor teachers reflected on their beliefs, practices, and understandings about science teaching, evidence supported the determination that they remained dedicated to their reform-oriented teaching practices, most importantly their focus on evidence and explanation as critical practice, and did not consider these to be the latest fad for science education.

### 6.2.7.2 Evidence

An examination of participants’ self-reports revealed evidence that as they spent more time engaging in reform-oriented science teaching practices, they either continued implementing the same practices that they had been with minor modifications, or they enriched their practice by learning more and/or becoming more knowledgeable about inquiry science and reform-oriented teaching practices.
Having adopted an inquiry orientation toward teaching and learning and as such utilizing science-specific teaching strategies contributed to what Julie attributed as success with her students in the classroom.

Oh, my kids love science! That's their favorite part of the day, and when we have our closing circle and we sit, and what went well today, if it's not lunch or recess, it's basically science. (J1-31:10)

Seeing this excitement in her students allowed her to evaluate her practice and to make changes in her teaching. As she discussed in the following quote, this increase in confidence in her teaching abilities was what led to her change in thinking differently about science. She said,

I think it was increasing my confidence in my practice, which led to a change in thinking. I think the practice came, and the comfort came, prior to actually changing my thinking. (J1-16:26)

The more she developed a student-centered classroom and encouraged her students to focus on gathering evidence and formulating their own explanations about their ideas, the more ownership of their learning she witnessed. As Julie experienced this she became more and more comfortable with teaching in this manner. As a result, the way that she thought about science teaching changed. She no longer viewed science as a collection of facts that she taught to her students using cute and crafty activities, but recognized that her students could learn on a much deeper level of understanding than she had realized before.

Two years later, as Julie described, her commitment to reform-oriented science teaching practices spread from continuation in her own classroom to her desire to help other teachers adopt these practices as well. She stated,

One thing that has really impacted me too is that I’m on the committee that’s looking at the primary curriculum and making the changes in science and social studies. I think we’re getting there. I think there are lots of things that will be going out the window. And I think one thing we want to stick with both in Science and Social Studies is developmentally appropriate curriculum. And I think we have to be careful because not everybody is not out here where I am. So
what we are looking for is something that is kind of inquiry-driven but is open-ended enough so that teachers that are out there can run with it and ask questions and take off and go, but for people who aren’t as comfortable, it’s got some inquiry kind of structure for them to help them. (J2-10:13)

Her commitment to reform helped her recognize the importance in providing structure for those teachers who may not have the self-assurance to tackle reform methods on their own.

Lynne’s testimony about her change in her first interview reflected Elizabeth’s opinion. Two years later, in her final email correspondence, she revealed how she, on her own, registered to take a graduate science education course for the sole purpose of helping her to become a better science teacher and to make changes toward more inquiry-based teaching in her classroom. She wrote:

Now, you may be wondering why I spent so much time talking about the projects—it's because this, too, has influenced my practice. Since I find the PDS classes so valuable, I have been taking them off and on as my schedule fits. In fact, I decided to take another one this fall—in SCIED! We looked at how to bring more inquiry into our practice, and what that might look like at a primary level. Another teacher and I have decided we would like to tackle a primary science unit that we teach in the last quarter of the year. This unit is "The Wonderful World of Nature" which means we cover 6 animal categories and much about plants. I have been dissatisfied with this unit since I started teaching it many years ago, because it is "too broad" and not "deep enough". (Lynne, 2nd interview email correspondence)

This is reflective of Lynne’s commitment to an inquiry stance in science and to her continued practice of using reform-oriented teaching methods in her science classroom. Similarly, evidence that Paul remained committed to using reform-oriented teaching methods came as he described a three-day inquiry that he developed in his science class as a result of his frustration with the non-inquiry methods through which it had been historically taught. He described his lesson as follows:

I developed this whole “Sponge Bob Square Pants” thing. I was given sponges and mollusks in my rotation in science and my children were at the age where
they were watching Sponge Bob on TV. So, I thought, “Hmmm, there’s a sponge and there’s a squid there. If I could get a starfish in there [that would be good], so I asked and I got “Patrick” in there as a starfish. So, it’s my question, not theirs, but I set up a scenario where Patrick was watching TV, a national geographic special, and they said that all animals were related. So [Patrick] wants to be related to Squidward and Sponge Bob. So Sponge Bob and Patrick are excited, but Squidward is less than excited. So the research question is “Are they related?” and that is their driving question. I set up note taking for characteristics, habitat, animals that they are related to, and what they eat. The students take notes from materials that I have - we don’t have time to go down to the library or use the internet like we probably should - and then they write a little mini letter to me at the end that says “Mr. Smith, I think they are or are not related because…” and they support their answer and explanation with the research that they have collected. (P2-09:35)

All nine of the participants who gave interviews two years later reflected similar commitment to their use of reform-oriented teaching methods. However, many were also perceptive of the fact that this steadfastness did not come without struggles at time. In her final interview, Lynne tried to capture why she believed that some of her non-PDS colleagues did not remain as committed as she was to inquiry science. Having an intern in her room on a consistent basis, as well as having a colleague with which to work, helped her to stay committed to her reform efforts. She stated,

I think that’s one reason teachers tend to keep doing what they are doing because they don’t have that person saying “Hey, I got this really cool thing, do you want to, you know, let’s work on this together and revise it? (L2-18:23)

Julie supported this belief when she explained,

Well and I think, too, it’s just such a different way of thinking and it really and truly I think you have to experience it to see that it does work. I think it’s scary for people especially if you didn’t learn that way and you are uncomfortable with science to begin with and you are uncomfortable with the unknown because you really have to be ok with saying, “Well we might get there we might not”. And you have to be comfortable with questioning and I think that’s something hard for a lot of people, me included I think. You know, we just get better at it but I don’t always feel like I’m even there yet. (J2-17:24)
Commitment to change in practice was not necessarily one that was always easy to adhere to for all teachers. Margaret captured this phenomenon as she explained why she believed this type of commitment might be difficult for her colleagues. She described,

> Because it’s a little scary [for them]. Maybe they are not interested in, or the avenue… isn’t smooth. It [incorporating reform-oriented teaching methods] isn’t like taking those hands-on experiments, knowing I can do this experiment and this experiment then we will talk about it and we’re done. Because when you go to the “other side” you’ve really taken it from the kids and are building your science from that. And when you take it from the kids’ questions to build what you want to do from there. Certainly getting the experiments set up to find the evidences because of their wonderings takes time. So do the teachers have the time? Do they have the interest? Do they really want to go there? Do they need more hands to do it? (M2-02:31)

Although Lynne remained committed, she admitted to her own struggles at times. She described,

> And I still catch myself doing that and I [have to tell myself to] quit answering their questions! I don’t know everything. I’m not supposed to know everything. I’m supposed to help them figure out how to find it out. So “[I used to tell them] Go look it up!” I don’t want to do that. I want to say, “What do you think? What could you do to find out?” Here I am, I’ve been working with this for 8 years and I still fall into the same trap of answering the question! (L2-50:49)

However, it is critical to note, that although Lynne was tempted to revert to her prior practice, she recognized the importance of not doing this and as a result, she sought assistance from within the PDS community to support her learning commitment to teaching science using a lens of evidence and explanation. She said,

> Well I tell them [the students] “I’m learning how to do this, too and what kinds of things do you hear me saying?” And that’s one reason that I was so excited because I knew that that would be a link to professional development… it was very difficult, too but that kicked it off. But I was afraid that I would go back to doing what I always did if I didn’t have another reason for explaining why I did it the way I did it. (L2-55:21)

Even Lana, after years of wrestling with her ideas of what science teaching should look like in the classroom and her belief that, as she eluded to in her first interview, this too shall pass, pointed out very matter-or-fact in her final interview:
No, it never was that for me. My big thing was that inquiry is not always necessary. That was one of my beliefs for a successful gathering of knowledge in science. But my second one honestly was “Been there, done that.” I thought, it will happen again in 5 more years, like a pendulum swinging. But then when I really looked at it, I never really saw the pendulum in inquiry and I’ve been hear for 20 years. It’s really not a curriculum. It’s really not a teaching style. It’s really a philosophy of learning in my opinion and it makes the most sense to be in science but truthfully it’s in every subject. It just happens to be that science is where we look at it with the PDS students. It’s in math, in reading, it’s in social studies, it truly is. (La2-15:52)

Finally, affirmation not only from observations of excitement and learning by each teacher’s students in the classroom, but affirmation from others within their community may have attributed to each participant’s commitment to changed practice. Many of the mentor teachers in this study have had the opportunity to attend conferences at the local, state and national levels and to share their success stories with others in attendance. This, as Julie described, was both affirming and rewarding. She said,

I’ve also had the opportunities to go to conferences and to present my work with inquiry and science, which I never - I mean to get up and speak in front of people about what I'm doing is affirming, but also pretty rewarding. I have people come up to me and say, "Wow, here's my card. Email me about that project, it's really exciting." (J1-35:30)

As the school district in the coming years revisits the elementary science curriculum, there are many within the district, these study participants included, who are dedicated to ensure that these curricular changes are reflective of inquiry-based science and incorporate reform-oriented teaching methods. As Lynne stated,

That’s why I’m looking forward to seeing what happens in the next couple of years. I mean, granted we still have to teach in the next few years and try to find ways to make what we teach (until they change things) more interesting, more inquiry-based for the students. But I can’t help thinking, I’m hoping that when they get in to revising the curriculum that they try to do it more on Table 2.6 and less out of the book, you know? I don’t know what’s going to happen – but it’s exciting. (L2-21:12)
In summary, Perhaps Julie captured the concept of commitment best for this group of participants when she stated, at the very beginning of her first interview, “…and I haven't looked back” (J1-01:58).

Julie made this bold statement about tossing aside her former methods of teaching science and modifying them to reflect reform-oriented teaching practices. This position, reflective of each of the participants’ self-reports through the duration of this study, is evidence of their commitment to reform-oriented teaching practices.

6.2.7.3 Discussion

One critical area for research and development in science education as recognized by Duschl and colleagues (NRC, 2007), is in the area of professional development and teacher learning. They assert:

A substantial commitment is needed to empirical research on the practices of building expertise in science teaching. These include using science specialist teacher (in K-5), mentoring, teacher work groups, instructional materials designed to support teacher learning, and long-term professional development. It is important to understand how local circumstances enable or limit the effect of these models. This research needs to establish an empirical relationship between professional development and student learning. (p. 353)

Although this research study did not set out to investigate this phenomenon, it is believed that there is evidence to support the notion that, in this particular professional development school community, teacher development and commitment to science teaching methods are reflected in classrooms which suggests the building of expertise in science teaching.

Change is a process that takes time and persistence (Loucks-Horsley et al., 2003). Persistence and commitment are not mutually exclusive. One cannot be persistent without also being committed. In the case of this research, mentor teachers were committed to the implementation of reform-oriented science teaching practices as was confirmed by their
continued use of these practices two years following their first interviews. These reform practices included a focus on the use of evidence and explanation as the basis for learning in the science classroom, while also reflecting an inquiry orientation toward learning. This, coupled with science-specific learning strategies, such as the use of KLEW charts and science talks to support student-centered and student-driven learning experiences in the classroom, were the most recognized reform methods used by mentor teachers in this study.

