ELEMENTARY TEACHERS' SCIENCE PRACTICE, BELIEFS, AND CONTENT KNOWLEDGE DURING AND FOLLOWING A REFORM-BASED PROFESSIONAL DEVELOPMENT PROGRAM

by

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ABSTRACT

This study examined patterns of change in the science teaching practice, beliefs, and content knowledge of 15 upper-elementary teachers from three Title I schools during their participation in a yearlong, reform-based science professional development program and during the year following the program. Further, this study sought to understand the school factors that hindered or supported these patterns in the year following the program. This study responds to calls for research on understanding teachers' continued learning within the context of their classroom and school environment following professional development experiences.

A mixed model design, integrating quantitative and qualitative data, was used. Quantitative data were used to examine changes in teachers' practices, beliefs, and physical science content knowledge across the 2 study years. Qualitative data were used to corroborate this data and provide additional insights into observed patterns. Both data types were used collaboratively to understand the barriers and supports in teachers' schools to their continued learning following professional development.

The study findings indicated that scores in all three measures increased a statistically significant amount in Year 1. Scores continued to increase in Year 2, but only content knowledge scores increased significantly. Qualitative data corroborated the survey findings in teachers' beliefs and practices.

A combination of school- and individual-level factors impacted the Year 2 changes. School-level factors were: (a) supportive same-grade teams and/or a mentor who advocated inquiry science and prioritized science as a subject, (b) principal prioritization of science, and (c) easy access to and training in the use of relevant materials. The individual-level factor was teachers' degree of willingness and readiness to change their beliefs in fundamental ways.

The study results suggested that professional development, along with school and personal factors, impacted teacher change. These findings inform the education literature bases as well as professional development providers and school administrators about the types of support and resources that teachers require in the school context in order to maintain or enhance professional development experiences. The decisions teachers make about whether and how to implement and sustain new practices, and the reasons for these decisions, ultimately determine the success of reform-based professional development in science education.

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Vladimir and Tanya Drits

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CHAPTER 1

INTRODUCTION

The reform vision for K-12 science education is complex and requires a significant change in the way science teaching and learning is conceptualized. Beginning nearly two decades ago, national reform documents, including *Project 2061: Benchmarks for Science Literacy* (American Association for the Advancement of Science [AAAS], 1993), the *Scope and Sequence Project* (National Science Teachers Association, 1993), and the *National Science Education Standards* (NSES) (National Research Council [NRC], 1996) have advocated a change in elementary science education. This includes promoting a classroom culture that fosters a deep understanding of subject matter rather than rote memorization, and implementing classroom practices and assessments that complement this goal (Darling-Hammond & McLaughlin, 1995).

These documents identify inquiry-based teaching and learning practices as central to achieving this reform. Inquiry can be defined as processes by which students engage with, or pose, scientifically-oriented "questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories" (NRC, 1996, p. 214). Inquiry-based classrooms are student-centered. Students, with various degrees of guidance, ask scientific questions and use investigations to advance their science learning. Inquiry can be implemented in numerous ways in the classroom. Teachers may provide more to less direction, depending their learning objectives and on student preparation. Inquiry's defining feature, the process of observing and using evidence to create scientific explanations, is foundational to science learning.

To achieve this goal, reformers advocate the need for inservice teachers to supplant their traditional methods of teaching science with one aligned to the reform documents (AAAS, 1989; NRC, 1996). The National Research Council (1996) identifies professional development as the greatest catalyst of change in science teaching. Professional development that meets the current reform vision will prove crucial to the science learning of *all* students (NRC, 1996).

Background to the Problem

In order to achieve the needed reform, inservice teacher education should be geared toward changing: (a) the amount of teachers' science content knowledge; (b) teachers' beliefs about how students learn science, beliefs about their role as science teachers, and beliefs about the benefits of reform teaching; and (c) classroom science teaching practice (Fishman, Marx, Best, & Tal, 2003; Gess-Newsome, 2001; Pajares, 1992; van Driel, Beijaard, & Verloop, 2000). These changes are particularly complex when one considers science teaching in the elementary context. Elementary students are not receiving the quantity or quality of science instruction described in the reform documents (Fulp, 2002). Science is under-prioritized as a subject, and little time is typically devoted to this subject (Wallace & Louden, 1992). When science is taught, the norm is to use traditional practices (such as worksheets, lectures, and whole-class discussion), even if teachers report they value inquiry-based practices (Marshall, Horton, Igo, & Switzer, 2009).

Teachers' subject knowledge influences practice (Ahtee & Johnston, 2006; Guskey, 2002a; Supovitz & Turner, 2000). Research shows that elementary teachers' science content knowledge is alarmingly low (Rice, 2005). Enhanced content knowledge is necessary to enact the science reform efforts, especially since inquiry-based teaching requires more content knowledge, as well as more attention to student engagement, than traditional teaching (Crawford, 2000). Keys and Bryan (2001) explain, "Teachers who use an inquiry approach must have rich and deeply developed understandings of science content, student learning, the nature of science, and ways to engage students in investigative practices" (p. 637).

Beliefs also play a central role in influencing science teachers' practice. "Teacher beliefs about the nature of science, student learning, and the role of the science teacher substantially affect planning, teaching, and assessment" (Keys & Bryan, 2001, p. 636). The role of beliefs may be even more important in enacting teacher change in science than in other subjects because elementary teachers, specifically, must overcome a well-documented reluctance to teach science (Appleton & Kindt, 1999; Ramey-Gassert & Shroyer, 1992; Rice, 2005).

Research on the sequence of change between practice, beliefs, and knowledge is mixed. Some studies suggest that successful change in practice is followed by belief change, as teachers are motivated to change after witnessing positive shifts in student learning (Gess-Newsome, 2001; Guskey, 2000; Pajares, 1992). Other scholars report that there is little consistency as to which occurs first, and that it differs for individuals (Fennema et al., 1996; Richardson, 1994). Increases in content knowledge are related to changes in teacher beliefs and practice, as shifts in one can affect shifts in the others (Kennedy, 1998a; Schoon & Boone, 1998).

The amounts, types, and processes of change in the content knowledge and beliefs of inservice teachers during professional development have been extensively researched (Bell & Gilbert, 1994; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003; Wee, Shepardson, Fast, & Harbor, 2007). Research on which professional development elements effectively advance this teacher change is also substantial. These elements include long-term engagement, collaboration with other teachers, focus on student learning, and connectivity to classroom practices (Gess-Newsome, 2001; Loucks-Horsley et al., 2003; van Driel et al., 2001). Recent literature recognizes the important role of support from within teachers' school contexts, including support from school administrators and colleagues, for professional development goals to be met and sustained (Guskey, 2000; Loucks-Horsley et al., 2003).

Statement of Problem and Rationale

While the literature is clear on the effective elements of professional development and the importance of beliefs and knowledge in teacher learning, little research has been conducted on what happens to this learning after the professional development is complete. How is the learning that takes place during professional development subsequently translated into teachers' science teaching practice?

Webster-Wright (2009), in a comprehensive review of research on professional development, argues that future research must move away from evaluating the delivery of professional development toward understanding the continued learning within the context of teachers' workplace. She calls for research that connects the learning that occurs in professional development programs to the continued learning that occurs afterward in teachers' classrooms and school environments.

In reviewing the literature on teacher change, including change through professional development, Richardson and Placier (2001) find that more research is needed regarding how school context affects teachers. Keys and Bryan (2001) suggest that future research on inquiry science teaching and learning should focus on the beliefs of teachers who are implementing inquiry-based instruction and on the impact of school settings upon these beliefs. They explain, "As yet, we have little knowledge of teachers' views about the goals and purposes of inquiry, the processes by which they carry it out, or their motivation for undertaking a more complex and often difficult to manage form of instruction" (p. 636).

This study responded to these calls for further research on professional development by examining trends in teachers' inquiry-based practice, inquiry-based beliefs, and content knowledge during professional development and in the year following professional development. It also examined the contextual, situated factors that impacted these trends in the year following professional development.

Research Questions

This study examined changes in the inquiry practice, inquiry beliefs, and content knowledge of 15 upper-elementary teachers from three high-need, diverse schools who participated in a yearlong, reform-based professional development program. The primary goals of the *Physical Science Inquiry Academy* (PSIA) were to enhance teachers' physical science content knowledge and to provide teachers with new understandings about, and experiences in, teaching and learning science through inquiry. Changes in the three outcome measures were also examined in 12 of the 15 teacher participants in the year following the professional development program.

The study was designed to determine which of several potential patterns of change occurred. Teachers might show an immediate and substantial change toward increased inquiry practice, inquiry beliefs, and knowledge in the professional development year that that was sustained in the 2nd year. Teachers might show a gradual change over the 2 years. They might show an initial change in the 1st year followed by a return to baseline in the 2nd year. Or teachers might show no change.

This study further sought to understand the school contextual factors that facilitated or impeded the maintenance of the learning that occurred during professional development in the year following the program. Data were collected that examined these school factors, such as administrator and collegial support for inquiry science teaching, and availability of relevant materials and supplies, that may have affected continued change and learning in the outcome measures.

These three measures—teachers' practice, beliefs, and content knowledge—were examined because they were the focus of the professional development program and have been shown in the literature to be instrumental in achieving the reform-based vision for science education. This study was guided by the following research questions:

1. What changes occur in teachers' inquiry-based practices, inquiry-based beliefs, and content knowledge during a year of professional development and a year of classroom practice?

2. What impact do school-level factors have on the changes that occur in teachers' inquiry-based practices, inquiry-based beliefs, and content knowledge during the year after a professional development program?

Methods

A mixed model approach was used in this study, following Tashakkori and Teddlie's (1998) parallel mixed model study design. In this model, mixing occurs *within* each stage of the study. Both confirmatory (quantitative) and exploratory (qualitative) research questions were asked, and both quantitative and qualitative techniques were used in data collection and data analysis (Tashakkori & Teddlie, 1998). Quantitative data, supported by qualitative data, were used to answer research question one. Qualitative data, supported by quantitative data, were used to answer research question two. The data integration of both methods occurred at the end of the 2nd year of the study. Results were reported across the group, by individual case, and across cases.

Significance of Study

This study fills a gap in the literature on how the learning that takes place during professional development is translated into teachers' science teaching instruction during professional development and in the following year. It also addresses gaps in understanding the supports and barriers that impact this translation within the school context.

Understanding the direction and nature of change in teachers' inquiry-based practice, inquiry-based beliefs, and physical science content knowledge during and following professional development can inform the practice of professional developers teachers, and school administrators in their approaches toward science teaching and learning during and following professional development. The decisions teachers make about whether and how to implement and sustain new practices, and the reasons for these decisions, ultimately determines the success of reform-based professional development in science education.

Summary

This study examined the impacts of a yearlong professional development program on teachers' inquiry-based practices, inquiry-based beliefs, content knowledge, and the school context factors that supported or hindered these impacts in the year following the program. Chapter 1 provides a brief general overview of the study. Chapter 2 is a review of the literature pertinent to this study.

Chapter 3 describes the professional development context and research methods used in the study. Chapter 4 provides a detailed description of the school contexts and teacher profiles. This is followed by a description of the patterns of teacher change by total participants, by participants within a school, and by individual teachers. The impacts of school-level factors on teacher change are also reported. Chapter 5 presents the study conclusions and implications.

CHAPTER 2

LITERATURE REVIEW

The purpose of this research study was to investigate the patterns of change in elementary teachers' inquiry-based practice, inquiry-based beliefs, and physical science content knowledge during a year of professional development and the following year. This study further examined the impacts and interactions of school context factors on these teacher characteristics in the year after the professional development program.

This chapter first provides an overview of the current reform vision for science education, highlighting inquiry teaching and learning. This overview is followed by a description of the state of elementary science education, including student science learning and elementary science teaching. Next is a review of the literature on teachers' inquiry-based beliefs and science content knowledge, and their inextricable relationship to teachers' implementation of inquiry-based practices in the classroom. Following this is a description of reform-based professional development and its impact on teacher change in practice, beliefs, and knowledge. This chapter concludes with a description of the important impact of school context on teacher reform-based practice.

The Vision for Science Education Reform and Inquiry Practice

Elementary science education has been a target for reform efforts for over 50 years, with a steady stream of concern over the quality of elementary science, as indicated by declining student achievement in science (Marshall, Horton, Igo, & Switzer, 2009; Wallace & Louden, 1992). National reform documents, including *Project 2061: Benchmarks for Science Literacy* (AAAS, 1993), the *Scope and Sequence Project* (NSTA, 1993), and the *National Science Education Standards* (NRC, 1996) represent a new wave of reform efforts that began in the late 1980s. They advocate the need for a change in vision of K-12 science education that is grounded in extensive research on student science learning, especially the type of learning that results in deep, conceptual understanding. This vision includes classrooms where teachers and students share responsibility for learning, where communities of science learners are engaged in scientific discourse, and where the use of scientific evidence is preeminent in student science learning (NRC, 1996).

The *National Science Education Standards* (NSES), possibly the most recognized and influential reform document for elementary and secondary education, states that the reform vision must occur at multiple levels to be effective. These levels are science teaching, science content, assessments in science, science education programs at the school and district levels, science education systems that include interactions between stakeholders within the education system or between education and other systems, and professional development.

The success of the reforms, however, ultimately depends on the teaching and learning that occurs in the classroom, through teachers' instructional practices in science. Most closely tied to classroom science teaching and learning are the *NSES* science content and the science teaching standards.

Content Standards

The *NSES* content standards incorporate traditional content standards but add additional standards. Integral to the content standards defined in the *NSES* is the new emphasis on developing students' abilities to do scientific inquiry in the classroom. Inquiry science promotes the use of investigation and evidence to develop scientific explanations. Inquiry-based classrooms are student-centered. Students, with various degrees of guidance, ask scientific questions and use investigations to advance their science learning. Inquiry can be defined as processes by which students engage with, or pose, scientifically-oriented "questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories" (NRC, 1996, p. 214).

An NRC publication in 2000 consolidated the *NSES* descriptions of inquiry in the classroom into five "essential features" for inquiry. These are:

1. Students engage in (or pose) scientifically oriented questions.
2. Students prioritize evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
3. Students use evidence to formulate explanations to scientifically oriented questions.
4. Students measure their explanations relative to alternative explanations, especially those that reflect scientific understanding.
5. Students justify proposed explanations through communication.

The content standards have reflect an emphasis on studying a few fundamental concepts in science rather than many (depth over breadth), and *understanding* these concepts rather than simply knowing scientific facts and information. The physical science content standards in grades 5-8, for example, reflect these emphases. Only three fundamental concepts and principles (properties and changes of properties in matter, motions and forces, and transfer of energy) underlie these standards instead of traditional approaches of "breadth over depth." The *NSES* also added the nature of science (NOS) to its content standards, which includes the philosophical underpinnings of scientific knowledge, and learning science content in the context of technology, personal, and social perspectives.