But how did the mentor teachers get there? How did their development over time contribute to their change in teaching practices in such a way that they remained dedicated to continuing these practices over time?

In a study by Mundry and Loucks-Horsley (1999) which focused on professional development in science and math reform, they found that when the intervention was focused primarily on changing teachers’ philosophy and beliefs about science and math reform, changes in actual practice and use of new curriculum were disappointing. Similarly, they found that in sites that focused on practice to the exclusion of philosophy and beliefs needed, the desired changes were again disappointing and not achieved. Importantly, they discovered that in order for there to be success and implementation, it was important to “maintain a balance between philosophic and pragmatic approaches and be responsive to changing teacher needs and dynamic school context” (p. 4) in order for the change in teaching practice to take root. Participants in this study have been afforded both of these aspects – application of teaching practices and opportunity to reflect on philosophical beliefs about those practices and as a result, how they feel their students have been successful.

How teachers view the learning of science is critical to the ways they respond to children’s questions and how they enact science teaching practices in the classroom. For
instance, if the meaning teachers attach to science learning is focused on finding the right answer, then they will more than likely focus on providing factual answers to children through a direct instruction and text-based approach (Rowe, 1996). On the other hand, if the meaning teachers attach to science is focused on scientific practice modeled after expert practice, then they will more than likely teach science in a manner that provides children the opportunities to enhance their abilities to inquire through experiences that engage them in investigation, discourse, interaction with data, and construction of ideas and explanations. Mentor teachers’ self-reports reflected such science teaching practices and a commitment to providing children these types of opportunities for learning science.

Research on teacher change indicates that changes in beliefs (in this case about science teaching and learning) often comes later after teachers use a new practice and are able to see the benefits to their students (Ball & Cohen, 1999). This phenomenon could be a significant aspect to explore further with these mentor teachers to fully understand the connections between their commitment to change and epistemological beliefs about science teaching and learning. This question of the relationships between actions and thoughts is important to understanding, more in-depth, the value of commitment.
CHAPTER 7: LESSONS LEARNED

Following case study tradition as advised by Lincoln and Guba (1985), the focus of this chapter is on “lessons learned” from the study of this case. The format of the chapter provides a summary of the research findings followed by implications and discussions of those findings and future research possibilities.

7.1 Summary of Findings

Current PDS research focuses more on implementation at the elementary level (Scharmann, 2007). In the area of science education, much of the research is either at the secondary level, or it examines the study of pre-service teachers. This study centered on an area of PDS research that has been overlooked in the research agenda - elementary science with a specific focus on in-service teachers within the context of a PDS partnership.

The participants in this study were all classroom teachers who had served as mentor teachers to interns within a district’s Professional Development School partnership with a local university. The eleven participants were purposefully selected from a larger pool of mentor teachers who had responded to a comprehensive survey that attempted to uncover how the PDS had impacted their thinking and practice as it related to several aspects of their classroom teaching. The participants were selected specifically based on self-reports of how their science teaching had changed as a result of their involvement as mentor teachers within the PDS.

This inquiry was designed to answer three main research questions: (1) How do mentor teachers describe their science teaching practices and how have they changed as a result of participation in PDS? (2) What is the relationship between the levels and types of involvement in PDS to change in thinking about and practices of teaching science? and (3) What is the depth of
commitment that mentors convey about changes in science teaching practices? Sub questions within these three overarching questions were: (a) In what ways do PDS mentor teachers’ descriptions of practice reflect contemporary reform ideas and practices in science education? (b) To what extent do their stories emphasize technical aspects of teaching versus epistemological changes in their thinking and knowledge? and (c) How is student learning in science reflected in teachers’ stories of practice?

A summary of each question of this study will be discussed in the following pages, addressing specifically how the data provided answers to these questions. The initial data collected in the impact survey indicated that mentor teachers recognized that their involvement in PDS had affirmed and/or changed their teaching of science in a positive manner. Initial data collection and analysis (Badiali et al., 2011) determined that mentoring a PDS intern played a critical role in the change process of mentor teachers, serving as the catalyst for change for each mentor teacher. This study sought to consider the nature of this change and to determine if the changes were toward contemporary reform-oriented practices as reflected in current science education literature.

The first research question for this study was, “How do mentor teachers describe their science teaching practices and how have they changed as a result of participation in PDS?” To begin to answer this question, a “story of practice” was developed and written for each individual participant based on his/her self-report of change. Using information garnered from interviews, framed by national standards for science teaching and for professional development (NRC, 1996) as well as the framework for essential features of classroom inquiry (NRC, 2000), a rubric was developed that reflected levels of teachers’ self-reported inquiry use based on these stories of practice. Using this rubric as a guide, a story of practice was written for each
participant which provided detailed information regarding each mentor teachers introduction to the PDS, his/her reported science teaching prior to PDS involvement, reported science teaching following initial introduction to PDS, and reported science practice two years following initial data collection. Throughout each story of practice, close attention was paid to the following four themes: (1) focus on evidence in science teaching; (2) focus on explanation in science teaching; (3) classroom discourse; and (4) science-specific strategies used to promote scientific inquiry. These stories provided a description of practice and presented a detailed account of each participant’s change in practice over the course of their years involved in PDS. As a result, these stories provided insight from which to answer three sub-questions that were developed for the purpose of capturing the understanding of the nature of this teacher change.

The first sub-question focused specifically on teachers’ descriptions of their practice. It stated, “In what ways do PDS mentor teachers’ descriptions of practice reflect contemporary reform ideas and practices in science education?” In order to answer this question fully, contemporary reform ideas and practices in science education were unpacked. In order to be consistent across all participants, the essential features of classroom inquiry (NRC, 2000) were used as the main means of comparison. Although these essential features (Appendix A) focused on what the learner does as he/she engages in classroom inquiry, interpretations were made as to what the teacher does in order to provide these structures for the students. As a result, the Levels of Inquiry Use: Science Teaching Rubric Based on Stories of Practice (Appendix I) was developed as a means to synthesize teacher practice.

As a result of their PDS participation, mentor teachers made significant changes away from traditional science teaching methods toward methods that involved reform-oriented methods such as in-depth questioning, focus on evidence and explanation, and the use of science-
specific strategies. The assertion that developed stated: *Participants utilized reform-oriented science teaching methods in the classroom and viewed former didactic teaching methods as ineffective procedures for teaching and learning science.*

Ten of the eleven participants reported that they used hands-on activities to support the learning of facts as their main means of teaching science prior to PDS involvement. The remaining participant reported that her pre-PDS science teaching was more focused on memorization and reading from the text with scattered use of hands-on activities to support that learning.

As PDS involvement began and progressed, mentors reported that science lessons became less teacher-directed, more student-centered, and were taught in a more inquiry-based manner. Rote memorization and disconnected craft-like hands-on activities were recognized as ineffective methods for teaching and learning science. Hands-on experiences were integrated throughout the learning process as science teaching involved more activity and less textbook-based pre-packaged teaching. For some teachers, this recognition was made during their first year as a mentor teacher upon watching their intern implement inquiry-based lessons as required by their methods class. For others, it took several years to recognize or acknowledge. However, all eleven participants recognized and reported that their former methods of teaching science in a didactic manner were ineffective and did not support student learning in science. At the conclusion of this research, mentor teachers reported that they no longer taught science using these didactic methods, and at least three mentors were actively engaged in modifying and developing current science units to meet the requirements of reform-oriented science teaching practices.
Additionally, it is important to note that during the two years that elapsed between interview one and interview two, none of the mentor teachers reverted back to former teaching methods. All either remained at their reported level of implementation or had a more advanced understanding of inquiry-based science that was reflected in their story of practice.

The second sub-question, “To what extent do their stories emphasize technical aspects of teaching versus epistemological changes in their thinking and knowledge?” determined whether or not these mentor teachers were able to recognize changes to their practice, to their beliefs about science, or to both. The data revealed that mentor teachers easily recognized and described technical changes that they made to their practice. The assertion developed to describe this finding stated: *Mentor teachers demonstrated a shift from the use of generic inquiry teaching strategies in the classroom to the use of science-specific inquiry teaching strategies and as such demonstrated a more profound view of science teaching and learning.* Data revealed that there were two leading science-specific strategies that every mentor teacher discussed using in the classroom to varying extents: KLEW charts and science talks. These strategies were implemented at varying degrees based on how knowledgeable each mentor was about how to utilize them throughout their science units. For some teachers, they were just learning how to use talk in the classroom and were just beginning to make the change from traditional KWL charts to KLEW charts. For others, this transition was challenging, but they described the benefits of using these science-specific strategies over generic inquiry methods to promote science learning. Still others reported being quite skilled in using KLEW charts and science talks throughout their practice as a result of extended use over many years and these mentors talked profoundly about the differences in learning that they observed in their students by using these strategies.
While data did not uncover definitively that teachers had made epistemological changes in the ways that they viewed science, their practice changed to include methods that engaged children more meaningfully in science. Teachers reported feeling affirmed in these changes due to what they observed in their students’ learning and attitudes toward science.

Even though teachers’ pedagogy changed, data were not conclusive as to whether or not there was an epistemological change in their thinking and knowledge about science as well. In order to understand if this type of an epistemological change occurred, more needs to be known about each mentor’s views of the nature of science. Interview questions specific to this topic were not asked, and therefore, any assertion about epistemological views of science would be unsubstantiated. However, mentor teachers reported a shift in the ways that students learned science, and recognized their use of reform-oriented methods and strategies as more effective tools to aid in each child’s learning process. As such, data supported and were conclusive about an epistemological change in mentor teachers’ thinking and knowledge about science learning.

Teachers possess beliefs about their professional practices and these beliefs impact their actions in the classroom. Observed changes in student learning and understanding of science concepts as a result of modified practice affected each teacher’s thinking, knowledge and beliefs about how students learn science that resulted in strong commitment to the use of strategies to support such learning.

The third sub-question was designed to capture student learning as interpreted by the mentor teachers. The question was, “How is student learning in science reflected in teachers’ stories of practice?” One claim resulting from this research is that mentor teachers acknowledged an increase in student interest and excitement toward participation in science as a result of their shift from traditional teaching methods to reform-oriented science teaching.
One might ask the question, “How can the observations of teachers of student excitement in science class prove that there is better student learning taking place without actual documentation of increased grades or other information?” I argue that when students take an interest in something, they are more likely to learn more about that something. In order for students to develop an appreciation for science and how it relates to their personal lives, learning experiences need to connect with their own personal interests and experiences and should be taught in ways that make these experiences meaningful to them. The data show us that as mentor teachers changed their teaching practices to reflect the use of contemporary reform methods, their students became more excited about science class and more interested in the topics being studied. Mentors reported that science class became a time of involvement and engagement around science concepts and a time that children looked forward to during their school day. Additionally, teachers reported that this excitement expanded beyond the classroom into their home environments on many occasions.

Research suggests that personal interest, experience, and enthusiasm, critical to children’s learning of science at school or other settings, may also be linked to later educational and career choices (NRC, 2011). A “rich science education has the potential to capture students’ sense of wonder about the world and to spark their desire to continue learning about science throughout their lives” (p. 2-4). Therefore, although it is not implicit that increased interest and excitement lead to increased student learning, data from this study supports the inference that there is a strong connection between interest/excitement and learning in the science classroom.