Teaching Standards

The *NSES* teaching standards for science classrooms also emphasize inquiry. The changing emphases of these teaching standards include teaching through inquiry by engaging students in scientific discourse and modeling investigation-based skills to create a community of science learners (NRC, 1996). Inquiry teaching includes engaging students in activities that are both "hands-on" *and* "minds-on" (NRC, 1996; van Driel et al., 2000). Inquiry can include the nature of science, the process of doing science, and the process of teaching science, all of which are interrelated and occur at various stages in inquiry learning.

Inquiry can be implemented in numerous ways and to different degrees. Depending on the intent of the lesson, for example, teachers can vary in the amount of structure and guidance they provide during inquiry teaching. *Guided* inquiry requires teachers to take greater responsibility for posing questions, designing investigations, or communicating results. *Open* inquiry requires the learners to take more of this responsibility. Guided inquiry can aid in the understanding of particular science concepts, while open inquiry allows for learners' cognitive development and scientific reasoning (NRC, 2000).

The *NSES* provides teachers with a guiding framework and philosophy for science teaching, but does not dictate a specific order of activities and lesson plans. Keys and Bryan (2001) explain that the *NSES* "provide important suggestions for the goals of inquiry teaching, content for inquiry learning, and some examples of the kinds of activities in which students may be engaged. However, it will be up to classroom teachers to formulate patterns of teaching actions that accomplish these goals" (p. 632).

In sum, the reform documents advocate an inquiry-based approach to science teaching and learning. Among other types of standards, the documents outline both content standards and teaching standards for teachers to implement in their classroom. These standards are intended to promote the reform vision of science education that fosters deeper learning for all students.

The Reality of Elementary Science Education

Elementary Science Classrooms

Elementary students are not receiving the quantity or quality of science instruction described in the reform documents (Fulp, 2002). Two fundamental, interrelated problems are described in the science education literature. First, science is under-prioritized as a subject and is often taught infrequently or omitted altogether. Second, when science is taught, it is typically taught using traditional (or noninquiry-based) methods, even if teachers report they value inquiry-based practices (Ramey-Gassert & Shroyer, 1992; Wee et al., 2007).

Elementary science continues to be viewed as irrelevant by teachers, administrators, and the public, as indicated by the little instructional time devoted to science compared to language arts and mathematics (Fulp, 2002). Case study research has revealed that science is not seen as basic and important in elementary classrooms (Wallace & Louden, 1992).

Time is always scarce for teaching science. Therefore the amount of time teachers invest in science teaching is small compared to the rest of their professional obligations (Schoeneberger & Russell, 1986). The many demands of other subjects, meetings, preparation, duty, and phone calls result in little time for elementary teachers to plan science activities (Wallace & Louden, 1992).

Further, when science is taught, it typically does not match the vision of reform. A national survey of science and mathematics education conducted in 2000 revealed that most elementary school science lessons consist mainly of traditional teaching practices, such as whole class discussions, lectures, solving worksheet or textbooks problems, and reading about science (Fulp, 2002). Further, student preparation of written science reports and making science presentations were reported as infrequent. Some teachers reported occasional hands-on or investigative activities, but "students were much more likely to be following specific instructions in completing an activity or investigation than designing or implementing their own investigations" (Fulp, 2002, p. 14).

Often, teachers claim to be open to inquiry but do not implement it in practice. Elementary teachers in one recent study reported a fairly high amount of time ideally devoted to inquiry instruction (60%), which indicates that elementary teachers value the idea of inquiry. However, a nationwide study found that elementary teachers used the elements of effective inquiry instruction in less than 18% percent of their lessons (Weiss, Pasley, Smith, Banilower, & Heck, 2003).

Characteristics of Elementary Teachers

Student learning is ultimately impacted by teacher practice in the classroom. Teacher practice, in turn, is linked in complex and powerful ways to their content knowledge and beliefs (Keys & Bryan, 2001).

Beliefs About Inquiry Teaching and Learning

Elementary teachers' beliefs about inquiry teaching and learning also affect their ability and willingness to implement inquiry in their classrooms. Coble and Koballa (1996) describe the role of beliefs in influencing implementation of science reforms:

> Teachers are directly responsible for implementing the changes associated with this new vision of science education in the classroom. However, what is known about the attitudes, beliefs, and actions of science teachers suggests that they are not adequately prepared to enact the changes that accompany this new vision of science education. (p. 462)

Even though many elementary teachers claim to support inquiry teaching (Marshall et al., 2009), they are "unclear about the meaning of inquiry as it relates to pedagogy and assessment, and this confusion causes them to perceive inquiry as being difficult to implement in the classroom" (Wee et al., 2007, p. 64). Similarly, Bybee (2000) reported that teachers often claim scientific inquiry is time consuming, costs too much, and is simply too advanced for students. While many teachers have heard of inquiry, only 42% of teachers in a 2000 national study had heard of the *NSES* (Fulp, 2002). Inquiry (and science) is often "viewed as a body of knowledge, rather than a process in which a better understanding of the world can be obtained" (Wee et al., 2007,

p. 63). This indicates that teachers may have an inaccurate understanding of inquiry (and science) teaching and learning.

Many elementary teachers lack training in inquiry methods and have had few opportunities to work with scientists to develop a genuine understanding of scientific inquiry (Banilower, Heck, & Weiss, 2007; Wee et al, 2007). When attempting to incorporate bits of inquiry into their classrooms, for example, teachers often fail to realize that there is a "difference between 'doing science' and doing science activities. The former emulates real-world science processes, while the latter simply provides interactive, hands-on opportunities for students" (Wee et al., 2007, p. 64).

Elementary teachers reported feeling better prepared to teach more general pedagogical practices, such as working in cooperative groups or listening and asking questions, than practices aligned with the *NSES*, such as students use of investigative practices and developing conceptual understandings (Fulp, 2002). A lack of preparation in teaching science through inquiry and lack of confidence in teaching science as a subject often result in teachers dismissing or disregarding inquiry as irrelevant and inconvenient in favor of traditional models of teaching and learning (Wee et al., 2007).

In a case study of four elementary teachers, for example, Wallace and Louden (1992) found that the teachers attempted to incorporate bits of reformed science instruction that were advocated by district administration, into their lessons. The teachers, however, questioned the effort involved in preparation and eventually returned to a teaching style they felt comfortable using and which they believed had served them well in their teaching experience. Without adequate preparation in reform-based instruction, then, teachers stay with traditional forms of teaching over the unknown.

Content Knowledge

Much research has demonstrated that elementary teachers have inadequate content knowledge in science (Duschl et al., 2007; Rice, 2005), making it a subject in which many elementary teachers feel unprepared and lack confidence (Schoeneberger & Russell, 1986). In a study of 67 inservice elementary teachers, for example, 52% failed to answer any of three basic science-related questions correctly (Rice, 2005). Each question represented a different science disciplinary area (physical, biological and earth science). The author concluded that the results revealed a lack of conceptual understandings of basic science.

Over half of surveyed teachers in a 2000 national survey had not taken a university science course since 1990, indicating “a serious need for retooling a large percentage of the elementary school teaching force” (Fulp, 2002, p. 10). This lack of science coursework limits teachers’ content knowledge of science (Schoeneberger & Russell, 1986).

A national study revealed that 71% of elementary teachers themselves reported needing to improve their science content knowledge, their understanding of how students learn science, and their science assessment (Weiss, Banilower, McMahon, & Smith, 2001). By contrast, 77% felt well prepared to teach language arts.

Teachers’ physical science content knowledge is particularly low. Thirty-six percent of upper elementary teachers have taken no physical science coursework, a higher percentage than those who have taken no life science (8%) or earth science (17%) coursework (Fulp, 2002).

Finally, teachers reported higher confidence in teaching science and in teaching through reform-based methods when their content knowledge and pedagogical content knowledge increased (Kennedy, 1998a; Schoon & Boone, 1998). Teachers' low content knowledge, therefore, affects teachers' abilities and their willingness to teach through inquiry (Schoeneberger & Russell, 1986).

In sum, reform documents such as the *NSES* have an expanded, reformed vision of how science teaching and science learning should occur in elementary classrooms. The reality, however, is that elementary teachers do not embrace science as a subject and do not utilize inquiry-based instructional methods in the classroom. Research has revealed that teachers have fundamental beliefs that question the effectiveness of inquiry science and their ability to teach inquiry-based science. Further, teachers have low content knowledge in science. Both factors can negatively affect teachers' implementation of inquiry science in their classrooms.

Meeting the Challenges of Reform

For the type of teaching necessary to maintain the goals of reform in the science classroom, teachers must alter their practice. Guskey (2002) explained that if teachers do not alter their practice to reflect reform principles, "little improvement in student learning can be expected" (p. 3). To effectively change teachers' practice in order to meet the goals of the science reform movement, then teachers must feel more prepared and be better skilled not only in teaching science as a subject, but in teaching it through inquiry. This means shifting teachers' beliefs about the value and feasibility of teaching through inquiry-based practices and increasing teachers' content knowledge in science (Gess-Newsome, 2001; Loucks-Horsley et al., 2003; Pajares, 1992; van Driel et al., 2000).

Richardson (1996) posited that discussions about teacher change should focus on fostering changes in teachers' knowledge and beliefs (along with attitudes). These are the components of teachers' cognitions most strongly linked to classroom practice. Teachers' beliefs and knowledge, then, must change in order for practice to change and to be *sustained* in that change (Loucks-Horsley et al., 2003; Thompson & Zeuli, 1999; van Driel et al., 2000).

Professional development has been identified as a primary source of providing inservice elementary teachers with the necessary experiences to understand and enact the science teaching reforms (Duschl et al., 2007; NRC, 1996). These experiences can include the exploration of teachers' beliefs about inquiry, content knowledge enhancement, and modeling of the reform-based practices. High quality professional development experiences can enhance content knowledge, foster shifts in beliefs about inquiry science, and provide the support and means for enacting reforms in practice (Banilower et al., 2007; Loucks-Horsley et al., 2003; NRC, 1996; Supovitz & Turner, 2000).

The following section describes the current research on the influence of beliefs, content knowledge, and professional development on teacher change in practice. Following this is a discussion about the mitigating influence of school and classroom context on teacher change in practice. Finally, a call is made for further research on teacher change through professional development and the influence of context on this change.

Teacher Beliefs and Practice

Beliefs play a key role in influencing science teachers' practice and may ultimately determine whether teachers choose to implement a new practice (Richardson & Placier, 2001; Pajares, 1992; van Driel et al., 2000). Calderhead (1996) defines beliefs as "suppositions, commitments, and ideologies" (p. 715). Pajares (1992) explains that the *beliefs* construct has taken on a variety of meanings, including people manipulating knowledge for a particular purpose or circumstance (Abelson, 1979); dispositions to action and major determinants of behavior, although the dispositions are time and context specific (Sigel, 1985); an individual's representation of reality that has enough validity, truth, or credibility to guide thought and behavior (Rokeach, 1968).

Teachers hold beliefs about each subject area they teach. These "tend to be associated with a range of beliefs concerning epistemological issues—what the subject is about, what it means to know the subject or to be able to carry out tasks effectively within that subject domain" (Calderhead, 1996, p. 720). Elementary teachers hold many types of beliefs about science. This study focuses on the relationship between two types of teacher beliefs and their science classroom practice. These are beliefs about science teaching and beliefs about student science learning.

Beliefs About Science Teaching and Practice

Teachers' beliefs about science teaching can influence the types of instruction they use in their classroom practice. As previously discussed, elementary teachers' school environments tend to foster beliefs that deprioritize science compared to other subjects (Fulp, 2002; Wallace & Louden, 1992). Teachers, as a result, do not seek professional development in science to the same extent they do in other subjects, such as math (Fulp, 2002). This lack of preparation affects teachers' confidence in teaching science as a subject, and especially in teaching science through inquiry. This, in turn, results in teachers dismissing or disregarding inquiry as irrelevant and inconvenient in favor of traditional models of teaching and learning (Ramey-Gassert & Shroyer, 1992; Wee et al., 2007).

Beliefs About Science Learning and Practice

Teachers' beliefs about learners and learning are "the assumptions teachers make about their students and how their students learn [which] are likely to influence how they approach teaching tasks and how they interact with their students" (Calderhead, 1996, p. 719). Much research has revealed that teachers' beliefs about the benefits of the current reform movement for student learning in science are related to their teaching practices (Bell & Gilbert, 1994; 1996; Supovitz & Turner, 2000; Wee et al, 2007; Yerrick, Parke, & Nugent, 1997). Research has also determined that teachers' beliefs about the benefits of reform can be held dually. Even if teachers hold favorable views of inquiry, these beliefs are tempered by their beliefs that inquiry may not result in efficient learning (Keys & Bryan, 2001). These beliefs, in turn, impact the choices elementary teachers make in deciding whether to use reform-based science practices in their classroom (Appleton & Kindt, 1999; Marshall et al., 2009).

Several studies have demonstrated the relationship between teachers' beliefs about science teaching, teachers' beliefs about science learning, and teachers' instructional practices. One study focused on the relationship between beliefs and the implementation of a reform-based curriculum unit and associated reform-based teaching practices (Cronin-Jones, 1991). The two rural fifth- and sixth-grade teachers who participated in the study were provided with the new curriculum materials and a written description of the philosophy and proposed teaching style that would accompany the materials. The theoretical orientation guiding the new curricula and intended teaching style was discovery-oriented constructivism (students learn from their experiences, from making discoveries on their own, from interacting with others, and from reflection), which underlies some of the current educational reform ideas. A 2-hour meeting was held to introduce the curriculum and instructional theory to the teachers. The implementation of the curriculum lasted more than 6 weeks.

Data sources were qualitative. They included field notes collected from observations from the implementation of the curriculum unit; formal semistructured interviews with the teachers before, during, and after implementation; and informal interviews that occurred after each class period during implementation. Case studies were developed for each teacher. Data analysis included coding and the creation of assertions about each case.

The findings revealed that for both teachers, four general categories of beliefs influenced their practice during the new curriculum implementation process. These were beliefs about the teacher's role in the classroom, how students learn, students' capabilities based on developmental level, and importance of science as a subject.