The second claim that emerged from data focused around student learning reflected in teachers’ stories of practice was that mentor teachers reported that science focused discourse and reform-oriented inquiry science experiences led to deeper understanding and more
meaningful student learning in science. Data sources such as reports, experiments or exams were not used as a means of assessing student learning. However, information regarding learning was reflected in teacher self-reports based on what was personally witnessed from their observations of their students. The mentor teachers in this study were all veteran teachers that had been teaching for no fewer than fourteen years. The teachers in this study reported their students were learning based on their experience in the classroom. Through their use of science-specific strategies such as KLEW charts and science talks, mentor teachers informally assessed understanding of concepts based on student contributions to conversations (discourse) in science as well as to the completion of information in the KLEW charts. For example, the implicit nature of using a KLEW chart throughout a science unit encourages reflection, collection of evidence and formulation of explanations based on that evidence. Mentor teachers recognized that as they used these tools in their classrooms, their students used the language of science more readily and exhibited learning characteristics that they had not previously observed. A specific example of this was when Lynne stated that as a result of using the inquiry-based Prehistoric Life curriculum, her students “learned better and more than they have in the other ways I’ve taught it.” Although some may argue that this information is not credible because it is based solely on perception, I argue that Lynne’s teaching expertise and experience teaching this particular science unit in the past strongly supports her authority. She recognized, as did the other teachers in the study, that student learning in science was different than it had been previously in that it was more meaningful and students had a deeper understanding of science concepts as a result of teaching science using reform methods.

The second main question, “What is the relationship between the levels and types of involvement in PDS to change in thinking about and practices of teaching science?” yielded
two assertions based on analysis of the data. The first assertion was that *mentor teachers who engaged in science-specific professional development opportunities were more likely to change their practice to reflect more reform-oriented approaches than mentor teachers who did not engage in science-specific opportunities*. An interesting finding within this assertion related to the aspect of time. Contrary to what might be considered predictable, mentor teachers with the greatest length of time involved in the PDS did not necessarily reflect those with the most advanced levels of inquiry use in the classroom. For example, Julie and Margaret were both involved for seven and six years respectively, and did exhibit the characteristics of exemplary teachers of science. However, Bobbie, Greg and Karen were also involved in the PDS for six or seven years and did not exhibit the same levels of use in the classroom. In addition, one mentor was only involved in PDS for four years before she transformed her practice to reflect specific characteristics of change.

The pattern that emerged from the data of all the participants was the role that science-specific professional development played in the change process. Mentor teachers who reported the most significant changes to their practices and reported the most in-depth use of science-specific strategies in their classrooms were also the teachers who had engaged in at least one science-specific professional development opportunity. Whether the professional development was formal (e.g., a summer science course, being part of a science planning team, engaging in a formal inquiry science project) or informal (e.g., working with science education faculty to review personal science lessons, working with an intern), this science-specific professional development was a critical juncture in the change process (Badiali et al., 2011). Mentors reported having a clearer understanding of what practices worked best for students and how to best implement such practices as a result of such participation.
The second assertion that emerged from the data, mentor teachers reported that collaboration within a community of practice mediated a change toward reform-oriented science teaching practices, provided information about the important role that support played in affecting change in teachers’ practice. The data showed that the types of relationships that were formed as a result of involvement in PDS - relationships between and among colleagues, university faculty, and interns - shaped the change process of each mentor teacher. Participants discussed how these relationships opened new doors by making them feel like professionals. As a result, they felt that their ideas and practices were valued. This collegiality brought mentors out of the isolation of their classrooms to the shared community of PDS through which they were able to make positive changes to their practice with the support needed to reflect and react in meaningful ways.

The final question, “What is the depth of commitment that mentors convey about changes in science teaching practices?” provided information regarding the dedication of mentor teachers to engage in inquiry-based science and to continue teaching science using reform-oriented teaching methods. The assertion that developed from this data set stated, mentor teachers who adopted and implemented evidence-based science teaching practices into their repertoire reported a strong commitment to their continued practice using reform-oriented science teaching methods. Data showed that all of the participants recognized a pedagogical shift and reported feeling positive about such changes. Not only did they feel empowered by their practice, but they actually liked what they were doing and did not consider this change to be another “fad” in the way to teach science. They saw inquiry as an effective and reasonable method that reflected how children learn science best both in and out of the classroom environment. One mentor teacher shared about how teaching through the lens of inquiry seemed
like a much more natural method of learning. She explained that growing up, the way she learned science outside of school was much different from the way she was taught science in school. Now, she was happy to be learning about how to use effective strategies to help her children learn in a more authentic manner.

7.2 Implications for this PDS

In her commentary focused on empowering policies in elementary school science programs and teacher professional development, Mensah (2010) claimed that teaching science in elementary schools immediately demands attention to teacher professional development for three reasons. First, she points out that science at the elementary level is not typically considered to be a priority subject in the overall school curriculum. Secondly, she discloses that most elementary teachers are not science experts in the sense that they are comfortable teaching science. Finally, she asserts that a strong elementary science program sets the foundational skills and knowledge needed for upper grades science learning and without this foundation science suffers in the middle and upper grades. (p. 977). These factors acknowledged, research on positive changes that elementary teachers are making in science classrooms toward more reform-oriented practices is necessary in order to provide an explanation as to what processes work and why.

This study was concerned with investigating the nature of reported change in PDS mentor teachers’ thinking and pedagogical practices toward science education in their elementary classrooms. The research explored the ways these experienced teachers, working within the PDS context, described their changes in both thinking about and teaching science. As a result, analysis revealed how one PDS program has affected change in the thinking and practices of elementary teachers as they teach science in their classrooms.
Through the change process of mentor teachers, there were two critical junctures that had to occur in order for change to take place. The first critical juncture was the introduction of reform-oriented science teaching methods as a result of having a PDS intern in the classroom. For the mentor teachers, being exposed to these new ideas in science was non-threatening and allowed them to both witness and experience new practices from the perspective of a support person rather than having to be the person to put it into practice with limited knowledge. As such, this PDS should carefully consider the important role that interns play in the development and change of in-service teachers’ practice. As mentor teachers understand more deeply the university methods course requirements in science education, and as teachers begin to borrow ideas, adopt, and implement these practices into their pedagogy, it will be necessary to help mentor teachers understand what (science content) they are teaching, how (method) they should teach it, and why they are teaching it in this manner.

Results from this study assert that achieving this outcome was best met through science-specific professional development opportunities. Therefore, this particular PDS should closely consider the assertion that engagement in some form of extended science-specific professional development opportunity was the second critical juncture in the change process for those teachers who took advantage of such opportunities. It is inferred, based on the teachers’ reports of their teaching, that the science that is taking place in their classrooms looks quite different from other classrooms across the district. Evidence of reform-oriented practices, which research supports as being effective and supportive of student learning, are being implemented on a consistent basis. Therefore, the consideration of having every mentor teacher engage in a science-specific learning opportunity is necessary. It is important to point out that this learning opportunity should not be confused with a one-day teacher in-service presentation or workshop
in science, but rather should be an extended professional development experience that is rooted in practical knowledge and tied directly to each teacher’s personal practice.

This implication is directly supported by information distributed in the recent framework for K-12 science education (NRC, 2011). It states, “Teacher preparation programs and professional development programs will need to provide learning opportunities for teachers themselves in order to deepen their conceptual understanding, engage in scientific and engineering practices, and develop an appreciation of science as a way of knowing in a community of knowledge builders. These programs will also need to enhance teachers’ skills in investigating students’ ideas, selecting effective teaching practices, assessing students’ progress, and developing classroom communities and discourses in which all students and their ways of knowing are valued and respected.” (NRC, 2011, p. 10-16).

It was also identified that length of time involved in a program was not necessarily associated with affecting change toward use of an innovation, in this case reform-oriented science practices. For example, several study participants were involved in the PDS for the duration of the program, yet still did not demonstrate highly developed ideas about reform practices in the classroom. It was only when a teacher took part in science-specific professional development that focused on his/her personal needs to understand science teaching methods that change was reported toward what current research states is how teachers should be teaching science. Additionally, these science-specific experiences were provided over an extended period of time, through summer workshops or semester higher-level education courses that allowed for extended time to work with colleagues and university science education faculty to answer questions and reason through problems and/or questions of implementation. Additionally, these
opportunities were always connected directly to each teacher’s own personal classroom experiences.

Schibeci and Hickey (2004) reported reluctance by elementary teachers to attend science-related professional development. They claimed that if teachers did not see the professional development opportunity as relevant to them, then they would not attend. Jones (2009) in her dissertation study of elementary teachers in the state of Pennsylvania asserted that the lack of comfort with science-related subjects makes some elementary teachers pause or refrain from delving into science opportunities and recommended that long-term professional development “is the only way we will be able to improve the current situation.” (p. 143). Therefore, this PDS learning community might be a more relevant venue in which to conduct and/or implement specific science education professional development due to its culture of simultaneous renewal and teachers’ comfort level and direct attention to their personal classroom experiences.

In addition to these two critical junctures in the change process, other findings were reported that should be considered not only by this PDS, but other PDSs as well as the science education community. One finding indicated that teachers observed a different, more meaningful kind of learning by their students in science class as a result of their change in practice. They reported that this learning was more authentic to how children should be learning science. However, assessing student learning is difficult to do in ways other than rote pencil and paper type methods, which are not necessarily the most appropriate assessment methods for this type of learning. Documentation of learning through KLEW chart contributions, contributions toward projects, and classroom discourse analysis of students’ participation would be considered more authentic and appropriate methods of learning documentation.
In *A Framework for K-12 Science Education* (NRC, 2011), it is reported that what students learn is clearly related to what they are taught, which in turn depends on many things, not limited to teachers’ knowledge and practices for teaching, how teachers elect to use the curriculum, and the kinds of resources, time, and space that they have for their instructional work. For science educators, this research opens up possibilities for reaching teachers at the elementary level who traditionally have not demonstrated the confidence to teach science using a lens of inquiry and reform-oriented teaching methods. It is shown that it takes a non-threatening, community-enriched environment in which science is not forced upon them.

Directly connected to this information, a second finding from the research indicated that having a supportive other in the classroom, in this case a PDS intern, who is there on a consistent basis for an extended amount of time contributed to the change processes of these mentor teachers. The relationship between intern, methods course responsibilities, and mentoring provided a structure that allowed for successful implementation. Following the initial involvement with interns, science-specific professional development opportunities allowed mentors to reflect on their teaching practice and challenge themselves to learn more about reform-oriented science practices in the classroom. This community provided the resources, time and space that teachers needed for their instructional work.

A third finding extended this community to involve teaching colleagues, university faculty and other outside resources to support change. Communities developed around the things that mattered to each mentor in order to meet his/her needs, in this case, the need to understand how to teach inquiry-based science. In her work within this PDS environment, Zembal-Saul (2009) pointed out that the PDS partnership provided a “mechanism for meaningful collaboration between experienced classroom teachers and university faculty around the work of teacher
education and supporting children’s meaningful learning.” (p. 713). This research reinforces this claim that this PDS is a supportive environment in which to learn to teach science in nontraditional ways, most specifically ways that reflect reform-oriented ideas in science.

7.3 Limitations of this Research

When reviewing and analyzing the results of this study, certain limitations were recognized and taken into account. Although this research spanned several years and was quite expansive, there were certain aspects of the context that were not examined and qualities of the study that need to be identified in order to fully disclose these limitations.

One limitation of the study refers to the use of mentor teacher self-reports as the foremost source of data. Teacher self-reports were the most logical and readily available sources of information regarding change in classroom practices. Although the personal reflection and self-reports of changes in science teaching practices conferred important data for answering the research questions, the use of observations of classroom practices would have added a level of confirmation of these self-reported practices. Two or more methods can be used in such a way that the weakness of one is compensated by the strength of another (Gay, Mills, & Airasian, 2006). This would have helped to obtain a more complete picture of what was being studied.

Another limitation of the study points to the notion that each participant had reported change and/or affirmation prior to the interview process. The data that were collected through self-reports came from teachers who reported a change or affirmation in their practice toward reform-oriented science. Although their reported change varied from little to great extent on the original survey instrument, nevertheless, all participants did report a degree of change. One way to counteract this limitation may have been to interview mentor teachers who reported no change.
in their science teaching. However, due to the nature of the survey and the option to volunteer for the study, those teachers who did report no change declined the option to be interviewed.

Finally, some may argue as to the generalizability of the study results to other PDS partnerships. This study evolved into an analysis of teacher change in this particular environment, an environment that is arguably one of the most exceptional models of successful PDS work in the nation, the crème de la crème, so to speak. Study participants were teachers who volunteered their time to be interviewed because they were proud of the work that they were doing and the accomplishments that they had attained over the years. This could cause some readers to attribute bias to the research process. However, I, as the researcher, feel that it is important to study successful partnerships in order to learn from such success. Research should not be prohibitive or selective based on perceived status. The assertions that evolved from the evidence are practical, reliable, and transferable.

7.4 Future Research Possibilities

Based on the findings and discussion, the following are recommendations for possible further research.

1. Continued research is needed with participants regarding their epistemological views toward the nature of science. The ideas that individuals hold about knowledge and knowing as it relates to the nature of science have been shown to be related to learning in various ways and have implications for teaching. The congruence between teachers’ beliefs and their actual practices is an important focus of inquiry (Hofer and Pintrich, 1999). The need to clarify issues that are central to each mentor’s beliefs about the nature of science is necessary in order to fully understand his/her motivation to modify or change practice, and to stay committed to this practice. There are several questions that can be asked regarding these changes in their personal
epistemology: What are mentors views of science as it relates to their teaching practice? Has their definition of “science” changed? Do their views of the nature of science drive their practice, or have they modified their pedagogical practices because they have noticed a change in student learning using these methods? Has this pedagogical understanding shifted in ways they can describe? How profoundly have teachers changed the ways in which they view the nature of science and science teaching and is their commitment directly connected to their epistemological view? Is their personal epistemology more reflective of science learning or nature of science? Self-report instruments developed for measuring personal epistemology such as the Epistemological Questionnaire (EQ), the Epistemic Beliefs Inventory (EBI) and the Epistemological Beliefs Survey (EBS) could possibly be used, however, recent research has found challenges and inconsistencies with these instruments (DeBacker, Crowson, Beesley, Thoma & Hestevold, 2008). However, using one of these surveys along with interviews focused on personal beliefs regarding the nature of science could build a better understanding of mentors’ personal epistemologies and how these are connected to change in practice within this community. This would be a significant contribution to the research communities in both PDS and science education.

2. Continuing research that follows-up with direct classroom observations and analysis of reported science teaching practices and their use of science-specific strategies such as KLEW charts and science talk is needed. Analysis of the implementation of such strategies would aid in the understanding of student learning in science.

3. There is still much to learn about the connection between PDS intern, community support, and science-specific professional development. Is there a particular sequence that is more readily identifiable with the change process? Are all three vehicles necessary for each
mentor teacher? In this study, the evidence supported that all three were necessary for these participants, and the order was consistent across participants. However, now that the program has been in place for several years, and more in the community are familiar with the “new way” of doing science, is this order essential? In other words, is it the sequence or the substance that matters?

4. Given the degree to which the connection between intern, culture of PDS, and content-specific professional development exists, additional research focused on the extent to which each of these structures influences teacher change would be interesting. What might we learn from studying each of these structures in-depth or individual variations in the sequence? Are they equally powerful or is it the combination of all three that motivates the transformation?

5. Teachers changed, so what? The assumption is often made that because teachers have changed that their students have changed as well, but is this true? There is a difference between the taught curriculum and the learned curriculum. Assertions three and four from this study reflected answers to these questions concerning children’s learning. Mentor teachers acknowledged an increase in student interest and excitement toward science as a result of their change in teaching practices. Additionally, mentor teachers reported that they believed that these changes also contributed to more meaningful student learning in science based on their observations of their students. However, this study did not investigate measurable learning changes that took place with the children based on how well they understood or retained information about science concepts after learning in this manner. Findings from this study determined that teachers recognized and observed changes in their students based on interest and excitement, which were indicative of change, however, these findings were based solely on teachers’ self-reports and observations. It is important to figure out which specific aspects of
teacher change predict or affect children’s learning. Examination of practices and their direct and measurable effect on student learning is necessary in order to understand how and why reform-oriented practices are significant. Further investigation that looks at student changes (even if they are changes in their motivation to learn science) as a result of teacher changes would be an important contribution to the literature.

6. When discussing the morale of a group, the term *esprit de corps* is often used. This term describes the capacity of people to maintain belief in an institution or goal, or even in oneself and others. According to Alexander Leighton (1949), morale is “the capacity of a group of people to pull together persistently and consistently in pursuit of a common purpose.” There is certainly *esprit de corps* in this PDS community. Further exploration into the mysteries of the effect of the PDS culture and how being in the PDS may or may not act as a catalyst to teacher learning is essential to understanding this partnership and this community.

7. The major focus of this study was on mentor teachers and examined their change process. One of the factors that played a significant role in this change process was the influence of the PDS intern. It would be beneficial to conduct further research that looks closely at this relationship and the affect or influence that these “learning mentors” have on their interns. Does being in the presence of a “learning mentor” who grows more enthusiastic about science as the year progresses enrich the experience of the intern?

7.5 Conclusions

Mensah (2010) asks at the conclusion of her commentary, “What do we need to do in order to have a greater impact on an elementary school science program?” Findings from this research can serve as the basis for future research in the area of science-specific professional

---

development for elementary teachers and how it can meet their needs in the classroom. Clark’s (1999) research found instances where teachers perceived professional development obtained through PDSs to be more valuable than the traditional method. Classroom teachers, therefore, experience learning and growth when reflecting on their own practice. Teacher educators warn that there is little evidence of PDS impact on teachers and assert that the consequences of this lack of evidence are dire (Badiali et al., 2011). Vare (2006) asks if PDSs are the powerful structures of the educational renewal that early proponents envisioned. Vare goes on to ask if current advocates can match their enthusiasm for PDS partnerships with evidence of positive impact on teachers’ professional development. A growing number of researchers believe that this research does reveal evidence of such an impact. As a direct result of their roles as mentor teachers within the PDS, the practice of each of these eleven participants has changed to reflect more reform-oriented teaching methods. Additionally, the ways that these teachers think about science learning has also changed. Although self-reports did not uncover deep epistemological changes in how teachers view the nature of science, changes did occur in teachers’ understanding of science learning. The level of questioning did not probe deep enough to uncover this knowledge about teachers’ views of the nature of science, however, evidence from their stories revealed a definitive change in thinking in such a way that every mentor teacher recognized and understood the importance of teaching science using a lens of inquiry.

From this study we learned about the nature of change in thinking and practice toward science education by these elementary PDS mentor teachers. The change processes of each mentor teacher in this study reflected both the personal and social nature of change. Embedded within each teacher’s stories of change were hurdles that they negotiated on a personal level (What does my practice look like? Why do I teach this way? How does this affect my
students?), as well as on a social level (How can I best work with my colleagues? Who can help me when I have questions?). Nevertheless, the pathway of change was not identical for every mentor teacher. Some recognized the need for a change immediately while others remained skeptical for a while. Some took a lead role in changing the curriculum while still others waited, followed, and adopted these changes later. However, the nature of each teacher’s change was similar. All changes in the process were made by choice, and every mentor teacher moved down the path of teaching science using a lens of inquiry and incorporating the practices consistent with reform-oriented guidelines as determined to be best practices in science education. The change process may have taken longer for some than others, but as a result of their involvement in the PDS as mentor teachers, whose job it was to provide guidance and support to PDS interns, all of these participants have changed the ways they teach science to reflect inquiry practices. By examining the long-term impact that PDS has had on the science teaching practices of these eleven mentor teachers, there is a better understanding of the kinds of experiences that are meaningful as part of the change process.

In conclusion, significant educational change in the area of science education requires extensive and continuous time, resources, professional development and implementation support across systems involved. The connection to the issue of change in teaching practices has grown out of the need to determine the impact that this PDS partnership has had on the professional growth of the elementary mentor teachers that have been involved in this alliance.

In chapter ten of *Taking Science to School*, Duschl, Schweingruber and Shouse (NRC, 2007) make two claims about supporting quality science instruction. Their first claim states that student learning of science "depends on teachers having adequate knowledge of science" (p. 296). They go on to discuss how elementary teachers have limited knowledge of science as well as
having limited opportunities to learn science. As a result, due to limited undergraduate coursework in science and the focus of that coursework being very fact-based in presentation and learning style, elementary teachers often follow that same teaching model in their own classrooms.

Their second claim asserts that in order for elementary teachers to teach science using more reform-oriented methods, they will need "sustained science-specific professional development in preparation and while in service. Professional development that supports student is rooted in the science that teachers teach and includes opportunities to learn about science, about current research on how children learn science, and about how to teach science" (p. 296).

This research study provides evidence to support these claims that teachers need in-depth science-specific professional development opportunities, as well as a supportive community such as the PDS in which to practice, in order to become highly qualified teachers who continually use a lens of evidence/explanation to guide their practice.
REFERENCES


(Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 3-32). San Francisco: Jossey Bass.


Bell, G.L. (2002). Elementary science teaching enhancement through a professional development schools model. In proceedings of the annual international conference of the Association for the Education of Teachers in Science (AETS). Charlotte, NC.


knowledge in the classroom. *Educational Researcher, 23*(7), 5-12.