Teacher One believed that factual content was most important for students to learn and that her students required significant direction. These beliefs were reflected in her classroom practice. The new curriculum was designed for whole group, small group, and individual instruction in equal amounts. The teacher, however, devoted 70% of her class time to whole-class, teacher-directed instruction, while 22% of the time was student-led small group work, and 8% was individual work time. Further, she indicated that she did not believe all of the content topics and activities were worthwhile, and eliminated several of the activities. Thus, this teacher's beliefs about the importance of factual content and how students learn precluded the curriculum objectives for student outcomes, such as problem solving and improved science attitudes. These beliefs also hindered the potentially positive effects of the curriculum's discovery-oriented model of learning.

Teacher Two believed that students learned best through repeated drill and practice and that factual knowledge acquisition was the most important student outcome. Her beliefs about small group work changed somewhat during the course of the study. Originally she did not believe this was effective and implemented this type of instruction 20% of the time (instead of 33%, as dictated by the curriculum). However, as she reflected on her teaching and found that both she and her students enjoyed the small-group work, she modified her practice. The teacher's beliefs about her students' cognitive abilities resulted in practices that provided no opportunities for student interaction and exploration, as was intended in the curriculum. Thus, this teacher's beliefs mostly had negative impacts on the intended student outcomes of this curriculum, such as increased student problem-solving skills. The researchers concluded that beliefs exert powerful influences on teachers' choices during implementation of curriculum, including choices of instructional practice.

In another study, Luft (2001) explored the effects of a reform-based professional development program on teachers' beliefs about inquiry and their classroom practices. The goal of the 18-month program was to foster the development of beliefs that would promote the implementation of extended inquiry lessons. The program provided opportunities for teacher learning about different models of inquiry, to practice using inquiry in teachers' own classrooms, and to examine and reflect on their practice as they utilized inquiry instruction.

Study participants were 14 secondary science teachers who were enrolled in the professional development program for 18 months. A multimethod design was used. Data sources included four observations of classroom practice that were scored on a 1-5 scale with a 5 representing the highest degree of implementation of an extended inquiry lesson and 1 the lowest. Standardized interviews that measured teachers' instructional practices and philosophies (for example, teacher-directed versus student-directed) were conducted pre- and postprogram. Both types of data were analyzed statistically.

Semistructured interviews pre-, mid-, and postprogram were conducted to capture teachers' beliefs about their role in the classroom and their understandings of inquiry. These data, along with field notes from classroom observations, notes from follow-up meetings with the teachers, and email correspondences, allowed the researchers to capture participants' experiences in ways quantitative techniques could not. Case studies were developed for each participant. The cases were compared to one another and changes in the teachers' beliefs and practices were established.

The results showed that although teachers changed toward more inquiry-based instruction at a statistically significant level, changes in beliefs were not statistically significant. At the beginning of the program, all 14 teachers reported that inquiry-based instruction was important; however, only six of the teachers implemented inquiry instruction in their classroom. Luft (2001) explained that teachers entered the program with beliefs that were already student-centered in their nature and had likely enrolled in the program with the intention of implementing student-centered instruction. Therefore, their beliefs influenced their shift in practice once they were supplied with the means and skills to do so.

So, "while participants' beliefs may have directed their inquiry practices, their inquiry practices did not noticeably affect their beliefs" (p. 530). Further, interviews showed that subtle changes in beliefs "reinforced their implementation of extended inquiry cycles and classified their ideas about student-centered instruction" (p. 530). The study results demonstrate the strong influence of beliefs on teacher practice.

Summary

Teachers' beliefs about science teaching, learning, and reform are vital in shifting their practice to be more reform-based, and specifically, more inquiry-based. The important relationship between teacher content knowledge in science and science practice is discussed next.

Teacher Content Knowledge and Practice

Researchers have defined *knowledge* in many ways. Calderhead (1996), for example, defines knowledge as "factual propositions and the understandings that inform skillful action" (p. 715). Scholars have divided the knowledge types that teachers use into several discrete categories. Calderhead (1996) describes three of Shulman's (1986) categories of teachers' knowledge about the subjects they teach: *content knowledge* (the facts of the discipline, how they are organized, and how they are tested to be valid); *pedagogical content knowledge* (what enables the content to be taught, having the skills to transform content into knowledge understandable to students); and *curricular knowledge* (available materials and their ideas, coherence, and progression).

Pedagogical content knowledge is often cited as the type of knowledge teachers must have in order to instruct effectively, or knowing *how* to teach (Kennedy, 1998a; Kimble, Yager, & Yager, 2006). Kennedy (1998b) explains that pedagogical content knowledge depends on teachers having a conceptual understanding of the content. The focus of this study is *content knowledge*, or knowledge of the subject matter, which is understood to be an essential *component* of pedagogical content knowledge.

As previously discussed, science content knowledge affects elementary teachers' confidence levels and sense of preparedness to teach science, which influences their instructional practice. Teachers' content knowledge, then, influences their instructional practice (Cohen & Hill, 2000; Duschl et al., 2007; Guskey, 2002a; Kimble et al., 2006; NRC, 1996). Inquiry requires rich and deeply developed understandings of science content that surpass teachers' needs during traditional teaching (Crawford, 2000; Keys & Bryan, 2001). Teaching through reform methods has been shown to "force" elementary teachers to confront their lack of subject knowledge and to begin to slowly build it (Wallace & Louden, 1992).

Several studies demonstrate the relationship between content knowledge and reform science practices in the classroom. In a large-scale, quantitative study, Supovitz and Turner (2000) investigated how K-8 teachers' reform-based professional development experiences, which included content enhancement, teachers' background characteristics, and school factors, were related to teachers' inquiry-based practices.

Data were collected from 3,464 K-8 teachers and 666 principals from 24 programs participating in a large-scale National Science Foundation initiative, the Local Systemic Change (LSC) through Teacher Enhancement program. These data represented "a rare national view of science teaching and support" (p. 968). The philosophy of the LSC program aligns with the reform vision in science, including utilizing best practices in professional development to enhance teaching in science, mathematics, and technology. Cross-sectional data from 1 year of the initiative were reported in this study.

The researchers used a series of hierarchical linear models (HLM) to analyze the relationship between predictor and outcome variables. The predictor variables included teachers' self-reported content preparedness, school factors, and teachers' attitudes toward reform, perceptions of principal support, and available resources. The content preparedness scale measured how well teachers felt they were prepared to teach 11 commonly taught elementary school science topics, such as electricity and sound. The two composite outcome variables were *classroom practices*, which measured the frequency of teachers' use of reform-based practices in science, and *culture of investigation*, which measured the investigative nature of teachers' classroom instruction in science.

The researchers found that content preparation and hours spent in the professional development program were the most powerful predictors of reform teaching, in both the classroom practice and the culture of investigation scales. Further, the results showed that regardless of the number of hours spent in professional development, the level of content preparation resulted in notable differences in teachers' reform practices. The greater the content preparedness, the greater the reform-based teaching practices. The researchers concluded, “This reinforces the emerging consensus about the critical importance of content knowledge in science teaching” (Supovitz & Turner, 2000, p. 976).

In another study, Garet, Porter, Desimone, Birman, and Yoon (2001) used survey data from the Eisenhower Professional Development Program, a different teacher enhancement initiative, to investigate the effects of enhanced content knowledge on changes in elementary and middle school science and mathematics teachers’ practice. The surveys, administered to a national sample of 1,027 teachers, were designed to determine the effects of professional development structural features (reform-based versus traditional, duration, and collective nature) and core features (focus on content enhancement, active learning, and coherence in teachers’ professional development) on two teacher outcomes. These outcomes were (a) changes in classroom practice (i.e., cognitive challenge of activities used, instructional methods used, assessments used) and, (b) increases in subject content knowledge and skill enhancement in use of curriculum, assessment, and technology.

The researchers estimated a formal causal model, hypothesizing that the structural features of professional development will play an important role in determining the core features, which, in turn will contribute to the teacher outcomes. Analysis was conducted using ordinary least squares regression.

The results indicated that a focus on content enhancement and coherence has strong positive effects on increases in content knowledge and skills. Enhanced knowledge and skills, in turn, have a strong positive influence on change in teaching practice toward more reform-based practices. Professional development that is focused on content without skill enhancement, however, negatively influenced changes in teaching practice. This finding suggests that content knowledge must be nested within opportunities for pedagogical content knowledge enhancement.

The authors concluded that the study's results confirm the importance of having a focus on science and mathematics content during professional development. "Much of the literature on professional development focuses on the process and delivery systems; our results give renewed emphasis to the profound importance of subject-matter focus in designing high-quality professional development" (p. 936).

In a study of preservice elementary school teachers, Ahtee and Johnston (2006) examined the relationship between teachers' physical science content knowledge and their perceived science teaching practice. Specifically, the researchers investigated (a) how the participants connected content knowledge and pedagogical content knowledge within a topic in physical science, and (b) the teachers' perceived challenges in teaching a physics topic.

The study participants were 187 English and Finnish preservice teacher participants who had completed some coursework in physics. Data consisted of a short essay and an open-ended questionnaire based on students' experiences observing a physics demonstration in their university classroom. After students observed the initial phase of the physics demonstration, they were asked to predict and explain on paper what would occur if the objects were manipulated in a certain way. The demonstration was then completed and the scientific concepts were explained to the teachers. The teachers then completed the seven-item questionnaire.

The questionnaire items were intended to probe teachers' (a) content knowledge and knowledge of teaching strategies and curriculum, (b) ability to identify their pupils' scientific conceptions about the physics topic and perceived ability to utilize this understanding during instruction, and (c) perceived concerns and difficulties when teaching the physics topic. Answers were classified into groups, and the frequencies of answers per category were recorded.

The results revealed that the student teachers had low content knowledge and low motivation for teaching science. They reported concern about their own lack of knowledge in physics. This, in turn, prevented them from “seeing which aspects of physics are connected; thus they suggest teaching many small details instead of looking at coherent connections that would lead pupils towards deeper conceptual understanding and scientific principles and laws” (p. 215). In addition, the participants’ low content knowledge in physics seemed to “prevent the student teachers from concentrating on pupils’ thinking and process skills. They seemed to be unaware of the variation in pupils’ presuppositions and beliefs” (p. 215).

The results further indicated that student teachers have negative attitudes toward teaching science. The researchers attribute this to participants’ lack of content understanding and also to negative experiences in science from their own schooling experiences.

Low content knowledge, therefore, along with unfavorable attitudes toward teaching science, negatively affected the students’ perceived ability to teach a concept in physical science. The researchers concluded that low content knowledge may prevent teachers from teaching through inquiry and creating the learning environments that reformers envision in science classrooms.

Summary

Adequate science content knowledge is necessary for elementary teachers to feel confident and to skillfully teach science through inquiry. Professional development, discussed next, has been shown to advance shifts in teachers' beliefs, content knowledge, and practice that can lead to the kinds of teaching practices advocated in the reform documents.

Change and Professional Development

The literature on the amounts, types, and processes of change for inservice science teachers during professional development is extensive (Akerson & Hanuscin, 2007; Bell & Gilbert, 1994; Gess-Newsome, 2001; Loucks-Horsley et al., 2003; Richardson, 1994; Wee et al., 2007; Yerrick et al., 1997). Well-designed professional development has been shown to promote teacher change in content knowledge, reform-based beliefs, and reform-based practice (Akerson & Hanuscin, 2007; Bell & Gilbert, 1994; Duschl et al., 2007; Loucks-Horsley et al., 2003). This research reveals the complexity and difficulty of inducing, understanding, and maintaining these changes. Studies have demonstrated, for example, that teachers who did not have high-quality opportunities to understand and experience inquiry may try elements of inquiry but will typically resort to their preexisting beliefs about student science learning and to traditional practices (Gess-Newsome, 2003; NRC, 1996; Thompson & Zeuli, 1999). The next section discusses the means through which reform-based professional development in science can create the conditions for teachers to enhance their content knowledge, to shift their beliefs, and to alter their science teaching practice.

Teacher Content Knowledge and Belief Change Through Professional Development

Researchers of teacher change explain that content knowledge change can be straightforward and can occur relatively easily through experiences such as content-oriented professional development programs (Gess-Newsome, 2003). Many teachers attend professional development programs with the goal of updating their content knowledge (Bell & Gilbert, 1996).

By comparison, changes in beliefs are much more difficult to promote. Belief change through professional development has been the focus of recent research in professional development. Beliefs, by their nature, are conservative and resistant to change, even when all evidence points toward the benefits or even necessity of change (Loucks-Horsley et al., 2003; Pajares, 1992; Thompson & Zeuli, 1999). Gess-Newsome (2003) and Pajares (1992) identified several characteristics of beliefs that determine their level of resistance to change. These include:

1. *The age of a belief* (Gess-Newsome, 2003; Pajares, 1992). The older a belief, the more embedded it is.
2. *Connectedness to other beliefs* (Gess-Newsome, 2003; Pajares, 1992). The more connected a belief is to other beliefs, the more it is resistant to change.
3. *Value for an individual* (Pajares, 1992). The more a belief aids in determining action, logical or not, the more it is resistant to change.
4. *Connection to self-identity* (Pajares, 1992). Once beliefs are formed, people tend to develop causal explanations for them and stick to them, regardless of whether they are real or invented explanations.

Beliefs about science teaching and learning through inquiry, and beliefs about the benefits of reform, are deeply resistant to change (Gess-Newsome, 2003). People, especially teachers, have deep-seated ideas about teaching and learning, largely based on personal experiences growing up in the school system (Thompson & Zeuli, 1999). The investigative, student-directed nature of inquiry "contradicts some of our most deep-seated beliefs about teaching and learning…it runs counter to conceptions of knowledge as facts, teaching as telling, and learning as memorizing. Telling is the dominant mode of teaching most of us experienced growing up" (Thompson & Zeuli, 1999, p. 349). This creates a basis for understanding the resistance to change in beliefs toward science reform.

Effective Elements of Professional Development

Without being in a situation where they are challenged, beliefs will "endure, unaltered" (Pajares, 1992, p. 316). The literature indicates that for belief change to occur, professional development programs must create an environment for teachers to make explicit their implicit belief systems about teaching and learning, and to question their own sometimes contradictory beliefs about teaching (Calderhead, 1996; Gess-Newsome, 2003). Challenging teachers' beliefs can include creating the conditions for teachers to examine incongruities in their beliefs about how students think about and learn science, and about whether their teaching is creating the conditions for students to think and learn (Thompson & Zeuli, 1999).

The key to successful change through professional development is to provide teachers with the means to alter their beliefs about teaching and learning *and* to be given the means with which to enact these altered beliefs in the classroom (Richardson, 1994).

"Genuine changes will come about when teachers think very differently about what is going on in their classrooms, and are provided with the practices to match their different ways of thinking" (Richardson, 1994, p. 102).

Some consensus has been reached as to which components of high quality professional development are effective in fostering change in teachers' knowledge, beliefs, and practice. Duschl et al. (2007) described professional development that is specific to K-8 teachers as:

1. Rooted in the subject matter that teachers teach
2. Focused on student learning
3. Rooted in the activities of teachers' work
4. Designed to take place over an extended time
5. Actively supported by administration (p. 313).

Other elements of high quality professional development include:

1. Focusing on examining teachers' knowledge and beliefs (Gess-Newsome, 2001; Richardson & Placier, 2001; Thompson & Zeuli, 1999; van Driel et al., 2001).
2. Providing opportunities for collaboration with others, provided it is structured to be productive (Gess-Newsome, 2001; Guskey, 2003).
3. Providing sustained, long-term support (Akerson & Hanuscin, 2007; Gess-Newsome, 2001).
4. Considering teachers to be learners rather than recipients of information (Bell & Gilbert, 1994; NRC, 1996).
5. Being designed for individual types of learners (Bell & Gilbert, 1994; Gess-Newsome, 2001).

6. Helping teachers learn science content in the way they will be teaching it, such as through modeling appropriate inquiry (Gess-Newsome, 2001; Loucks-Horsley et al., 2003; NRC, 1996).

Teacher Change in Practice Through Professional Development

The research on the effect of professional development programs on teacher change in practice and beliefs shows mixed results. Several studies demonstrate the challenges and the successes of inquiry-based professional development programs on shifting teacher practice. Akerson and Hanuscin (2006) examined teacher change in elementary teachers who participated in a 3-year professional development program designed to improve their beliefs, understanding, and implementation of the Nature of Science (NOS) through inquiry. NOS is another fundamental goal for scientific understanding discussed in the reform documents (NRC, 1996). Using inquiry instruction to teach NOS "can provide a vehicle for teachers to learn about NOS because these mimic as closely as possible how scientists go about their work" (Akerson & Hanuscin, 2006, p. 655).

The professional development program was designed to utilize high quality practices that would lead to sustained teacher change. Half-day monthly sessions for 3 years engaged teachers in the same inquiry and NOS experiences that they would enact with their own students. The activities were not science content specific; rather they focused on modeling, experiencing, and discussing NOS concepts through inquiry instruction. The sessions also included lesson adaptations toward inquiry and NOS, time for collaboration and idea sharing, reflection on new ideas, and group feedback on instruction.

Extensive classroom support was also provided throughout the program, which included bimonthly on-site classroom visits by the project staff as teachers implemented new strategies from the workshops. These visits allowed project staff to provide feedback, discuss teachers' ideas, and teach model lessons. One of the advantages cited by the researchers of the individualized support was the professional developers' ability to tailor the professional development to each teacher's changing needs. The total monthly workshop time was 84 hours and the total individualized support in teachers' classrooms amounted to approximately 42 hours.

Three elementary teachers from one school were purposefully selected, based on their agreement to participate in the full, multiple-year research activities. Data sources included teacher interviews and open-ended questionnaires that measured changes in teachers' views and conceptions about NOS. These were administered at the beginning of the program and at the end of each year. Transcripts and field notes from professional development activities and classroom instruction "provided insight into teachers' developing ideas about the nature of science and inquiry" (p. 662). Videotapes of teachers' instruction in their classrooms revealed how their practice changed over time. Teachers also viewed the videotapes with the researcher and were asked questions about their decision-making processes and conceptions. Teachers' lesson plans and written descriptions of their changes in instruction in NOS and inquiry throughout the span of the program gave researchers further insight into teachers' own conceptions of their changes.

The data collection and analysis was ongoing, triangulated through multiple data sources from both researcher and teacher perspectives, and used to inform subsequent professional development sessions. Case study profiles were developed to capture changes in practice for each participant.

The findings indicated that all participants improved in their views and classroom implementation of NOS through inquiry to different degrees over the 3 years. Initially teachers held “inadequate views of most target elements of NOS” (p. 675) and did not incorporate NOS into their instruction. However, by the end of the program, all teachers had revised their NOS conceptions, and all were addressing NOS elements and using lessons from the workshops in their science teaching without prompting. Further, the findings revealed that the teachers “readily internalized the importance of inquiry as an instructional objective” while teaching NOS (p. 675).

The authors attributed the long-term nature of the program along with extensive opportunities for individualized classroom support for these positive findings. They concluded, “This program allowed teachers to develop ideas over time, and then change their practice over time, later enabling them to track the influence of their instruction on their students’ knowledge” (p. 674). The teachers did not revert to their original practices over the 3 years of the study because they were supported individually in sustaining the change.

In another study, Banilower et al. (2007) used survey data from 7 years of a national science reform initiative to investigate teacher change through professional development. The research examined the relationship between teachers’ participation in professional development and changes in their beliefs and practice, among other factors.

The national reform initiative, the Local Systemic Change (LSC) through Teacher Enhancement, is the same teacher professional development program described in

Supovitz and Turner (2000). The strength of the Banilower et al. (2007) study is the longitudinal nature of the data, as opposed to the cross-sectional design in a single year as used by Supovitz and Turner (2000). The LSC initiative used reform-based elements in professional development programs that prepared teachers to implement high quality, reform-based mathematics and science instruction in their classes. The programs were substantial in length (130 hours), situated in classroom practice, and focused on the science content teachers use in their classroom.

The national data set came from self-reported, Likert-scale surveys completed by 18,657 science teachers in grades K-12 across 42 LSC projects. The survey asked teachers to report their attitudes toward *NSES*-based teaching; perceptions of pedagogical preparedness; perceptions of science content preparedness; use of traditional teaching practices; use of investigative teaching practices; frequency of use of the instructional materials designated by the LSC project; and amount of time devoted to science instruction. The data were analyzed through two methods. First, the researchers created a series of multilevel regression models that were analyzed using hierarchical linear modeling (HLM). Second, the researchers estimated a structural equation model (SEM). These two techniques complemented one another as SEM could not account for the nesting of teachers within projects, and HLM could not examine the relationships among the outcome variables.

The study results revealed that participation in the LSC professional development was positively related to changes over time in all outcome variables measured except the use of traditional teaching practices. These results include positive increases in reform-based teaching practices, in teachers' attitudes toward science instruction, in perceptions of science content preparedness, and in the use of reform-based instructional materials. Further, teacher attitudes (or beliefs) about reform-based instruction along with teachers' perceptions of preparedness were found to be important predictors of whether teachers used reform-based classroom instruction (including arranging seats to promote student discussion, requiring evidence-based student responses) in their science lessons.

While these studies revealed that reform-based professional development can facilitate fundamental teacher change in practice, other studies demonstrate the difficulty of promoting sustained change. Even when many of the characteristics of effective professional development are incorporated into a program, change often does not occur in fundamental ways. This demonstrates the resistant nature of beliefs, and, therefore, the difficulty of changing practice.

For example, Wee et al. (2007) reported on the effects of a professional development institute on elementary and secondary science teachers' change in their understanding of inquiry and inquiry classroom instruction. The 4-week summer institute incorporated many of the high-quality elements of professional development, including an emphasis on science content and the development of teachers' understanding of inquiry teaching and student learning through inquiry. Teachers participated in field studies, worked in scientific laboratories, and conducted environmental science research, all of which emphasized inquiry teaching and the engagement of teachers in inquiry activities. Other features included teacher evaluation of curricular and instructional materials and discussions about the *NSES*. The program also included 1 to 2 days of instructional support by program staff in teachers' classrooms during the following school year, and a spring workshop. Four teachers were purposefully selected to participate in the study.

A qualitative design, with an inductive approach that allowed "patterns to emerge from the 'realities' of inquiry teaching in the science classroom" (p. 67) was used. The researchers purposefully selected 4 teacher participants in order to represent a range of teacher characteristics.

Data sources were two lesson plans the participants had developed, in order to determine teachers' inquiry design abilities. Participants completed these at the beginning of the institute and 1 year later. An open-ended interview during the school-year site visit probed teachers about their goals related to inquiry, their understandings about inquiry, and their inquiry teaching practices. Field notes were also collected during the site visit. Teachers completed concept maps that were intended to demonstrate individual understanding of inquiry, which were collected at the end of the summer institute and during the spring workshop. Finally, open-response assessments, administered before the institute and 1 year later, were used to evaluate teachers' understanding of inquiry "within the context of classroom pedagogy" (p. 72). Case profiles were developed for each participant, and triangulation was achieved through the use of multiple data sources and analysis by multiple researchers.

The results indicated that the 4 teachers did not change in their individual understanding of inquiry over the course of the program. They did not distinguish between doing science activities, which are interactive, hands-on opportunities for students, and "doing science," which emulates the thinking processes that scientists use when doing science. While the findings revealed that teachers changed in their understanding of how to design inquiry activities, they did not implement these types of activities in the classroom.

The researchers concluded that professional development programs should provide greater, and longer-term support for teachers in their school contexts. They suggested that this type of support might have facilitated the movement from teachers' demonstrated understandings of inquiry design into inquiry implementation.

In another study, Yerrick et al. (1997) examined the effects of a 2-week summer institute on changes in middle-school teachers' inquiry beliefs and presumed practices. Specifically, the researchers examined how teachers' belief systems affected the way they interpreted the reform-based views of science teaching and learning. Teachers were encouraged to reflect on the curriculum and teaching within their own classroom teaching experiences and to compare this instruction to the reform science initiatives. Teachers also worked on realigning their science lessons to include elements of inquiry.

Participants were eight randomly selected teacher volunteers from the summer institute. All data were qualitative and consisted of pre- and postinstitute structured interviews that were intended to assess changes in participants' future teaching decisions and implicit beliefs about teaching and inquiry. Other data included video clips of small group work during the institute to understand teachers' use of the concepts and strategies they were exposed to during the professional development. Teachers' institute journals were also collected to understand their interpretations of institute activities and potential application in their classrooms.

The findings showed that teachers entered the institute with traditional views in their treatment of concepts and in their pedagogical and assessment decisions. While teachers shifted in their *talk* about teaching, content, and assessment toward the end of the institute, the data indicated that these shifts did not reflect a change in their belief systems. Instead, teachers fit these new conceptions into their existing sets of beliefs about inquiry teaching and learning, which were of skepticism about the benefits of inquiry. The participants ultimately held firm and unyielding beliefs that their traditional views of teaching and learning in science would result in the desired student learning outcomes.

The researchers concluded that future work must focus on understanding conflicting beliefs systems in teachers. Otherwise, science education reformers may proceed in their efforts with false impressions of compliance with the reforms.

Summary

Central to the reform efforts is teacher participation in high quality professional development as described in the professional development literature. Research has shown that some professional development programs result in more fundamental practice and belief change than other programs. Programs that have the greatest success provide teachers with research-based learning opportunities and the structure for belief and practice change. The literature, then, has shown that teacher change in inquiry-based practice, inquiry-based beliefs, and content knowledge can occur through professional development, though it is a complex and difficult endeavor.

Classroom and School Context

Classroom and school context play an important role in determining whether teacher change during a professional development experience is manifested in teacher practice. Research shows that even if some fundamental belief change toward inquiry has occurred, change in practice does not always follow. In a review of research on teacher beliefs and practices, Fang (1996) explains that a common contradiction in the literature exists regarding the relationship between practice and beliefs. While some research shows consistency between teacher beliefs and practice, other research shows inconsistencies between them.

van Driel et al. (2000), in a review of literature on science teacher change through professional development, reported problems in all studies with inconsistencies between teachers' spoken beliefs and classroom practices. Fang (1996) explained that the inconsistencies "suggest that contextual factors can have powerful influences on teachers' beliefs, and in effect, affect their classroom practice" (p. 53). In other words, inconsistencies between beliefs and practice may often be attributed to contextual factors in the teachers' schools.

Elementary schools and classrooms can create conflicts for teachers that may result in these inconsistencies. Researchers describe the typical school culture encountered by many elementary teachers. Teachers are often judged by their students' test scores rather than by how well they are meeting their students' individual learning needs. "Many teachers want student learning to be based on individual needs, yet their schools expect them to improve standardized test scores, cover prescribed curricula at a set pace, and maintain an orderly classroom" (Feiman-Nemser & Floden, 1986, p. 517). This can result in conflicting goals and standards between what teachers want and what is expected of them.

School contexts can also create obstacles to inquiry implementation. In a study of elementary and secondary teachers, for example, Bell and Gilbert (1996) described the difficulties teachers participating in a long-term professional development program had in implementing inquiry. These included fear of losing control in the classroom, covering all of the curriculum, meeting assessment requirements, and evaluation by administrators.

Feiman-Nemser and Floden (1986), in a review of teacher culture, describe elementary school classrooms as busy places where teachers constantly manage group and individual needs, promote learning, establish routines and assess students, among other responsibilities. Many elementary teachers, in order to keep up with the "immediacy and complexity" of the classroom, resist proposals for change in practice or curriculum (p. 517).

Several studies have investigated the contextual factors that can affect the implementation of reform practices. Appleton and Kindt (1999) investigated the impacts of elementary school contexts on the science teaching practices of novice teachers. The researchers examined the school, system, and geographical locations that advanced or hindered beginning teachers in teaching science and influenced their instructional choices in science teaching.

The 9 study participants were selected from the academic top 30% of their preservice program graduating class. It was assumed that these teachers would have higher self-confidence levels in teaching science, especially using reform-based practices. Participants' teaching assignments ranged from preschool to grade 6.

Researchers used qualitative methods to capture teachers' perceptions of their science teaching and the influences of their school contexts. The researchers visited participants in their schools once during the year following graduation. The visits spanned much of the day during which researchers conducted semistructured interviews with the teachers and collected field notes from classroom observations of science lessons and other subject lessons. Member checking and data triangulation provided a means of validating the data. Discourse analysis was used to derive meaning from the data and themes were identified and fit into broad categories.

The findings revealed that both personal and contextual factors influenced teachers' science instruction. Higher confidence levels were related to greater use of reform-based practices. Collegial support was related to teachers' willingness to try non-traditional instructional methods, and to fostering self-reflection. Collegial support and self-confidence in teaching science were also related to time spent teaching science.

The teachers' school contexts prioritized English and mathematics over science, which negatively impacted the participants' science teaching. Science lesson allocation was just 1 to 1.5 hours per week in most of the schools. This perception of low priority influenced the participants to relegate science to the end of the day.

Finally, there was a lack of resources for science and lack of organization of resources at the schools. This resulted in teachers' not covering some scientific topics. Further, this often determined the instructional practices they used to teach certain topics within science. The findings, then, showed that unless teachers had high levels of self-confidence or had support from colleagues, they were unwilling to take the extra time to prepare reform-based materials for science.