National Research Council (2007). *Taking science to school: Learning and teaching science in


## APPENDIX A

### Essential Features of Classroom Inquiry

<table>
<thead>
<tr>
<th>Essential Feature</th>
<th>Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Learner engages in scientifically oriented questions</td>
<td>Learner poses a question</td>
</tr>
<tr>
<td>2. Learner gives priority to evidence in responding to questions</td>
<td>Learner determines what constitutes evidence and collects it</td>
</tr>
<tr>
<td>3. Learner formulates explanations from evidence</td>
<td>Learner formulates explanation after summarizing evidence</td>
</tr>
<tr>
<td>4. Learner connects explanations to scientific knowledge</td>
<td>Learner independently examines other resources and forms the links to explanations</td>
</tr>
<tr>
<td>5. Learner communicates and justifies explanations</td>
<td>Learner forms reasonable and logical argument to communicate explanations</td>
</tr>
</tbody>
</table>

| More--------------------| Amount of Learner Self-Direction--------------------| Less |
| Less--------------------| Amount of Direction from Teacher or Material------------------| More |

Table 2.6

**Essential Features of Classroom Inquiry and Their Variations (NRC, 2000, p.29)**
November 17, 2011

Jackie Manno
839 Firetower Road
Brookville, PA 15825

Dear Ms. Manno:

You have requested permission to reprint the following material copyrighted by the National Academy of Sciences in a dissertation:

Table 2-6, Inquiry and the National Science Education Standards: A Guide for Teaching and Learning, 2000

Your request is granted for the material cited above provided that credit is given to the copyright holder.

Suggested credit (example):
Reprinted with permission from (title), (year) by the National Academy of Sciences, Courtesy of the National Academies Press, Washington, D.C. (This credit may be edited pursuant to the publisher’s house style and format so long as the essential elements are included).

Thank you,

Barbara Murphy
Permissions Coordinator
National Academies Press
APPENDIX C

Mentor Survey 2005

Purpose and Directions: This survey is a bit unusual as surveys go in that it asks you to check several response columns for each item. We'd like you to respond in several ways to each item. We are trying to determine what impact, if any, the PDS has had on your classroom practice and your thinking about teaching. In each case we are asking you to signify the extent to which your thinking about teaching and your teaching practices have been affirmed and/or changed by the connection with PDS work. The survey results will be used to inform our planning for the future. We also would like to report our findings to others involved in PDS work throughout the country. Your individual answers will be kept confidential. They will be pooled with others so that no answers can be traced back to individual respondents. Please take your time and give this your full attention. You are providing the best information here that we can possibly get. Thank you.

Part I: What has been your involvement in the PDS?

Number of years of teaching: ________  Current grade level: ________

<table>
<thead>
<tr>
<th>PDS Activity</th>
<th>Involvement</th>
<th>Description/comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working with an intern in your classroom</td>
<td>Number of years</td>
<td></td>
</tr>
<tr>
<td>Working with PDS planning teams</td>
<td>Number of years</td>
<td>Which team(s)?</td>
</tr>
<tr>
<td>Collaborating with university faculty</td>
<td>Number of times</td>
<td></td>
</tr>
<tr>
<td>Engaging in teacher inquiry</td>
<td>Number of times</td>
<td></td>
</tr>
<tr>
<td>Participating in professional development courses or workshops</td>
<td>Number of times</td>
<td>Which ones?</td>
</tr>
<tr>
<td>Reading intern applications or interviewing interns</td>
<td></td>
<td></td>
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<tr>
<td>Hosting intern in your partner classroom.</td>
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<tr>
<td>Other types of involvement (identify)</td>
<td></td>
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</tbody>
</table>

PDS Mentor Survey - 1
Part II: To what extent has your involvement with the PDS influenced your thinking and/or practice? Throughout the rest of the survey, when we say "the PDS connection," we are referring to the following types of activities: working with interns, working with classroom PDA, serving on a methods planning team, collaborating with university faculty, engaging in teacher inquiry, participating in professional development activities (e.g., summer courses and workshops), working with other mentors in your school, working with mentors from other buildings, etc.

For items 1–8, please put a check in any appropriate column.

1. My teaching of science...

<table>
<thead>
<tr>
<th>The extent to which the PDS connection</th>
<th>Great Extent</th>
<th>Some Extent</th>
<th>Little Extent</th>
<th>Not at All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affirmed my thinking</td>
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<tr>
<td>Changed my thinking</td>
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<tr>
<td>Affirmed my practice</td>
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<td></td>
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<tr>
<td>Changed my practice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Influenced my students' learning</td>
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</tbody>
</table>

Please provide a brief explanation of your answers.

2. My teaching of math...

<table>
<thead>
<tr>
<th>The extent to which the PDS connection</th>
<th>Great Extent</th>
<th>Some Extent</th>
<th>Little Extent</th>
<th>Not at All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affirmed my thinking</td>
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<tr>
<td>Changed my thinking</td>
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<td>Affirmed my practice</td>
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<tr>
<td>Changed my practice</td>
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</tr>
<tr>
<td>Influenced my students' learning</td>
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</tbody>
</table>

Please provide a brief explanation of your answers.

3. My teaching of social studies...

<table>
<thead>
<tr>
<th>The extent to which the PDS connection</th>
<th>Great Extent</th>
<th>Some Extent</th>
<th>Little Extent</th>
<th>Not at All</th>
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<tbody>
<tr>
<td>Affirmed my thinking</td>
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<tr>
<td>Changed my thinking</td>
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<td>Affirmed my practice</td>
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<tr>
<td>Changed my practice</td>
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<tr>
<td>Influenced my students' learning</td>
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</tbody>
</table>

Please provide a brief explanation of your answers:

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PDS Mentor Survey - 2

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348
4. My teaching of reading and language arts...

<table>
<thead>
<tr>
<th>The extent to which the PDS connection</th>
<th>Great Extent</th>
<th>Some Extent</th>
<th>Little Extent</th>
<th>Not at All</th>
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</thead>
<tbody>
<tr>
<td>Affirmed my thinking</td>
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<td>Changed my thinking</td>
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<td>Changed my practice</td>
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<tr>
<td>Influenced my students' learning</td>
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Please provide a brief explanation of your answers.

5. How I handle the classroom environment (management)...

<table>
<thead>
<tr>
<th>The extent to which the PDS connection</th>
<th>Great Extent</th>
<th>Some Extent</th>
<th>Little Extent</th>
<th>Not at All</th>
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<tbody>
<tr>
<td>Affirmed my thinking</td>
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<td>Changed my practice</td>
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<tr>
<td>Influenced my students' learning</td>
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</table>

Please provide a brief explanation of your answers.

6. How I use technology...

<table>
<thead>
<tr>
<th>The extent to which the PDS connection</th>
<th>Great Extent</th>
<th>Some Extent</th>
<th>Little Extent</th>
<th>Not at All</th>
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<tr>
<td>Affirmed my thinking</td>
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<tr>
<td>Influenced my students' learning</td>
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</table>

Please provide a brief explanation of your answers.
7. How I mentor interns...

<table>
<thead>
<tr>
<th>The extent to which the PDS connection</th>
<th>Great Extent</th>
<th>Some Extent</th>
<th>Little Extent</th>
<th>Not at All</th>
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<tr>
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<tr>
<td>Influenced my students' learning</td>
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Please provide a brief explanation of your answers.

__________________________________________________________________________

__________________________________________________________________________

8. My teaching in general...

<table>
<thead>
<tr>
<th>The extent to which the PDS connection</th>
<th>Great Extent</th>
<th>Some Extent</th>
<th>Little Extent</th>
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<td>Affirmed my thinking</td>
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<tr>
<td>Influenced my students' learning</td>
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Please provide a brief explanation of your answers.

__________________________________________________________________________

__________________________________________________________________________
**Part III: How have particular activities of the PDS influenced your thinking and/or practice?**

<table>
<thead>
<tr>
<th>PDS Activity</th>
<th>Great Extent</th>
<th>Some Extent</th>
<th>Little Extent</th>
<th>Not at All</th>
<th>No Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working with an intern in your classroom</td>
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<tr>
<td>Working with PDS planning teams.</td>
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<tr>
<td>Working with classroom PDA's</td>
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<tr>
<td>Collaborating with university Penn State faculty</td>
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<tr>
<td>Working with other mentors in my school</td>
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<tr>
<td>Working with mentors from other schools</td>
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<tr>
<td>Engaging in teacher inquiry</td>
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<tr>
<td>Participating in courses and workshops for mentors</td>
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<td></td>
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<tr>
<td>Other (Please specify)</td>
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</table>

Please provide a brief explanation of your answers.

___________________________________________________________

___________________________________________________________

___________________________________________________________

**We know how busy you are, but would you be willing to take part in an interview to talk more about your answers?**  
Yes ____ No ____

If you said yes, please provide your name. ____________________________

Note: If you agree to talk with us, your interview will be scheduled during the school day while your intern is teaching.

**When you have completed the survey** please seal it in the envelope and return it to your PDA. Our sincere thanks for your participation.

---

PDS Mentor Survey - 5
APPENDIX D

INFORMED CONSENT FORM FOR SOCIAL SCIENCE RESEARCH
The Pennsylvania State University

Title of Project: Dissertation - Mentor Teachers Perspectives of Individual Change in the Teaching of Science and Use of Technology in the Elementary Classroom influenced by a Professional Development School Partnership.

Principal Investigator: Jacqueline L. Manno
Doctoral Candidate
Department of Curriculum & Instruction – Science Education

839 Firetower Road
Brookville, PA 15825
(814)328-2322 – home
(814)594-5270 – cell
jal286@psu.edu

Advisor: Carla Zembal-Saul, PhD
Chambers Building
University Park, PA 16802
(814)865-6565
czem@psu.edu

Other Investigator(s): N/A

1. Purpose of the Study: The purpose of this research is to identify what impact, if any, the Professional Development School has had on the classroom practices and thinking about teaching of State College Area School District mentor teachers in the areas of elementary science and technology use. This study will attempt to describe the nature of change in thinking about science and the practice of teaching science and using technology while examining the factors that mentors report as being significant to that change.

2. Procedures to be followed: You will be asked to participate in one interview that will last approximately one hour. This interview will be digitally recorded. At the conclusion of the interview, the conversation will be transcribed and you will be asked to review the transcription for errors. You have the authority to clarify any points within the written transcription at this time.

3. Discomforts and Risks: There are no foreseeable discomforts or risks in this research.

4. Benefits: The benefits to you include insight into your own teaching practice and reflection on how you have grown as a professional throughout your career – especially related to your teaching of science and your use of technology in the classroom.

   The benefits to society include, at the conclusion of the study, a better understanding of the processes by which teachers come to change their practice – the methods and strategies that work best – in order to provide additional information to the theoretical understandings of professional development of teachers, particularly in the areas of science and technology.

Page 1 of 2
5. **Duration/Time:** Approximately 1 hour to participate in the initial interview and approximately 30 minutes to 1 hour to review the interview transcript.

6. **Statement of Confidentiality:** The Office for Research Protections and the Social Science Institutional Review Board may review records related to this project. Pseudonyms will be used for each interviewee and the digital recordings will be saved for no less than 5 years. These recordings will be held confidential by the researcher only and will not be released to any other individual without express written consent by the interviewee. The researcher will be the only individual with access to this data and the participants' identity.

7. **Right to Ask Questions:** You can ask questions about this research. Contact Jackie Manno at (814) 594-5270 or jal286@psu.edu with questions. If you have questions about your rights as a research participant, contact The Pennsylvania State University's Office for Research Protections at (814) 865-1775. Should significant new findings develop during the course of the research which may relate to the participant’s willingness to continue in the study will be provided.

8. **Compensation:** No compensation will be provided to either the participants or to the researcher involved.

9. **Voluntary Participation:** Your decision to be in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer.

You must be 18 years of age or older to consent to take part in this research study. If you agree to take part in this research study and the information outlined above, please sign your name and indicate the date below.

You will be given a copy of this signed and dated consent form for your records.

_____________________________  _________________
Participant Signature        Date

_____________________________  _________________
Person Obtaining Consent     Date
APPENDIX E
Dissertation Questions & Interview Protocol

Developed, reviewed and approved: 5/4/05
Purpose of Study: The purpose of this study is to describe the nature of change in the thinking and practice of teaching elementary school science by teachers that have been involved in a Professional Development School setting.

- How have teachers through their involvement with the PDS changed their thinking about science teaching?
- How have teachers through their involvement with the PDS changed their practice of teaching science?
- To what extent has their involvement with PDS influenced these changes?
- What are the major factors that have contributed to this change?
- Do teachers believe that there is a connection between their change and student learning?

### PRIMARY INTERVIEW QUESTIONS

<table>
<thead>
<tr>
<th>FOLLOW-UP PROBES/ PROMPTS</th>
<th>INFORMATION ANTICIPATED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part I: Establishing the Interview Setting</strong></td>
<td>X</td>
</tr>
<tr>
<td>a. IRB in place – discuss consent</td>
<td></td>
</tr>
<tr>
<td>b. Discuss format of interview</td>
<td></td>
</tr>
<tr>
<td>c. Discuss original survey results of participant – selected for study because they have noted a change in their thinking and/or practice in teaching of science and technology.</td>
<td></td>
</tr>
<tr>
<td>d. Describe purpose of study.</td>
<td></td>
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<tr>
<td>e. Record everything – 3-column notebook handy for jotting notes.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Part II: Understanding of involvement in PDS (similar data as collected from survey, elaborated)</strong></th>
<th><strong>Mentor teacher</strong></th>
<th><strong>PDA</strong></th>
<th><strong>Other</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. How long have you been involved with the PDS?</td>
<td>• Mentor teacher</td>
<td>• PDA</td>
<td>• Other</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>b. To what extent have you been involved in PDS? What kinds of professional development did you participate in?</td>
<td>• Mentor Teacher/worked with intern?</td>
<td>• PDA?</td>
<td>• Planning teams – which ones?</td>
</tr>
<tr>
<td></td>
<td>• PDS Workshops – when/which ones?</td>
<td>• Engaging in teacher inquiry?/ formal or informal?</td>
<td>• Collaborating with university faculty?</td>
</tr>
<tr>
<td></td>
<td>• Was there continuous</td>
<td></td>
<td></td>
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</tbody>
</table>

I know what to expect as recorded on Impact Survey results. However, there was limited space here, so some teachers may have left information out of the survey instrument.
### Part III: Science teaching practices and beliefs – How have they changed? Why have they changed?

#### Context for Teacher Change:

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. How have you grown as a professional since your involvement in PDS?</td>
<td>I expect that since responses on survey either affirmed or changed thinking and practice, that will be reflected here.</td>
</tr>
<tr>
<td>b. What personal growth have you experienced?</td>
<td>I'm not sure what participants will acknowledge as personal growth.</td>
</tr>
<tr>
<td>c. Do you have any new roles that you have taken on in relation to science?</td>
<td>It is anticipated that at least some of the participants have taken on different roles that are strong in relation to science.</td>
</tr>
</tbody>
</table>

#### Professional Growth:

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. How have you grown as a professional since your involvement in PDS?</td>
<td>I expect that since responses on survey either affirmed or changed thinking and practice, that will be reflected here.</td>
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<td>b. What personal growth have you experienced?</td>
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<tr>
<td>c. Do you have any new roles that you have taken on in relation to science?</td>
<td>It is anticipated that at least some of the participants have taken on different roles that are strong in relation to science.</td>
</tr>
</tbody>
</table>

#### Changes in Teaching and Learning Science:

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. How has your instruction in science changed since you have been involved in PDS?</td>
<td>I expect that responses will include different inquiry-based science teaching strategies. If mentioned, will transition into next question…</td>
</tr>
<tr>
<td>b. Have you implemented any science inquiry strategies into your daily classroom routine?</td>
<td>It is anticipated that participants will talk about things that the interns have introduced into the classroom from their methods courses. Also things they have learned through professional</td>
</tr>
<tr>
<td>Question</td>
<td>Response</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>c. How has the science curriculum been affected by the district’s involvement in PDS?</td>
<td>I have heard about the Dinosaur Addendum so I expect that some teachers will talk about this curriculum enhancement.</td>
</tr>
<tr>
<td>d. How have the changes in teaching and learning science at your school affected your students?</td>
<td>• Positive or negative? It is expected based on researcher’s experience in teaching that there will be an increase in student interest in doing science.</td>
</tr>
</tbody>
</table>

**Barriers:**

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Have there been any obstacles that you have faced in making these changes in relation to science?</td>
<td>Not sure what to anticipate from these responses.</td>
</tr>
</tbody>
</table>

**Lessons Learned:**

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. What have been the most exciting things about being involved with the PDS?</td>
<td>• Specifically in relation to science? Not sure about this.</td>
</tr>
<tr>
<td>b. Do you believe in this method of teaching science?</td>
<td>• Why or why not? I think participants will respond that they do like it. I am not sure however, if they will consider it another changing fad or not</td>
</tr>
</tbody>
</table>
May 1, 2005

Dear _____________________________,

My name is Jackie Manno and I am a graduate student working with Carla in researching the teaching of science and the important changes that have taken place in classrooms across the district over the past few years. I was especially excited about these changes after attending the inquiry conference last Saturday. What an inspiration to all teachers and future teachers as well! Like you, I am trained in elementary education and taught 5th grade for many years and wish that I had known then what I know now about how to teach science to my students. It’s inspiring to see the exciting things that you are doing with science in your classrooms!

I have contacted you because of your response to the mentor survey that was given out earlier this spring regarding your involvement in PDS and to what extent your involvement has influenced your thinking and/or practice in each of the curricular areas. Your response indicated that you recognize and report a change in your thinking/practice in relation to science and/or technology as a result of your involvement with PDS. Also, you indicated that you would be willing to take part in an interview to talk more about your experiences. I know that this is an extremely busy time of the year for you, but I was wondering if you would still be willing to participate in a short (approximately 1 hour) interview to discuss the impact that the PDS has had on your work, specifically in relation to science?

I am especially interested in conducting this research within the context of the Professional Development School as a study for my dissertation to try to understand what the factors may be that have helped to contribute to any instructional change in relation to science. Additionally, I believe that the information that you share would be a great contribution to the larger PDS community in helping to capture the most essential portion of what makes the State College PDS successful. This information will be vitally important to the future of science education for our elementary school children and the university’s preparation program.

Thank you in advance for your consideration. I am able to meet at almost any time and will do my best to work around your teaching schedule. I have attached a schedule of the dates and times that I am most readily available, however, I can meet other times if needed. As I stated earlier, I know how busy you are and appreciate your time and consideration. Just an email to me with a few dates and times that work in your schedule and I can schedule our meeting. Also, I have attached a list of questions to the end of this email if you would like to look them over prior to our interview. I am thankful for your contribution to this study. Looking forward to meeting with you,

Jackie

ADVANCE QUESTIONS: Here is a list of key questions that I will be asking throughout the interview. Please feel free to look them over and think about them ahead of time.

RESEARCH STUDY: Change in science thinking and practice within the PDS.
PURPOSE OF THE STUDY: The purpose of this study is to identify what impact, if any, the Professional Development School has had on the classroom practices and thinking about teaching in the area of elementary science. This study will attempt to describe the nature of the change in thinking about science and the practice of science while examining the factors that mentor teachers report as being significant to that change.
QUESTIONS:
(1) During your time as a mentor teacher in the PDS, you have undoubtedly experienced many interesting things in relation to your change in understanding science. Could you share one or two of your most memorable and/or meaningful stories? These stories can focus on any aspect of your experience, from your work with interns to your personal experiences in the science classroom or in university courses.
(2) Context for teacher change:
   a. Could you provide information on your professional background in both elementary teaching and science?
   b. How has your involvement in PDS affected relationships with your colleagues in education?
   c. What is the nature of collegiality at your school? In particular, in relation to science?
   d. How has your relationship with the university changed since you have been involved in PDS activities?
(3) Professional Growth:
   a. How have you grown as a professional since your involvement in PDS?
   b. What personal growth have you experienced?
   c. What personal growth specifically in science have you experienced?
   d. Do you have any new roles that you have taken on in relation to science?
(4) Changes in Teaching and Learning Science:
   a. How has your instruction in science changed since you have been involved in PDS?
   b. Science assessment?
   c. Planning?
   d. Have you implemented any science inquiry strategies into your daily classroom routine?
   e. How has the science curriculum been affected by the district’s involvement in PDS?
   f. How have the changes in teaching and learning science at your school affected your students?
(5) Barriers:
   a. Have there been any obstacles that you have faced in making these changes in relation to science?
(6) Lessons Learned:
   a. What have been the most exciting things about being involved with the PDS (in relation to science)?
   b. Do you believe in this method of teaching science? Why/not?
PDS Science 2nd Interview Questions:

(1) Give a description of what a typical science lesson looks like in your classroom.
   a. What are the kids doing?
   b. What are you doing?
   c. What do you want the children to know/be able to do by doing science this way?

(2) Since our last meeting, have you continued to have interns? Have they brought any “new ideas” in science to the classroom? How important is having this intern in your classroom when it comes to teaching science?

(3) How long have you now been involved in the PDS? Have you taken any new courses or had other types of involvement since we last met nearly 2 years ago? Have any of these been specifically related to science?

(4) Briefly describe your BELIEFS about how science should be taught in the elementary classroom.