The researchers concluded that, except for occasional collegial support, there "appeared to be no systematic support in the schools or school systems for the teachers to teach science, except that which occurred fortuitously, or arose from the teachers own beliefs or high level of self-confidence" (Appleton & Kindt, 1999, p.166) These findings demonstrate the powerful hindrances school context factors have on science teaching practices. Unless the teachers had high levels of self-confidence or supportive colleagues, they were unable to overcome the school barriers that devalued science and the use of reform-based practices in science.

In another study, Steele (2001) examined the personal and contextual factors that facilitated or hindered elementary teachers' reform-based mathematics teaching after graduation from their preservice education programs. The four teachers who participated in the study were chosen because during the final 2 years of their preservice programs they had demonstrated a shift in their conceptions about teaching mathematics toward ones that were more cognitive-based and focused on problem-solving, which are considered reform-based. The study investigated whether these shifts were sustained over the teachers' first 2 years of teaching.

Case studies were developed for each participant. Case studies were used because they provided the researcher with "the richness and detail that was needed for [the researcher] to understand the process in which the teachers engaged as they implemented practices in or out of harmony with their conceptions" (p. 142). Data collection consisted of six interviews with the teachers during the 2-year study period along with field notes and reflections from 2 days of classroom observations. Additional sources of data included informal interviews with principals and other teachers at the participants' schools, field notes of teachers' interactions with students and other teachers, and artifacts such as lessons plans and assessments from participants' 2 years of teaching. The data were organized, classified, and consolidated during data analysis.

The findings revealed that some teachers sustained the reform conceptions and implemented them to varying levels, while others reverted to traditional conceptions and practices. These results were influenced by both personal and school contextual factors.

One personal factor was *personal commitment and professional strength*, which the researcher defined as commitment to teaching in ways beyond the traditional approaches and having the confidence to do so. Another personal factor was *views of the flexibility of curriculum, planning, and assessment*, in which teachers' planning and assessment were influenced by how they viewed the flexibility of the curriculum. The teachers who maintained a more reform-based approach used the textbook primarily as a guide for scope and sequence, and expressed their intent to be curriculum decision makers. Those who reverted to more traditional practices tended to follow the textbook closely in terms of content, sequence, and instruction. A third personal factor was teachers' *beliefs and knowledge about teaching and learning mathematics*, including beliefs about how students learn mathematics and teachers' levels of subject knowledge. Teachers who maintained their reform-based beliefs and who had adequate subject knowledge used more reform practices in their teaching.

The contextual factor that influenced teachers' conceptions and practice was *support from community and school administration*. This included constraints or support from the teachers' school administrators and from parents. One teacher who maintained her shift in reform-based conceptions "appeared to have complied with the constraints of the school administration and pressures from parents while continuing to implement her own conception of teaching" (Steele, 2001, p. 166). She did this, for example, by purchasing the mathematics manipulatives she used in her classroom with out-of-pocket funds.

Another teacher reverted to traditional conceptions about teaching and learning. The challenges this teacher faced were a mandated curriculum at her school, and colleagues who held traditional beliefs about teaching and who practiced traditional ways of teaching. The researcher explained that this teacher "had internalized and complied with the constraints of her school district" (p. 167). This study showed that both personal and contextual factors play a significant role in whether teacher change is sustained in the classroom.

In a study of middle-school teachers from two schools engaged in a 2-year, reform-based professional development program, Johnson (2007) found that support from administration was a key factor in teacher change in science teaching practice. The professional development program had a whole-school design, in which all of the teachers from both schools participated in the program. The goals of the program were to strengthen teachers' science content knowledge, provide opportunities to experience science as envisioned in the *NSES*, encourage reflection, and provide the skills for implementing reform-based strategies in their classroom.

The participants were a stratified sample of six teachers, three from each school, representing low, medium, and frequent users of reform-based teaching practices before inception of the program. A multimethod design was used in data collection and analysis, chosen to examine subtle changes in teachers' classroom instruction and beliefs, and to identify school-based factors that contributed to the changes.

Data sources were four unannounced classroom observations each year and one semistructured interview each year. Two observations were scored using a protocol that ranked teachers on degree of standards-based classroom instruction within categories such as design, implementation, and content. Field notes were also taken to document events that could not be recorded on a quantitative instrument. The interviews asked teachers to describe their decisions for classroom instruction and the factors that impacted these decisions. For example, teachers were asked about barriers to implementing standards-based practices, their perceptions of support by the administration, and their beliefs about how students learn science. The interviews and field notes were analyzed through a qualitative software program. Quantitative data from the observation protocol were analyzed statistically and categorized by teacher and protocol category, and scores were compared for change over time. Case studies were developed for each teacher.

The results indicated that teachers at both schools had increased their use of inquiry-based instruction during the 1st year of the program. Significant differences between the two schools were found in the 2nd year of the program, however. The teachers from one school showed ongoing changes toward more reform-based instruction. The second school, however, experienced a series of setbacks during the year. These setbacks included halting funding for the professional development, lack of funds for science supplies, and a push from the administration to "teach to the test" through drill and practice. The teachers' practice reflected these setbacks. By the end of the 2nd year, the teachers had mostly reverted to traditional modes of teaching science. For example, one teacher (who had shown growth in the 1st year by including weekly student investigations and science projects in his teaching) had reverted to using little student investigation, more independent work, and relying on textbooks in his lessons.

Based on the study results, the researcher concluded that reform-based professional development that is collaborative and sustained can successfully foster changes in instruction. However, the results show evidence for the "importance of support for reform efforts in science. Administrators cannot give verbal support without backing it up with resources and protection from the outside forces that can take the steam out of teacher efforts to improve instructional practices and to grow professionally" (Johnson, 2007, p. 657).

This study showed that school context, including support from administration, plays a significant role in sustaining teacher change. These findings are consistent with Banilower et al. (2007), who demonstrated that elementary and secondary teachers' perceptions of their principal's support for reform-based science instruction was a significant predictor of the teachers' efficacy beliefs in teaching reform-based science.

Summary

While teacher content knowledge and inquiry-based beliefs are pivotal to teacher change in practice, school and classroom contexts also play an important mediating role in this change. School and classroom contexts include collegial support, administrator support, and teachers' perceptions of administrator support for reform (Banilower et al., 2007; Johnson, 2007; Loucks-Horsely et al., 2003). While the research shows that classroom and school contextual factors can support or create barriers to inquiry implementation, this research is mostly limited to changes during professional development or following preservice programs. More research, therefore, is needed on the impacts of these factors once professional development has ended. This is the focus of this research study, described in Chapters 3 through 5.

Context and Change: A Call for Further Research

Much research has been conducted on how well professional development effects teacher change. This research has demonstrated the importance of (a) beliefs and knowledge to changing practice, (b) high quality professional development to achieving fundamental change, and (c) contextual factors to changes in practice during professional development. Little research, however, has investigated the sustainability in shifts of inservice teachers' knowledge, beliefs, and practice after professional development is complete. There is a dearth of information, therefore, about how the learning that takes place during professional development is translated into teachers' science teaching practice after the experience has ended, including the contextual factors that impact this process.

Webster-Wright (2009), in a comprehensive review of research on professional development, argues that future research must move away from evaluating the delivery of professional development and toward understanding teachers' continued learning within the context of teachers' classroom and school environments. In a review of the literature on teacher change, including change through professional development, Richardson and Placier (2001) found that more research is needed on how school context affects individual teacher change. Keys and Bryan (2001), too, suggest that future research on inquiry science teaching and learning focus on understanding the beliefs of teachers who are implementing inquiry-based instruction and the impact of school settings on those beliefs.

This study responded to these calls for further research on professional development. It examined trends in changes in teachers' inquiry-based practice, and inquiry-based beliefs, and content knowledge during and following professional development and the school-based contextual factors that impacted these trends in the year following the professional development.

Measuring Teacher Beliefs, Knowledge, and Practice

Researchers use both single-method (qualitative or quantitative) and multimethod approaches to investigate the impacts of professional development on teacher change toward reform. Some research relies exclusively on quantitative approaches (Banilower et al., 2007; Garet et al., 2001; Supovitz & Turner, 2000). These studies used such techniques as observational protocols and self-reported data through Likert-scale questionnaires to examine potential causal relationships or correlations between aspects of professional development and teacher change. Although there is disagreement among educational researchers about the validity of self-reported data, when subjected to rigorous testing of validity and reliability, this type of data has been shown to reflect accurate measures of teacher practices (Banilower et al, 2007; Supovitz & Turner, 2000). Less certain, however, is the accuracy of quantitative data in measuring complex constructs such as teacher beliefs and changes in beliefs, which qualitative techniques may do more effectively (Pajares, 1992).

Researchers have also used solely qualitative methods, usually to understand the impacts of professional development on teacher change in beliefs (Akerson & Hanuscin, 2006; Cronin-Jones, 1991; Steele, 2001; Wee et al., 2007; Yerrick et al., 1997). Most of these studies used multi-subject case study designs (Akerson & Hanuscin, 2006; Cronin-

Jones, 1991; Steele, 2001). Data collection techniques included open-ended interviews and surveys with teachers and administrators; field notes, videotapes, and transcripts from lesson observations and professional development activities; analysis of teachers' lesson plans; and concept mapping. Combinations of these techniques were used to triangulate the data, and the constant comparative method was often used for data analysis (Lincoln & Guba, 1985).

Other researchers of professional development and teacher change use multimethod designs to understand the impacts of professional development on teacher change (Bell & Gilbert, 1994; 1996; Blanchard, Southerland, & Granger, 2008; Johnson, 2007; Luft, 2001). These methods have included a combination of interviews, field observations, survey instruments, and observational protocols to understand causal relationships or correlations along with potential explanations for these relationships (Johnson, 2007; Luft, 2001).

This study used a multimethod design, which allowed for the examination of trends over time through the analysis of quantitative survey, test, and observational data. The design also facilitated elucidation of the meanings behind these trends through the analysis of qualitative interview and field notes. The study results provide new understandings about trends in teacher knowledge, beliefs, and practice during and following professional development, and the contextual factors that influence these teacher characteristics in the year following the professional development.

Summary

This chapter began by describing the current reform goals for science education as outlined in documents such as the *National Science Education Standards*. These documents highlight inquiry teaching and learning in the classroom. This introduction was followed by an overview of the state of elementary science education, revealing that changes are needed in classroom instruction in order to meet the goals of the reform. The importance of changes in teachers' beliefs about inquiry teaching and learning, and content knowledge was discussed next, illustrating that they are key to change in teacher's reform-based practices. Professional development as an effective means of fostering this teacher change was then described. Finally, the mediating role of classroom and school contexts on teachers' implementation of reform-based teaching practices was outlined.

CHAPTER 3

METHODOLOGY

This study investigated the patterns of change in elementary teachers' inquiry-based practice, inquiry-based beliefs, and physical science content knowledge during a yearlong professional development program and in the year following the program. This study also sought to understand the contextual supports and barriers that may have influenced these patterns in the year following the professional development program. A longitudinal, mixed model design, which integrates quantitative and qualitative data, was used in this research.

This chapter describes the general characteristics of the teacher participants and their schools along with the professional development context of the study. The research design, data collection strategies, and data collection timeline are outlined. Lastly, the procedures for data analysis and data integration are explained.

Research Questions

The following research questions guided the study:

1. What changes occur in teachers' inquiry-based practices, inquiry-based beliefs, and content knowledge during a year of professional development and a year of classroom practice?

2. What impact do school-level factors have on the changes that occur in teachers' inquiry-based practices, inquiry-based beliefs, and content knowledge during the year after a professional development program?

Participants

The participants' and school demographic data are briefly presented in this chapter. Chapter 4 will provide a more comprehensive overview of teacher and school demographics.

Teachers

In Year 1, data were collected from all 15 teachers who participated in the Physical Science Inquiry Academy (PSIA) professional development program in 2008-2009. Teachers were: 6 fourth-grade teachers, 5 fifth-grade teachers, and 4 sixth-grade teachers from three different schools within one school district.

All 15 teachers were invited to participate in Year 2 of the study, the year following the professional development. Of these, 12 teachers participated: 6 fourth-grade teachers, 2 fifth-grade teachers, and 4 sixth-grade teachers. Two of the teachers who did not participate had moved to administrative positions within their schools and 1 had left teaching to raise a family.

Participation in PSIA was voluntary. Teachers from two of the schools, Watershed and Sycamore, were encouraged by their school administrators to participate. Teachers from Rivers received no encouragement from their school administration, and were recruited by one of the school's participating teachers. District and University IRB approval was received for both years of the study.

Schools

The three schools participating in the PSIA program in 2008-2009 received Title 1 funding, and served low-income, linguistically diverse populations in one school district in the Mountain West. The schools were selected because they scored lowest in the district on the statewide standardized science achievement tests (Criterion Referenced Tests or CRTs) and were deemed by the district science specialist to be in need of intervention through professional development.

Professional Development Context: Physical Science Inquiry Academy

The Physical Science Inquiry Academy (PSIA) program provided a reform-based, yearlong professional development experience to fourth- through sixth-grade teachers from schools that scored lowest in the target district in physical science on the CRT. The 2008-2009 cohort was the first group in this 3-year program. Each year a different cohort of teachers from among six schools participated in the program. Each cohort participated in a 3-day summer Institute and eight full-day monthly Academy sessions that took place during the school week. Substitute teachers for the monthly Academy session, a teacher stipend, and university credit were provided. Funding was provided by a Mathematics and Science Partnerships (MSP) grant from the Utah State Office of Education through funding provided by the U.S. Department of Education.

The primary goals of PSIA were to provide teachers with the tools for understanding, accepting, and implementing inquiry-based science teaching and learning, and to enhance teachers' content knowledge in physical science. Teachers were engaged in inquiry lesson modeling and inquiry-based experiences that they would use in their own classrooms. Other program elements included inquiry lesson adaptations and reflecting about inquiry science. Further, teachers were provided with inquiry-based kits, activities, and materials on all physical science topics in teachers' grade-specific state science core curricula, and training in their use.

Program Staff

The PSIA core staff was comprised of a university scientist who was also an education outreach specialist, the district science specialist, a district elementary science specialist, and a program evaluator. Master teachers, curriculum and assessment specialists, and university education specialists were invited to teach topic-specific sessions throughout the program. Table 3.1 provides a profile of the PSIA core staff.

Table 3.1.