(5) How do you feel that teaching science in this manner has impacted/influenced your students learning in science?
## APPENDIX H
Big Ideas, Categories and Codes within Research

<table>
<thead>
<tr>
<th>Big Ideas/ Categories</th>
<th>Codes</th>
<th>Definition</th>
<th>Sub-Codes</th>
<th>Exemplar Quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaboration with other professionals is critical to supporting change</td>
<td>(1) Collaboration</td>
<td>Collaboration is defined as “working together, especially in a joint, intellectual effort.”</td>
<td>Influence of intern on practice</td>
<td>I really feel like I have learned so much about my own practice from having an intern. It’s just so interesting because when you have to teach somebody something, you really have to think about that it is you do and why… and so each intern has taught me something about myself and made a change for me… they have really been how I learned at all about this because I’ve not taken any PDS science courses yet, so any of the little bit of learning that I’ve done about science and how to teach science differently has really come from an intern and their projects that they do and when they’re teaching science. Elizabeth</td>
</tr>
<tr>
<td>Teaching colleagues working together</td>
<td></td>
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<td></td>
<td>So we plan well together, we have fun, so we can play with science. Like when [we] did this magnet thing, we…played with the magnets and learned a little bit more about magnets ourselves, and then brought that to the classroom. There’s that kind of collaboration. And then, if things don’t go well or if you’re scared about something, to have somebody else to share the experience with who can say, “Well, that didn’t work for me either,” or “Well, I did it this way.” Or if she teaches a lesson before I teach it, I’ll go to her and say, “Okay, what happened? What worked, what didn’t work?” And she’ll do the same thing for me. So that it helps improve your teaching just by talking about pluses and minuses with somebody else. Julie</td>
</tr>
<tr>
<td>Influence of University science ed. faculty</td>
<td></td>
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<td></td>
<td>What I know is that my science teaching changed because of Connie [university science education faculty]. I’ve always liked science teaching…but our curriculum has not always lent itself to time and wonder, I guess. And it was Connie coming in who just helped that along. Margaret</td>
</tr>
<tr>
<td>Other connections</td>
<td></td>
<td></td>
<td></td>
<td>Leah [university science education faculty member from satellite campus] has been coming in and working with me sometimes. She comes in and helps me think about things</td>
</tr>
<tr>
<td>(2) Community of Support</td>
<td>Community of Support has been developed using a modified definition of Community of Practice. (Wenger, 1998) A community of support is organically created and provides mentor teachers a way to share best practices, ask questions, and provide support.</td>
<td>Learning from one another</td>
<td>I think collaboration is so important in all areas of teaching, but especially when you're trying new things. First of all, you've got a synergy of knowledge or ideas. You know, when two people come together you certainly get better than double the amount of ideas. Julie</td>
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<tr>
<td>Trust and Support</td>
<td>There was that support that you could get from the university…from the PDS collaborative…and I really liked the support that the PDS brings to science teaching. Marla</td>
<td>PDS groups for supporting science</td>
<td>I don’t think it always takes a collegial group, I mean, there are probably people in every building that take a look at this and go “Wow!” and can do it on their own. But for some of the rest of us, that groups, that collegial group is really important in kind of leaving those feelings of inadequacy in science and also frustration and trying to redesign your science lessons to be more inquiry-based. Marla</td>
<td></td>
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<tr>
<td>Mutual respect</td>
<td>The opportunities that are there for thinking deeper are not just because of my intern, but because I feel that my expertise from being in the classroom is well respected and valued and Jon is wonderful about that, and Connie is wonderful about that. You know, none of them would ever say they know more than any of us, and so Connie will walk into the classroom and learn something and so the respect on all levels is another reason that I feel allowed to explore why I’m doing things, and change. Shelley</td>
<td>Student learning in science</td>
<td>Student Learning was not measured through assessment strategies. Teachers’ ideas of learning were based on their reports of observation and interpretation of student learning.</td>
<td></td>
</tr>
<tr>
<td>(1) Effect on Student Learning</td>
<td>Student Learning was not measured through assessment strategies. Teachers’ ideas of learning were based on their reports of observation and interpretation of student learning.</td>
<td>Addressing misconceptions</td>
<td>And so, that, I think was a little bit hard, but yet, they talked about it, they know what endothermic and ectothermic are because I remember reading somewhere, try no to use the terms “warm-blooded” and “cold-blooded” because it has a misconception. Lynne</td>
<td></td>
</tr>
<tr>
<td>Student learning in science</td>
<td>…and I was astounded at some of the discoveries that the kids not only made but they remembered! The vocabulary in there is pretty tough. They learned what “bipedal” and “quadrupedal” were…and they can tell you, “Well, a quadruped walks on four legs and a biped walks on two legs.” Well, how do you know? “Well, because you look</td>
<td>Student learning in science</td>
<td>---</td>
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<tr>
<td><strong>Excitement toward science</strong></td>
<td><strong>Science-specific strategies</strong></td>
<td><strong>KLEW charts</strong></td>
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<tr>
<td><strong>Excitement</strong> in the science classroom was defined by the teachers’ observations of student interest and enthusiasm about the concepts as reflected by their words and actions.</td>
<td><strong>Science-specific strategies</strong> in effective reform science teaching include the use of KLEW charts and Science Talks as well as the use of effective questioning and addressing of misconceptions. When used together, these strategies help to focus learning on building a strong evidence base to support explanation building.</td>
<td>…like with the magnet unit, using their wonderings to propel the unit more than the content that the district says you have to teach. And the idea of using that evidence, and making them back up their claims with evidence is very – I had used KWL before, but now with this KLEW thing, and now focusing more on the wonderings. <strong>Julie</strong></td>
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| Student excitement or motivation | Increased interest in science | [The heart experiment] was one of the ways that one of the little boys that I dearly love, that motivated him to read and write – science. I mean, science was, you know, it wasn’t math, it was science that did that. **Margaret** |

<table>
<thead>
<tr>
<th>Reform-oriented science practices involve key teaching strategies</th>
<th><strong>Science Talk</strong></th>
<th><strong>Student prior knowledge</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Science-Specific Learning Strategies</strong></td>
<td><strong>Science Talk</strong></td>
<td><strong>Student prior knowledge</strong></td>
</tr>
<tr>
<td></td>
<td>Well, they have excellent wonderings. And if we really hear what they’re saying, and I know that we have an objective, and it’s kind of in that science talk, how can you tweak that wondering? I mean, where are we going to take that wondering? How are we going to get that evidence? <strong>Margaret</strong></td>
<td>And they said, “These microorganisms that cause germs or you to get sick, would cause mold.” Now don’t ask me how they knew that, but they just said, the one kid said, “It causes mold,” and somebody said, “Oh yeah, I’ve seen mold.” I mean, the conversation went, “Yeah, if you leave…bread around too long, it will get moldy.” <strong>Margaret</strong></td>
</tr>
</tbody>
</table>

| Questioning strategies | I think about how two years ago how I taught science and... | at the tracks! You know, the bipeds go like this and the quadrupeds go like that.” **Lynne** |
how I teach science now, totally different….I am allowing even now, its almost more questions and more answers to say, “I don’t know, but how can we find that out?”
Margaret

<table>
<thead>
<tr>
<th>(2) General inquiry practices</th>
<th>General inquiry strategies are instructional strategies that include questioning and discourse, but at a level that is more deductive than inductive.</th>
<th>Focus on questioning</th>
<th>Well, certainly, personally I feel like, or professionally, I guess this is, I feel like I’m a much better science teacher. I’m becoming very comfortable with questioning. I feel I’m getting much better at asking those questions to get my students to think. Julie</th>
</tr>
</thead>
<tbody>
<tr>
<td>General discourse practices</td>
<td>You know, now I will do that. I mean, I might have said, “What do you know about insects?” because I would figure that they would know something about insects, but I might not have asked, “Well, how do you think day and night, why do you think there’s day and night?” or something more complex kind of idea. Elizabeth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of Technology</td>
<td>And there was a really nice video that we were able to watch from that, so we were able to put that on then the kids could come and watch…so that’s kind of how I’ve used technology – not so much with the kids, but for the kids. Elizabeth</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Science-specific professional development contributes to change process</th>
<th>(1) Science coursework</th>
<th>Science Coursework refers to specific professional development opportunities that were available to mentors from sources such as university courses, district workshops, or other formal PD opportunities focused specifically on science.</th>
<th>Workshops and Courses are important</th>
<th>The other piece that really helped me with science education and the inquiry stance… is the fact that there were summer courses that were offered that were tailored specifically to our needs. Think about your own education, and when was the last time a university said to you, “What would you like to learn? Let’s look at your own curriculum. Let’s look at your needs. How can we design a course that fits your needs?” Marla</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(2) Personal Initiative</td>
<td>Personal Initiative refers to other opportunities that mentors sought on their own that were not formal coursework or workshops but still forms of PD that contributed to their knowledge and experiences in the change process.</td>
<td>Inquiry Projects</td>
<td>Then that year, I had to chair the Dinosaurs unit for our team, which was a dinosaur. And Connie actually was instrumental in helping me, and that became my inquiry project. And Margaret and our two interns helped me rewrite this unit and make it a very inquiry-based unit on paleontology. And I haven't looked back! Julie</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Working with Science Educators</td>
<td>[Co-teaching the science methods course] was a big, big change for me, and helping her [university science educator] teach the PDS course was really, you know,</td>
</tr>
</tbody>
</table>
whenever you teach something you always learn from it. *Julie*

**PDA experience – indirect PD**

Kate [pseudonym], that’s our PDA who’s a real science person, too. She’s one of the people who teaches science courses. So, she helped plan some lessons that I kind of just watched and listened to, and thought, this is really cool. You know, what are the kids going to learn from this? *Lynne*

**Frustration with former teaching methods or student learning is recognized by teachers – point of change**

| (1) Dissatisfaction | **Dissatisfaction** describes feelings that mentor teachers had toward the process of changing their science teaching practices. Dissatisfaction was directly related to factors within school boundaries, such as curriculum units, time constraints, and support systems. | **Frustration with curriculum** | We study ‘space’ as one of our science units and while there are some things you can do, there’s just a lot of facts about space. So that’s something that I’d like to think about how we might actually be able to change some of those things. *Elizabeth*

**Time is challenge to change** | Science has been the one that has been really hard because you tend to do things that…well, I have a limited amount of time for science. *Lynne*

**Lack of support** | …we are bound by the curriculum and a lot of the inquiry really far on the table is “let the students explore what they want to and we provide the materials and provide the background…” but we don’t have the training. We have a curriculum that binds us to we have to study these things and we may not have necessarily the support or the materials to do what needs to be done at a primary level. *Lynne*

**Apprehension toward change** | **Apprehension toward change** was reflected in teachers stories as factors that played a role in the change process. These factors were of a personal nature rather than issues that were directly related to school boundaries. | **Conflict with former practice** | I had set it up hoping they’d ask the right questions so we’d go a certain way, but they brought in their own information. *Margaret*

**Feeling of inadequacy** | ..because in the past, science had been…we had science units very much like we had social studies units. So, in our unit planning we would say, “Oh, all right, we’re working on ‘Medieval’ as our social studies them and ‘simple machines’ as our science theme. And everyone would bring their science unit that had been written by a group of teachers and our curriculum specialist and we’d kind of go through the main topics. And everything was pretty much written down for you. Here’s lesson number one or concept number one and here are some ideas to teach.
concept number one. Here’s concept number two and again, here are some things or some ideas to teach concept number two. So, I think, I was really open to any kind of science change because science in the past had been so frustrating. *Marla*

<table>
<thead>
<tr>
<th>Concept</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal desire to change</td>
<td>Personal desire to change has been developed through the stories of practice as mentor teachers reported measures of their willingness and desire to change.</td>
<td><em>Marla</em> I was really open to any kind of science change because science in the past had been so frustrating and science <em>has</em> to be hands-on. You know, I can’t imagine trying to teach any science concepts without having kids actually doing something.</td>
</tr>
<tr>
<td>Openness to change</td>
<td>I was really open to any kind of science change because science in the past had been so frustrating.</td>
<td><em>Shelley</em> I’m someone that likes change and I think that’s a personality thing, not a necessary definition of a teacher, it’s just me. Personally, I like change.</td>
</tr>
<tr>
<td>Personal background</td>
<td>I was always a science person, too. I actually started out in nuclear engineering, science and math.</td>
<td></td>
</tr>
<tr>
<td>Teacher reflection on practice</td>
<td>I question what I’m told to teach more now, and if I don’t like the way something is laid out, I’ll look for a different way to do it.</td>
<td><em>Julie</em> …but what I think is hard, and why I took the class in the fall, is we still have the same curriculum, we still have the same set of standards or expectations, outcomes, whatever. How do I take what’s there, on my own, and flip it around so that it’s more inquiry-based for our classroom students?</td>
</tr>
<tr>
<td>Personal reflection</td>
<td>And I think what I’ve learned from inquiry is that letting the children come up with their own answers is pretty important.</td>
<td><em>Margaret</em> …we thought we were pretty cool, or innovative, when we thought about hands-on stuff. Because at least we were</td>
</tr>
</tbody>
</table>

**Inquiry as way of thinking**

1. **Personal desire to change**

   Personal desire to change has been developed through the stories of practice as mentor teachers reported measures of their willingness and desire to change.