Profile of PSIA Core Staff

Position	**Degrees**	**PSIA grade level breakout sessions**
University STEM faculty and Science Education Outreach specialist (PSIA designer)	B.S, Biology Ph.D., Evolutionary Genetics Post-doctoral work in science education	4th-grade physical science core
District Science Specialist (PSIA designer)	B.S., Biology M. Ed., Instructional Design and Educational Technology	5th-grade physical science core
Elementary Science Specialist (PSIA contributor)	B.A., Education M.Ed., Education	6th-grade physical science core
Program Evaluator	B.A., Psychology M.A. Biological Anthropology	N/A

Summer Institute

The 3-day summer Institute focused on introducing teachers to inquiry through modeling, lesson adaptations, and reflection. The 5 E's of Inquiry: Engage, Explore, Explain, Elaborate, Evaluate (Biological Sciences Curriculum Study, 1997) was the primary model of inquiry used throughout the program. Teachers also experienced activities with different levels of inquiry, including confirmation, structured, guided, and open inquiry (Banchi & Bell, 2008; NRC, 2000), and used scaffolds for conducting investigations. Teachers experimented with inquiry lessons throughout the Institute and worked on adapting existing district science curricula to be more inquiry oriented. Discussions about student learning through inquiry and exploring implicit beliefs about inquiry spanned the Institute. See Table 3.2 for the summer Institute schedule.

Monthly Academy Sessions

The monthly Academy sessions took place 1 day a month during the school year. The sessions expanded on the inquiry experiences from the summer Institute and focused on grade-level physical science content knowledge enhancement.

The mornings consisted of different presentations and experiences in each session. These included teaching science to special populations (English language learners, special education, and gifted and talented), management of science centers, science notebooks, reading/literacy connections with science, and effective use of technology in science. These sessions were presented from an inquiry orientation, in which presenters modeled how to apply inquiry-based teaching and learning for that topic. Direct applications for teachers' classrooms were explicitly addressed. Further, teachers had opportunities to experience and practice each topic that was presented.

Table 3.2

Summer Institute Schedule

Time	**Day 1**	**Day 2**	**Day 3**
8:30	Breakfast, Welcome and Goals	Breakfast and Reflections	Breakfast and Reflections
9:00		Astronomy Workshop: Inquiry Modeling	Lesson Adaptation from Traditional to Inquiry–Based
9:30			
10:00	Evaluation Surveys		
10:30		Small Group Inquiry Reflection/Discussion	
11:00		Electricity and Magnetism Workshop: Inquiry Modeling	
11:30		Lunch	
12:00	Lunch		Lunch
12:30		Electricity and magnetism Workshop, continued: Inquiry Modeling	
1:00	Group norms	Small Group Inquiry Reflection/Discussion	Introduction to Inquiry-Based FOSS ® Kits and Other Inquiry-Based Materials
1:30	The Process of Inquiry: Lecture, Demonstration, and Discussion	Water and Water Cycle: Inquiry Modeling	
2:00			
2:30	Introduction to 5 E's: Lecture, Demonstration, and Discussion		
3:00		Reflection and Discussion: Identifying type of inquiry in today's activities	Continuation of Evidence and Explanation Scaffold from Day 1 (includes reflection from experience)
3:30	Teachers conduct experiment using Student Scaffold for Designing and Conducting Experiments		
3:50	Daily Evaluation/Feedback	Daily Evaluation/Feedback	Daily Evaluation/Feedback

The afternoons consisted primarily of grade-level breakout sessions where instructors modeled the use of grade-specific inquiry kits and inquiry lessons. Here, teachers experienced using the lessons, and were provided with the necessary materials and supplies for their classroom. All of the physical science state core curriculum topics for each grade level were covered during the year.

Teachers typically sat around a table during the breakout sessions. The instructor engaged the teachers in the 5 E model (BSCS, 1997) for each activity, allowing the teachers to experience what their students would experience during the activity. For example, when teaching an activity on physical and chemical change, the instructor would engage teachers' interest by asking what they believed was the difference between the two types of changes.

Next, she demonstrated a chemical change and asked teachers to discuss which type of change they believed it was, and why. Teachers would then engage in an experiment that they designed in pairs or groups to test different types of reactions, and recording their observations in science notebooks on whether the reactions were a chemical and/or physical change. The instructor periodically stopped to discuss any possible misconceptions the teachers, or their students might have, along with potential obstacles to classroom implementation of the activity. This was followed by writing as a form of self-evaluation, presentations to the group, and discussion. Table 3.3 provides an example of a monthly Academy day schedule.

School-Year Classroom Support

Participants also received classroom support from the elementary science specialist during the PSIA year in conjunction with the classroom observations conducted

Table 3.3

Monthly Academy Session Schedule, December 16, 2008

Time	Activity
8:30 – 9:00	Breakfast and reflections
9:00 – 12:00	Guest presenter: classroom management of science centers
12:00 – 12:40	Lunch
12:40 – 1:10	Participants share their experiences using foldables, presented in the November session. These include examples of student work, activities or teaching approaches used, examples of student reactions and student learning.
1:10 – 1:35	Professional Educational Video on inquiry teaching in a classroom, followed by a discussion
1:35 – 1:45	Break
1:45 – 3:45	Grade-level breakout sessions Soil and Earth – 4th grade Physical Properties – 5th grade Light – 6th grade
3:45 – 4:00	Daily evaluations

by the researcher. These visits occurred three times, at the beginning, middle, and end of the school year. The science specialist assisted the teachers with implementing inquiry-based lessons in the classroom and engaged in debriefing conversations with the teachers about the lessons immediately afterward. Other support provided by the elementary science specialist included email exchanges about challenges teachers were facing, continued conversations about the observed science lessons, and further visits to classrooms upon request.

Research Paradigm

Creswell (2003) explained that knowledge claims in quantitative studies stem from a *postpositivist* perspective (e.g., thinking in terms of cause and effect, reducing ideas to specific variables and hypotheses and questions). Knowledge claims in qualitative studies stem from a *constructivist* perspective (e.g., constructing meanings from individual experiences, with the intention of developing a theory and pattern) (Creswell, 2003). Knowledge claims in multimethod research often stem from a *pragmatic* orientation. Researchers use multimethod data in order to collect qualitative, text-based data and quantitative, numeric data simultaneously or sequentially to best understand research problems (Creswell, 2003; Johnson & Onwuegbuzie, 2004; Tashakkori & Teddlie, 1998).

Pragmatist researchers are consequence-oriented (e.g., making research choices based on intended consequences), problem-centered (e.g., having the freedom to make choices about methods, techniques, and procedures based on what best meets their needs), and pluralistic (e.g., not restricted to one epistemological or ontological stance, and conceptualizing truth to be “what works” to understand a research problem) (Creswell, 2003; Johnson & Onwuegbuzie, 2004). Pragmatist researchers contend that this paradigm is distinct from both postpositivism and constructivism, and as a result, both quantitative and qualitative research techniques can be compatible in one study (Creswell, 2003; Tashakkori & Teddlie, 1998).

Study Design

A longitudinal, mixed model approach was used in this study, following Tashakkori and Teddlie’s (1998) parallel mixed model study design. In this model, mixing occurs *within* each stage of the study over 2 years of data collection on the same participants. Both confirmatory (quantitative) and exploratory (qualitative) research questions were asked, and both qualitative and quantitative techniques were used in data collection and in data analysis. In this study, quantitative data, supported by qualitative data, were used to answer research question one. Qualitative data, supported by quantitative data, were used to answer research question two. Data integration of both methods occurred at the end of the study.

Longitudinal Design

Researchers of education advocate the use of longitudinal studies (Duschl et al., 2007; White & Arzi, 2005). White and Arzi (2005) define longitudinal designs as those that have two or more similar measures that are used to examine the same people over a period of a year or longer. These designs are effective because they allow researchers to compare people with their "earlier selves, allowing a more detailed, and probably more accurate, account of the factors that affect learning than cross-sectional studies" (White & Arzi, 2005, p. 147). Further, they are likely to capture shifts in teacher beliefs and practice, as these shifts typically take many years to occur and be measureable (Bell & Gilbert, 1996; Fennema et al., 1996; Loucks-Horsely et al., 2003).

Multimethod Design

Multimethod designs are advocated in reviews of research on the impacts of professional development on teachers (Bell & Gilbert, 1996; Pajares, 1992; van Driel et al, 2000). Multimethod approaches draw from the strengths of both quantitative and qualitative designs and reduce the weaknesses of both (Tashakkori & Teddlie, 1998). For example, the small sample sizes in qualitative data often prevent generalizability, while quantitative data typically lacks the ability to capture explanations or meanings behind the phenomena recorded. Researchers using multimethod designs may use their findings to generalize to the population *and* to obtain a detailed understanding of the meanings and the explanations behind the findings (Creswell, 2003). In Kagan's (1990) review of research methods used to examine teachers' cognitions, she explains that the most successful studies use "multi-method approaches, which appear to be superior, not simply because they allow triangulation of data but because they are more likely to capture the complex, multifaceted aspects of teaching and learning" (p. 459).

After an extensive review of multimethod studies, Greene, Caracelli, and Graham (1989) distinguished five goals for this research approach:

1. *Triangulation*, to corroborate the results from different methods.
2. *Complementarity,* to elaborate upon and clarify the results from one method by the other method.
3. *Development*, to use the results from one method to help develop or inform the other method.
4. *Initiation*, to discover paradoxes and contradictions through using different methods.
5. *Expansion*, to extend the breadth and range of research possibilities by using different methods.

A multimethod approach was chosen for this study for the purposes of triangulation, complementarity, and expansion. Triangulation of the data involved using qualitative data to corroborate conclusions reached about the patterns of teachers' inquiry beliefs and practice that were detected in the quantitative data. Data sources were semi-structured interviews field notes from lesson observations. Measuring beliefs, specifically, is difficult and requires a great deal of inference (Gess-Newsome, 2003; Pajares, 1992). Gess-Newsome (2003) explains that in order to understand the many dimensions of belief and belief change "multiple measures must be used over time and in different contexts and triangulated for validity" (p. 5). Both quantitative and qualitative data, therefore, were used to reach conclusions about changes over time in teacher beliefs.

The qualitative data were also used to elaborate and clarify the results of the quantitative data, for the purpose of complementarity. Interviews along with field notes from the classroom observations provided elaboration and clarification of teachers' results from the quantitative belief surveys and knowledge tests. These qualitative data also served to clarify and elucidate the teacher inquiry practices scores from the quantitative classroom observational protocols.

For the purpose of expansion, qualitative data provided answers to questions that are difficult and unlikely to emanate from quantitative methods alone. The interviews and field notes facilitated a wider understanding of teachers' experiences with inquiry in their classroom and school environment.

Data Collection

Quantitative data, supported by qualitative data, were used to answer research question one, which examined patterns in three teacher characteristics (inquiry-based practice, inquiry-based beliefs, and content knowledge) over the PSIA year and the following year. Qualitative data, supported by quantitative data, were used to answer research question two, which examined the impacts of contextual factors on the maintenance or continuing development of teachers' changes in Year 2.

Quantitative data sources were scores from a classroom observation protocol, a belief survey, and a content knowledge test. Primary qualitative data sources were semi-structured interviews, and secondary data were field notes from classroom observations.

Data analysis for research question one involved testing for trends in the three teacher characteristics for all teachers combined over the 2 years using statistical methods. The results for teacher beliefs and practices were corroborated by qualitative data and reported numerically and through written descriptions. Data analysis for research question two involved the development of case studies that summarized quantitative and qualitative data for each teacher over time. Cross-case analyses were conducted by grouping similar cases together, and resulting themes were developed.

Instruments that had construct validity and acceptable reliability coefficients were chosen to obtain the quantitative data. Similarly, to confirm the trustworthiness and credibility of the findings produced from the qualitative data, prolonged engagement with the teachers, member checking, and triangulation of data sources were used (Creswell, 2003; Guba & Lincoln, 1989). (See Appendix A Letter to Teacher Participants for Member Checking, Appendix B for Letter to Principal Participants for Member Checking, and Appendix C for Summary of Findings for Member Checking.)

Quantitative Data

Trends over the 2 years in teachers' classroom practice, inquiry beliefs, and physical science content knowledge were measured through quantitative instruments. The *Reform Teaching Observational Protocol* (RTOP) (Sawada et al., 2002) measured teachers' inquiry practice. The *Beliefs about Reformed Science Teaching and Learning* (BARSTL) survey (Sampson & Benton, unpublished) measured teacher beliefs about inquiry. The *Misconceptions–Oriented Standards-Based Assessment Resources for Teachers* (MOSART) tests (Science Education Department of the Harvard-Smithsonian Center for Astrophysics, 2006) measured teachers' physical science content knowledge.

Reform Teaching Observational Protocol

The *Reform Teaching Observational Protocol* (RTOP) was selected to measure teachers' classroom inquiry-based instruction. This instrument was chosen because of its (a) grounding in science reform-based principles, (b) focus on inquiry teaching and learning in every scale, (c) alignment with the PSIA program goals, (d) reputation in the science education community as a high-quality tool for assessment of inquiry practices, and (e) recommended use as an evaluation instrument by the U.S. Department of Education for Mathematics and Science Partnerships programs.

The 25 classroom observation items are scored on a Likert scale from 0 (never occurred) to 4 (very descriptive of the classroom). The RTOP contains three scales: Lesson Design and Implementation (5 items), Content (subscales: Propositional Knowledge and Procedural Knowledge, 10 items), and Classroom Culture (subscales: Communicative Interactions and Student/Teacher Relationships, 10 items). The range of possible scores is 0 to 100. Results were reported by total test (see Appendix D for RTOP scales with scoring rubric).

Norm scores for the RTOP during its development and testing in 14 middle school classrooms were 50 points out of a total possible 100 points with a standard deviation of 14.1. Norm scores for 25 high schools were 41.8 with a standard deviation of 20.

The RTOP instrument was shown to be valid and reliable by the instrument developers for secondary and postsecondary science classrooms (though this was not measured for elementary classrooms). Cronbach's alpha reliability score for the entire instrument was 0.97. Individual RTOP scales and subscale reliability scores are Lesson Design and Implementation (0.91), Content (Propositional Knowledge, 0.80, Procedural Knowledge 0.93), Classroom Culture (Communicative interactions, 0.91, Student/Teacher Relationships, 0.91). Test reliability was reanalyzed for the study population for internal consistency using Cronbach's alpha.

Although researchers typically use this instrument in secondary and post-secondary classrooms, it has also been used in elementary classrooms (e.g., Martin & Hand, 2009). However, because it has been used infrequently in the elementary setting, developing scoring criteria for elementary classrooms was deemed necessary by the researcher. To do this, the researcher trained the PSIA elementary science specialist to use the instrument through the use of videotapes of the first four teacher observations from the year 1 Fall observation. Then discussions about each item led to commonly agreed-upon scoring criteria that are appropriate for this elementary school setting (see Appendix E for RTOP categories with guiding criteria for elementary school settings).

A modification of the traditional technique for interrater reliability was used for scoring each observation. Instead of scoring each observation separately and then cross-checking, the researcher and elementary science specialist attended over 95% of the classroom observations together, and discussed and reached agreement for each item.

Beliefs About Reformed Science Teaching and Learning

The *Beliefs About Reformed Science Teaching and Learning* (BARSTL) survey was chosen to measure teacher beliefs about inquiry. After an analysis of the available quantitative instruments that measure beliefs, this instrument was chosen for its (a) focus on beliefs specifically about inquiry teaching and learning, (b) science reform-based orientation, (c) grounding in a theoretical framework on teacher beliefs and practical knowledge, (d) alignment with the PSIA program goals, and (e) strong construct and content validity. Other quantitative instruments that were considered, such as the *Science Teaching Efficacy Belief Instrument* (STEBI-B) (Riggs & Knochs, 1990), focus on teachers' efficacy beliefs instead of inquiry beliefs.

Instrument developer-reported reliability measures for the BARSTL indicated that the Spearman-Brown correlation was 0.80 and coefficient alpha was 0.77. While it is preferred that instruments have higher reliability, the BARSTL was deemed the best choice because of its inquiry focus, theoretical base, alignment with PSIA, and validity claims. Reliability scores for individual scales are unavailable. The reported mean for the norm sample of 146 preservice teachers during the development of the instrument was 94.4 points out of a possible 128 points with a standard deviation of 7.3. The instrument can be used for both inservice and preservice teachers (see Appendix F for the BARSTL instrument).

The BARSTL instrument has 32 items with four scales of eight items each: How People Learn about Science, Lesson Design and Implementation, Teachers and the Learning Environment, and The Science Curriculum. Each item is scored on a Likert scale, from 1 (strongly disagree) to 4 (strongly agree). The range of possible total scores is 32 to 128.

The Science Curriculum scale was removed in the analysis of this instrument because this scale focuses primarily on nature of science rather than on inquiry. The combined scores for the other three scales, How People Learn about Science, Lesson Design and Implementation, and Teachers and The Learning Environment were reported. Therefore, the range of possible scores were 24 to 96.

New reliability estimates were established and reported for the study populations. Reliability scores for internal consistency for the three subscales were reanalyzed for the study population using Cronbach's alpha.

Misconceptions–Oriented Standards-Based Assessment Resources for Teachers

The *Misconceptions–Oriented Standards-Based Assessment Resources for Teachers* (MOSART) tests were chosen to measure teachers' physical science content knowledge. Each test item is multiple-choice, with five choices per item. These tests were selected because they provided items that aligned with the physical science content covered in the PSIA program. *National Assessment of Educational Progress* (NAEP) and *OECD Programme for International Student Assessment* (PISA) items were also considered. However the released items did not adequately cover the topics presented in the PSIA program.

The MOSART tests were analyzed for content (all items were reviewed by at least five faculty in that field) and readability (all items were reviewed by readability experts) for each content standard. The tests were field tested and are recommended by the U.S. Department of Education for use with Mathematics and Science Partnership programs, such as this one. The reliability evidence consists of Cronbach's alpha and the Rasch model, both of which were within the acceptable range of 0.45 to 0.70. Individual test reliability measures are unavailable because the "public test" is composed of items from a variety of forms given to field test samples and were not given as a single test to a single group of people.

The MOSART tests were developed to align with the *National Science Education Standards* K-12 content standards. The core curriculum of the study state, however, does not map neatly onto the *NSES*. Therefore, items that matched the state's core curriculum and, when possible, from content taught in PSIA, were drawn from the different MOSART tests and compiled into one test for each grade level. Reliability measures were conducted for each test for the study population using Cronbach's alpha.

Test items were drawn from the following tests: (a) grades K-4 and 5-8 physical science tests and grades 5-8 earth science tests for fourth- and fifth-grade teachers, and (b) grades K-4 and 5-8 physical science and grades 5-8 astronomy tests for sixth-grade teachers. The compiled tests used in this study have 16 items in the fourth-grade test, 15 items in the fifth-grade test, and 21 items in the sixth-grade test.

Items chosen for the fourth-grade test reflect an even distribution of three of the five Standards in the fourth-grade physical science state core curriculum (water cycles, weather, and rocks and soil). The other Standards (fossils and Utah environments) were covered during PSIA but not in the MOSART test because appropriate items that matched the state core were not available. For example, the Standard on Utah environments is state-specific and therefore MOSART items were not available to test it.

Items chosen for the fifth-grade test reflect each of the four physical science Standards in the fifth-grade state core curriculum (chemical and physical change, geology, magnets, and electricity). All of these were covered during PSIA. The Standard on magnets is represented by only one item, however, whereas the other Standards have a fairly even distribution of items. Items chosen for the sixth-grade test reflect all five of the physical science state core curriculum Standards (moon phases, seasons, objects in the solar system, size and scale of objects in the solar system, and heat, light, and sound). All of these Standards were covered during PSIA. The Standard on seasons is represented by only one item, however, whereas the other Standards had a fairly even distribution of items (see Appendix G for the compiled MOSART test for each grade level).

Qualitative Data

Teachers' beliefs and understandings about inquiry, teachers' classroom practice, and the impacts of school contextual factors on the patterns of change in the three teacher measures (inquiry practices, inquiry beliefs, and content knowledge) in Year 2 were measured through qualitative data. Primary data sources were two rounds of teacher interviews, one in Year 1 and one in Year 2, and one round of principal interviews in Year 2. Case studies were developed for each teacher based on semistructured interviews, field observations, and summaries of quantitative data. These case studies allowed for the examination of teachers' contexts and inquiry-related experiences in Year 2 within and across teachers.

Primary Data Sources

Teacher Beliefs Interview. An adapted interview protocol about teachers' inquiry beliefs, the *Teacher Beliefs Interview* (Luft & Roehrig, 2005), was used for the Year 1 interview. Interview questions from the original protocol focus on teachers' beliefs about science teaching and student science learning. The questions included:

1. How do you describe your role as a science teacher?

2. How do you know when your students understand a scientific concept?

3. How do your students learn science best?

Questions added by the researcher included reasons for PSIA participation (such as administrator encouragement), school science environment, and experiences implementing inquiry ideas gathered from the PSIA summer Institute and the school-year Academy sessions. The interviews lasted 20-30 minutes and were audiotaped and transcribed (see Appendix H for the *Teacher Beliefs Interview*).

Teacher beliefs, practices, and influence of context interview. A semistructured interview protocol was used for the Year 2 interview to provide understandings about the contextual factors that may facilitate or hinder the impacts of the PSIA program on teachers' inquiry beliefs and practices. Questions were the same as those used in Year 1 from the *Teacher Beliefs Interview* (Luft & Roehrig, 2005), in order to provide continuity in the data for teachers' beliefs about science teaching and learning across the 2 years of the study.

Added questions queried teachers about their beliefs about the capabilities of their students to learn science (student demographic beliefs) (Duschl et al., 2007). Questions were constructed from the literature on school culture and science education reform (Banilower et al., 2007; Feiman-Nemser & Floden, 1986). These items provided evidence for factors in teachers' classrooms and schools that impacted their inquiry beliefs and practices. Questions also included perceptions of support for reform by school administration (Banilower et al., 2007; Feiman-Nemser & Floden, 1986) and perceptions of the prioritization of science instruction by their school administration (Appleton & Kindt, 1999; Rice, 2005).

A study on the personal and contextual factors influencing the implementation of reform practices in novice mathematics teachers also informed the development of interview questions (Steele, 2001). Interview questions adapted from this study included: How do students learn science? How have you been able to implement the types of classroom activities and tasks you believe most help students learn science? (Steele, 2001). The interviews lasted approximately 30 minutes, and were audiotaped and transcribed (see Appendix I for *Teacher Beliefs, Practices, and Influence of Context Interview*).

Principal interview. A semistructured interview was conducted with the principal from each participating school. An interview protocol was constructed from the literature on school culture (Feiman-Nemser & Floden, 1986), professional development, and organizational change (Loucks-Horsley et al., 2003; Richardson & Placier, 2001). The questions included principals' support for science as a subject, for the science reform efforts, and for the goals of the PSIA professional development program (Feiman-Nemser & Floden, 1986; Loucks-Horsley et al., 2003). Interview questions also included principals' perceived barriers and supports to teachers' inquiry implementation, including student demographics and other school-based factors (Duschl et al., 2007). Interviews were audiotaped and transcribed, and lasted approximately 30 minutes (see Appendix J for *Principal Interview*).

Secondary Data Sources

Field notes, in the form of scripted observations of classroom lessons, accompanied the use of the RTOP protocol during the three science lesson observations each year. This documentation process enabled the researcher to capture specific statements and actions made by teachers and students that may not have been reflected in the quantitative scoring of the instrument (Johnson, 2007). These field notes were used to inform the researcher on subtle aspects of teachers' classroom practices that would have been missed by quantitative scoring alone. These notes were not used directly to confirm or deny themes developed from the primary qualitative sources. Instead, the researcher used the notes to reflect on the teachers' science practice, and to begin forming preliminary theories and understandings about each participant and their changes over the 2 years.

Field notes were also collected on the post science lesson debriefing conversations between the elementary science specialist and teachers. These conversations occurred informally and lasted approximately 10 minutes. Approximately 50% of the lessons were followed by these conversations, due to teachers' time constraints. Similar to the observation field notes, the debriefing conversation notes were used to reflect on the teachers' science practice, and to begin forming preliminary theories and understandings about each participant and their changes over the 2 years.

They were not used directly during data analysis to confirm or deny themes developed from the primary qualitative sources.

Procedures

Classroom science lesson observations using the RTOP instrument were conducted in the Fall, Winter, and Spring of Year 1, and Fall and Winter of year 2, for five total observations during the study period. These time points were selected to provide sufficient time for shifts in teachers' practice to occur.

The BARSTL instrument was administered to the teachers three times during the study: at the beginning of the PSIA Summer Institute (Summer, Year 1), at the end of school Year 1 (Spring, Year 1), and at the end of Year 2 (Spring, Year 2). These time points were selected to provide sufficient time for shifts in teachers' beliefs to occur.

The MOSART tests were administered to the teachers three times during the study: at the beginning of the PSIA Summer Institute (Summer, Year 1), at the end of school Year 1 (Spring, Year 1), and at the end of Year 2 (Spring, Year 2). The three administrations of the test involved the same test each time, as sufficient time had probably passed to inhibit recall of the test. These time points were selected to provide sufficient time for shifts in teachers' content knowledge to occur.

Teacher interviews were conducted in the middle of Fall semester of Year 1 and in the beginning of the Spring semester of Year 2. Principal interviews were conducted in the beginning of the Spring semester of Year 2. Field notes were collected at each lesson observation (when using the RTOP instrument). Table 3.4 provides a timeline for the quantitative and qualitative data collection.

Data Analysis

Quantitative Analysis

Repeated measures ANOVAs were used for analysis across the 2 years and in order to reduce familywise error, or the probability of making a type I error in multiple pairwise tests. Post-hoc pairwise comparisons were made using *t* tests. Results from the three instruments were corroborated by nonparametric tests to account for the small sample size (*N* = 15 in Year 1 and N = 12 in Year 2). RTOP, BARSTL, and MOSART reliability coefficients were analyzed for the study population using Cronbach's alpha for internal consistency.

Table 3.4

Timeline for Administration of Study Instruments and Interviews

Instrument/ Interview	**Beginning Year 1 summer Institute**	**Beginning of school Year 1**	**Middle of school Year 1**	**End of school Year 1**	**Beginning of school Year 2**	**Middle of school Year 2**	**End of school Year 2**
BARSTL	X			X			X
RTOP & Field notes		X	X	X	X	X	X
MOSART tests	X			X			X
Interviews – teachers		X			X		X
Interviews – principals						X	

Reform Teaching Observational Protocol

Repeated-measures ANOVAs were used to analyze data collected from the RTOP, in order to determine patterns of change across the 2 years. Post-hoc pairwise comparisons, to determine where statistically significant changes occurred, were made using *t* tests. The results were reported in terms of change scores by total test.

Beliefs About Reformed Science Teaching and Learning

The BARSTL surveys were analyzed through a repeated-measures ANOVA to look for patterns of change across the 2 years of the study. Post-hoc pairwise comparisons, to determine where statistically significant changes occurred, were made using *t* tests. Results were reported by total change in the three inquiry-oriented scales combined (How People Learn about Science, Lesson Design and Implementation, and Teachers and The Learning Environment). Results from the fourth scale, Science Curriculum, were not reported.

Misconceptions–Oriented Standards-Based Assessment Resources for Teachers

The MOSART surveys were analyzed through a repeated-measures ANOVA to look for patterns of change across the 2 years of the study. Post-hoc pairwise comparisons, to determine where statistically significant changes occurred, were made using *t* tests. Results were reported by total percent change.

Qualitative Analysis

Qualitative techniques were used to analyze the interviews to develop a case study profile for each teacher. First, the constant comparative method (Glaser & Strauss, 1967;

Strauss & Corbin, 1990) was used in reading the transcripts of the teacher and principal interviews, by grouping similar responses and descriptions. The interviews were coded for evidence of teacher inquiry practice, inquiry beliefs, and inquiry understandings and reasons for the changes or lack of changes. Color coding was used to mark recurring themes across the data sources. Themes were then identified and grouped for each teacher in the development of the case study profiles (Creswell, 1998).

Data Integration

The quantitative and qualitative data integration involved four primary steps:

1. Case studies for each teacher were created that combined and summarized quantitative data and qualitative data over time. The quantitative data set was teachers' individual change scores across the 2 years. The qualitative data set was the case study profiles developed from the qualitative data. This within-case analysis was conducted by developing a summary for each teacher across these data sets (Creswell, 1998).
2. A cross-case analysis was conducted between cases (Creswell, 1998; Miles & Huberman, 1994). Cases were analyzed for similarities and differences and clustered into groups. For each cluster, a cyclical process of data analysis was conducted (Stake, 2005). Each category was refined and each case was revisited in light of new understandings during the cross-case analysis. In this continuous process, overlap between ideas and themes were assessed and themes were further refined within each cluster.
3. Trends and patterns were established in (a) teachers' inquiry practice, (b) teachers' inquiry beliefs, and (c) school-level (contextual) factors affecting

program impacts within each individual. Broader themes describing these trends and the experiences of inquiry practice and beliefs within the school contexts for each cluster were then developed (Miles & Huberman, 1994).

4. Member checks were conducted to establish further validity and trustworthiness of the data (Guba & Lincoln, 1989). The findings were mailed to the participants to assess whether the researcher's interpretation of the integrated data matched the participants' interpretations of the findings.