   *Marla* I was really open to any kind of science change because science in the past had been so frustrating and science *has* to be hands-on. You know, I can’t imagine trying to teach any science concepts without having kids actually doing something.

   *Shelley* I’m someone that likes change and I think that’s a personality thing, not a necessary definition of a teacher, it’s just me. Personally, I like change.

2. **Reflection**

   Reflection refers to carefully considering former or current actions or thoughts. In the case of this study, mentor teachers reflected on their views regarding science teaching practices or personal views of science learning. These reflections affected views of inquiry science teaching.

   *Julie* I question what I’m told to teach more now, and if I don’t like the way something is laid out, I’ll look for a different way to do it.

   *Lynne* …but what I think is hard, and why I took the class in the fall, is we still have the same curriculum, we still have the same set of standards or expectations, outcomes, whatever. How do I take what’s there, on my own, and flip it around so that it’s more inquiry-based for our classroom students?

   *Elizabeth* I have learned so much about my own practice from having an intern. It’s just so interesting because when you have to teach somebody something, you really have to think about what it is you do and why…so each intern has taught me something about myself and made a change for me.

3. **Personal reflection**

   And I think what I’ve learned from inquiry is that letting the children come up with their own answers is pretty important.

**Teacher-directed Science vs. Student-Activity-Based**

1. **Activity-Based Science**

   Activity-Based Science refers to instruction that is focused on hands-on teaching.

   …we thought we were pretty cool, or innovative, when we thought about hands-on stuff. Because at least we were
Centered Science
direct-instruction techniques and
the use of numerous hands-on
activities that often reflect a
disconnect with concept meaning
(Moscovici & Nelson, 1998). This
type of science is very teacher-
directed.

giving kids touches of it. You know, at least touch your
science stuff - you don't need books, you know. And when
you're doing hands-on science and they're doing things,
they are questioning, and that was all well and good.

Margaret

How it used to be, “Oh, this is such a cute idea and this
activity is going to be so much fun”…and you want it to be
enjoyable for the kids. Bobbie

Former practice
We had specific activities that we would have the kids do
[in the magnet unit]. And typically what I would do prior
to letting the children discover and see where their interest
is, we would sit down and every day I would explain to the
kids, “Ok, now this is the center that we are going to do
and we're going to see if the magnet will pull things out of
water. We’re going to see if it will pull things out of sand.
This is magnetic and this is magnetic.” And I’d have five
or six magnet centers. Bobbie

Disconnect between activity
and learning
It [the science unit] wasn’t even that hands-on. We were
studying each of the dinosaurs. I had put together little
booklets with cut and paste pages. It was not really
inquiry-based. Greg

Teacher-Directed Science
So we developed what we thought was pretty good science
for kindergarten at the time. It was, you know, month-long
investigations. And we would do things on evaporation,
and make rock crystals, or we would make ice cream or we
would have, we did a thing on planes, ramps… So we’d do
them in months, and every week they’d have a new little
experiment or something. But it was fairly teacher-
directed – it was hands-on, but it was fairly teacher-
directed. Julie

(2)
Explanation-Based Science
Explanation-Based Science refers
to the use of reform-oriented
science teaching practices that are
more student-centered. The focus
of such practices is on the use of
data to formulate explanations
(NRC, 1996, 2000).

Inquiry-based science
experience
But I think the idea of really trying to look carefully at how
the kids can do activities so that it helps lead them to the
solution, rather than talking about the solution and then
giving them an experience that helps reinforce it. You
know, for them to actually figure out why they think this is
happening. Elizabeth

Evidence building
I like the introduction of the evidence – support your
reasoning. That’s huge. Don’t just tell me, “This is what I

<table>
<thead>
<tr>
<th>Child-centered science</th>
<th>But it was really the whole idea of now, letting the curriculum go - not really, but taking it from the children's point of view, has been so empowering. Margaret</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructing explanations from evidence</td>
<td>…we talked about it and they had what they learned and their evidence…They compared it to the other groups. The dirty groups had them because we put them up and they compared. [Reading from the KLEW chart they created in the classroom] “And washing your hands is important for removing germs that make you sick because dirty hands group had the moldiest bread, washing hands group had the least.” So they drew that conclusion. “The bread was moldiest when you do not wash your hands” – it’s because they saw it. “I saw the mold on the bread.” Margaret</td>
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<tr>
<td>Lesson modification toward reform</td>
<td>Well, it [the focus of the unit] is mostly determining what the mystery dinosaur is. Actually working like a paleontologist, using what we know about ourselves or other animals and applying them to an animal that you can’t see…so it’s very, very engaging. So the students actually learn more than just dinosaur names and what they ate and stuff. They really come to understand them as animals and understand what it means to be a carnivore and what their skull would look like and what their teeth might look like. Julie</td>
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</table>
## APPENDIX I

Levels of Inquiry Use
Science Teaching Rubric Based on Stories of Practice

<table>
<thead>
<tr>
<th>Focus on Evidence in Science Teaching</th>
<th>0</th>
<th>1</th>
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<tbody>
<tr>
<td><strong>Using Evidence</strong></td>
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<tr>
<td>Little or no reference to use of <em>evidence</em> (as defined by NRC 1996) in science teaching</td>
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<tr>
<td>Little reference to <em>evidence</em> in science teaching. Teachers do talk about <em>data collection</em> but rarely use the term <em>evidence</em></td>
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<td>Beginning to apply use of the word <em>evidence</em> to data collected in science</td>
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<td>Regularly uses the term <em>evidence</em> to describe information gathered in science</td>
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<tr>
<td>Consistently uses the term <em>evidence</em> to describe information gathered in science</td>
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<tr>
<td><strong>Collection of Evidence</strong></td>
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<td>Evidence described as data being provided to students or very prescribed data collection (i.e. means to an end)</td>
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<tr>
<td>Students sometimes collect <em>evidence</em>, however, it is referred to as data – more often provided by the teacher</td>
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<tr>
<td><em>Evidence</em> is being collected by students more often and less often provided by teacher</td>
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<td>Teacher uses his/her role in the science classroom to assist students in determining “what counts” as <em>evidence</em></td>
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<td>Teacher allows learner to determine what constitutes <em>evidence</em> and how to collect it</td>
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<td><strong>Analysis of Evidence</strong></td>
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<tr>
<td>Data is rarely used or analyzed during science lessons</td>
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<tr>
<td>Sometimes uses data in science teaching. Focus is as an <em>end product</em></td>
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<td>If data is analyzed, teacher tells students how to analyze data</td>
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<td>Teacher uses his/her role in the science classroom to assist students in analysis</td>
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<tr>
<td>Teacher allows learner to determine how to analyze data</td>
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<td><strong>Focus on Explanation in Science Teaching</strong></td>
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<tr>
<td><strong>Explanation Building</strong></td>
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<tr>
<td>No reference to use of <em>explanation</em> building during science lessons</td>
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<tr>
<td>Little or no reference to use of <em>explanation</em> building</td>
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<tr>
<td>Describes naive views of <em>explanation</em> building during lessons. <em>Explanations</em> often given to students through definitions or modeled by teacher</td>
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<tr>
<td>Uses <em>explanation</em> building in science teaching. Students are given guidance in formulating <em>explanations</em></td>
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<tr>
<td>Uses lens of <em>evidence/explanation</em> to guide teaching practices and student learning in classroom</td>
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<tr>
<td><strong>Role of Explanation</strong></td>
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<tr>
<td>Rote memorization. Very little explanation of science concepts</td>
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<td>Explanations about content are given by teacher to build scientific knowledge</td>
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<td>Teacher provides evidence and gives possible ways to use evidence to formulate structured explanations</td>
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<td>Teacher guides process of formulating explanation from evidence</td>
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<td>Teacher provides time and opportunity for students to construct explanations based on evidence</td>
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<td><strong>Classroom Discourse</strong></td>
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<td>Discourse is focused from teacher to student – rote communication and feedback</td>
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<td>Students are given steps and procedures for communication from teacher</td>
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<td>Students are provided broad guidelines by teacher to sharpen communication</td>
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<td>Students are coached by teacher in development of communication</td>
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<td>Teacher provides opportunity for students to form reasonable and logical argument to communicate explanations</td>
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<td><strong>Frequency of Discourse Practices</strong></td>
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<td>Teacher engages students in questions provided by teacher, materials or other source</td>
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<tr>
<td>Teacher engages students in questions provided by teacher, materials, or other source</td>
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<tr>
<td>Teacher provides opportunity for students to sharpen or clarify questions provided by teacher, materials, or other source</td>
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<td>Teacher often provides opportunity for students to select among questions and/or pose new questions</td>
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<td>Teacher consistently encourages students to pose questions</td>
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<td><strong>Nature of questioning</strong></td>
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<tr>
<td>Nature of teacher questioning is on “What?”</td>
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<tr>
<td>Nature of teacher questioning is on “What?”</td>
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<tr>
<td>Nature of teacher questioning is on “What?” and “Why?”</td>
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<td>Nature of teacher questioning is on “What?” and “Why?” or “How?”</td>
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<tr>
<td>Nature of teacher questioning is on “What?”?, “Why?”?, and “How do you know that?”</td>
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<tr>
<td>Usage of Science Discourse</td>
<td>Science talk strategy is not used</td>
<td>Science talk is a part of classroom environment and is used as individual</td>
<td>Science talk is used/encouraged primarily to assess prior knowledge</td>
<td>Science talk continues to be used to assess prior knowledge, and this information is often used to guide next steps.</td>
<td>Science talk is used/encouraged as a way to negotiate meaning and to construct explanations of science knowledge.</td>
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CURRICULUM VITAE
Jacqueline L. Manno

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EDUCATION:

2004-2011 The Pennsylvania State University, University Park, PA
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2005-2009 Clarion University of Pennsylvania, Clarion, PA
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2004-2005 The Pennsylvania State University, University Park, PA
Department of Curriculum and Instruction
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Instructor, Student Teaching Supervisor

1994-1997 Prince George’s County Public Schools, District Heights, MD
Classroom Teacher, Grades 4 & 5

1992-1993 Department of Defense Dependent Schools, Baumholder, Germany
Classroom Teacher, Grades 5 & 6

CONFERENCE PRESENTATIONS:

2009 Association for Science Teacher Education National Conference, Hartford, CT
2007 Association for Science Teacher Education National Conference, Tampa, FL
2006 Professional Development School National Conference, Orlando, FL
2003 Pennsylvania Science Teachers Association, Hershey, PA

RESEARCH INTERESTS:
Professional Development Schools, Science Education in the early learning environment,
Informal Science Education