Reporting of Results

The integrated results were used to answer research questions one and two; however they were reported differently for each question. The results from research question one were reported numerically by whole group and elaborated upon and explained by text-based descriptions. The results from research question two were reported numerically by school and by individual, and by text-based descriptions of cases and themes and quotes supporting the proposed cases and themes (Creswell, 1998). The results were intended to provide understandings into both the effectiveness of the professional development program and the types of school contextual supports and barriers to inquiry implementation that exist in the year following professional development.

Validity and Credibility Claims

To support the validity and credibility claims in this study, the researcher used multiple data sources, a multimethod design, extended time with the teachers, and member checking (Creswell, 2003; Guba & Lincoln, 1989). Further, the researcher spent each PSIA summer Institute and school-year Academy session with the teachers, observed their science lessons three times a year for 2 years, and conducted interviews with them. These experiences provided the researcher with insights into teachers' personal and professional contexts.

Ethical Considerations

Participation in this study was voluntary. Teachers signed consent forms for participation in Year 1 and Year 2 (see Appendix K for Year 1 consent form and Appendix L for Year 2 consent form). Principals signed consent forms for participation (see Appendix M for Principal consent form). All participants and schools were assigned pseudonyms to protect their anonymity.

Summary

This chapter described the research methods used to examine (a) the patterns that resulted over the professional development program year and the following year in teachers' practices, beliefs, and content knowledge, and (b) the contextual supports and barriers that influenced these patterns in Year 2. The professional development context that is the focus of this study was provided. The longitudinal, mixed model research design used in this study was then described along with the data collection sources, strategies, and timeline. The data analysis techniques were then explained. These data provide understandings of the trends in teacher characteristics over time, along with understandings of the deeper meanings and influences behind the trends. The following chapter further describes the school and participant profiles examined in this study and presents the study findings.

CHAPTER 4

RESULTS AND DISCUSSION

This study examined whether teachers in a yearlong, reform-based professional development program experienced changes in their inquiry-based practice, inquiry-based beliefs, and physical science content knowledge. This study also investigated whether these changes were advanced, sustained, or hindered in the year following the program. Finally, school-level and individual-level factors impacting the progress of teacher change in the year following the program were examined.

Teacher Profiles and School Contexts

Teacher Profiles

The 15 teachers who participated in the Physical Science Inquiry Academy (PSIA) professional development program in 2008-2009 (Year 1) included 6 fourth-grade teachers, 5 fifth-grade, and 4 sixth-grade teachers. Their experience ranged from 1 to 30 years, with an average of 10.2 years. Most teachers held undergraduate degrees in elementary education. Six teachers had advanced degrees, including M.A. degrees in curriculum studies, elementary education, education technology, and mathematics. Two teachers held M.Ed. degrees in elementary education. None of the teachers had undergraduate or advanced degrees in science. Two teachers were White males and thirteen were White females. The 12 teachers who participated in Year 2 were 6 fourth-grade, 2 fifth-grade, and 4 sixth-grade teachers. Table 4.1 provides a complete overview of the teacher participants.

School Contexts

The three participating elementary schools, Sycamore, Rivers, and Watershed, received Title I funding, and served ethnically and linguistically diverse, low socioeconomic status (SES) communities. Sycamore had the largest student population of the three schools and the lowest percentage of minority students and English Language Learners. All schools had between 60 and 73% minority and over 42% ELL students. The schools had approximately equal percentages of students eligible for Free and Reduced lunch (around 85%). Sycamore and Watershed were year-round schools, while Rivers was on a traditional 9-month calendar. See Table 4.2 for a complete overview of the participating schools.

Participating in PSIA were 2 fourth-grade and 2 fifth-grade teachers from Rivers; 2 fourth-grade, 1 fifth-grade, and 2 sixth-grade teachers from Sycamore; and 2 fourth-grade, 2 fifth-grade, and 2 sixth-grade teachers from Watershed. Because Rivers had not made Adequate Yearly Progress (AYP) according to the No Child Left Behind Act for two consecutive years, the school had Title I: "In Improvement" status during the PSIA year and the following year. Sycamore had not made AYP in the 2006-2007 school year, but was not "In Improvement." Watershed, in contrast, had made AYP every year between 2006 and 2010. Students' standardized test scores in science were considerably lower for all three grade levels at Rivers compared to Sycamore or Watershed.

Table 4.1

Overview of Teacher Participants (2008-2009, Year 1)

Teacher	**Years Taught**	**School**	**Grade Taught**	**Degrees earned**	**College-level Science Courses Taken (number of courses)**
Danielle	6	Sycamore	4	•M.A., Curriculum & Instruction •B.A., Elementary Education	•Geology (1) •Elementary Science Methods (1)
Rachel	30	Sycamore	4	•M.A., Elementary Education •B.S., Elementary Education	•Geology (1) •Biology (1) •Astronomy (1) •Elementary Science Methods (1)
Rich	2	Sycamore	6	•B.A., Humanities/English	•Biology (1) •Chemistry (1) •Physics (1) •Health Science (1)
Clair	15	Sycamore	6	•B.S., Elementary Education (focus: Science/P.E.)	•Microbiology (2) •Chemistry (2) •Geology (2) •Physics/Astronomy (1) •Ecology (1) •Zoology (1)
Megan*	2	Sycamore	5	•.B.S., Elementary Education	•Geology (1) •Biology (1) •Elementary Science/Reading/Math Methods (1)
Michele	20	Watershed	5 and 6 (looping)	•M.Ed., Education •B.S., Elementary Education •B.S., Clothing and Textiles	•Biology (1) •Elementary Science Methods (1)
Mary	14	Watershed	6	•B.S., Elementary Education	•Physical Science (1) •Biology (1) •Elementary Science Methods (1)
Joanna	1	Watershed	4	•B.S., Elementary Education	•Science methods (1) •Elementary Science Methods (1)
Gina	21	Watershed	5	•B.A., Elementary Education	•Biology (3) •Physical Science (1) •Elementary Science Methods (1)
Jen	New	Watershed	4	•M.A., Elementary Education •B.A., Family and Human Development	•Biology (1) •Chemistry (1) •Elementary Science Methods (1)

Table 4.1 continued

Teacher	Years Taught	School	Grade Taught	Degrees earned	College-level Science Courses Taken (number of courses)
Alvin *	12	Watershed	5	•B.A., Early Childhood Development	•Astronomy (1) •Biology (1)
Tanya	8	Rivers	4	•M.A., Mathematics •B.S., Elementary Education	•Zoology (1) •Chemistry (1) •Microbiology (1) •Physics (1)
Louisa	8	Rivers	4	•M.Ed., Education (emphasis in reading) •B.S., Elementary Education	•Geology (1) •Genetics (1) •Astronomy (1) •Microbiology (1) •Physics for the •Elementary Teacher (1)
Polina *	10	Rivers	5	•M.A., Educational Technology •B.S., Elementary Education	•Geology (1) •Life science (1) •Earth Science (1) •Astronomy (1)
Julie	4	Rivers	5	•B.S., Exercise and Sports Science	•Elementary Science Methods (1)

* = Teachers who did not participate in the study in Year 2

Table 4.2

*Overview of Participating Schools (2009 Except Where Noted)**

Category	***Rivers***	***Sycamore***	***Watershed***
Number of Students (Oct, 2009)	615	780	650
Grade level of students served	Kindergarten – 6th grade	Preschool – 6th grade	Kindergarten – 6th grade
Hispanic/Latino (Oct, 2009)	55%	45%	52%
Caucasian (Oct, 2009)	31%	36%	24%
Pacific Islander (Oct, 2009)	4%	9%	3%
African American (Oct, 2009)	2%	3%	7%

Table 4.2 continued

Category	***Rivers***	***Sycamore***	***Watershed***
Asian (Oct, 2009)	6%	3%	11%
English Language Learners	52%	42%	53%
Free lunch	79.76%	73.97%	77%
Reduced lunch	7.49%	11.74%	9.22%
Regular lunch	12.75%	14.29%	13.78%
Student/Teacher ratio (district-wide)	27.3/1		
Per pupil expenditure (district-wide)	$5, 074		
Passed AYP	No (2006-07) No (2007-08) Yes (2008-09): In Improvement Yes (2009-10): In Improvement	No (2006-07) Yes (2007-08) Yes (2008-09) Yes (2009-10)	Yes (2006-07) Yes (2007-08) Yes (2008-09) Yes (2009-10)
% Proficient science in Criterion Referenced Test	2008 4th grade: 18 5th grade: 31 6th grade: 27 2009 4th grade: 19 5th grade: 44 6th grade: 31 2010 4th grade: 31 5th grade: 25	2008 4th grade: 35 5th grade: 24 6th grade: 44 2009 4th grade: 44 5th grade: 40 6th grade: 48 2010 4th grade: 40 6th grade: 38	2008 4th grade: 37 5th grade: 47 6th grade: 49 2009 4th grade: 43 5th grade: 58 6th grade: 34 2010 4th grade: 35 5th grade: 45 6th grade: 60
School calendar	Traditional 9 month	Multiple track year-round	Single track year-round
eMINTS teacher training (a long-term professional development program that integrates inquiry-based teaching and learning with technology)	One 4th grade teacher had participated in the eMINTS training.	One 4th grade teacher had participated in the eMINTS training.	* All 5th and 6th grade teachers had participated in the eMINTS training. * One 4th grade teacher was in the process of completing the training.

* = Data obtained from state, district, and schools sources

Reliability of Sample

Reliability measures were conducted on the three instruments for the population in this study. Cronbach's alpha internal consistency measures were computed for the RTOP and BARSTL instruments, which measured inquiry practice and inquiry beliefs, respectively. The RTOP Cronbach's reliability coefficients for the five data collection periods were 0.96, 0.92, 0.91, 0.94, and 0.91. These coefficients are generally considered high by education researchers and are consistent with the reliability scores reported by the instrument developers (Sawada, et al., 2002). The Cronbach's reliability coefficients for the BARSTL instrument for the three data collection periods were 0.71, 0.57, and 0.80. These coefficients are considered acceptable by education researchers and are consistent with the reliability scores reported by the instrument developers (Sampson & Benton, unpublished).

A split-half coefficient was computed for the MOSART tests, which measured teachers' physical science content knowledge. For the split-half coefficient, the items were divided by selecting odd or even items. The Cronbach's alpha reliability coefficients for the MOSART tests for the three data collection periods were 0.50, 0.51 and 0.66. These coefficients are in the reliability range, as accepted by the instrument developers (Science Education Department of the Harvard-Smithsonian Center for Astrophysics, 2006). However, these reliability coefficients suggest that the MOSART test results should be used with caution. Data reliability is addressed in later sections.

Results: Research Question One

> What changes occur in teachers' inquiry-based practices, inquiry-based beliefs, and content knowledge during a year of professional development and a year of classroom practice?

The RTOP, BARSTL, and MOSART instruments were used to measure teachers' practices, beliefs, and content knowledge, respectively. Teacher beliefs and content knowledge were measured three times: Summer of Year 1, Spring of Year 1, and Spring of Year 2. Teacher practice was measured five times: Fall of Year 1, Winter of Year 1, Spring of Year 1, Fall of Year 2, and Winter of Year 2. ANOVAs, *t* tests, and non-parametric statistics, all set at the .05 alpha probability level, were used to analyze the data. Qualitative data were used to corroborate and unpack the quantitative results in teachers' beliefs and practice.

Quantitative Data Results

One-way within-subjects analysis of variance tests were conducted on all three measures across the 2 years (See Figure 4.1). Results from each measure are reported next.

Changes in Practice

While the ANOVA results revealed statistically significant changes in practice during the 2 years, Wilks' $\Delta = .24$, $F(4,8) = 6.21$, $p < .05$, partial $\eta^2 = .76$, pairwise comparisons indicated no significant differences in any time period other than Fall to Winter in Year 1. Follow-up polynomial contrasts indicated a significant linear effect with means increasing over time across the two years, $F(1, 11) = 27.4$, $p < .01$, partial $\eta^2 =$

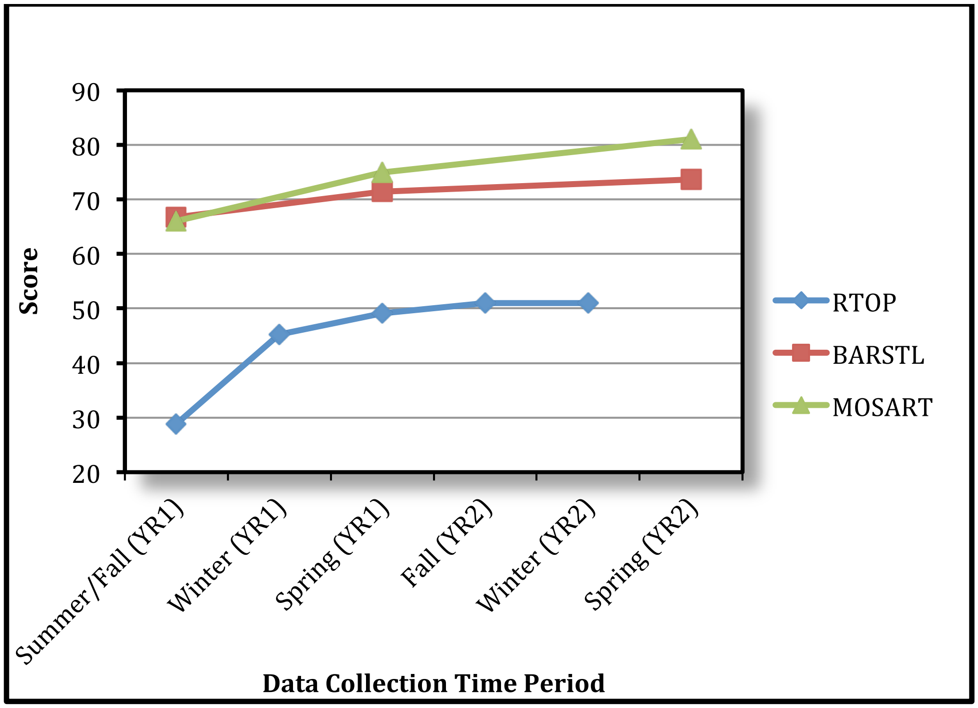


Figure 4.1. Change in teachers' RTOP, BARSTL, and MOSART scores in Years 1 and 2.

.71. Teachers' scores, then, rose for the entire RTOP data collection period, though at a considerably slower rate after Winter of Year 1.

Changes in Beliefs

Results from the teachers' inquiry-based belief measure also revealed statistically significant increases over the 2 years, Wilks' $\Delta = .24$, $F(2,10) = 16.21$, $p < .01$, partial $\eta^2 = .76$. While pairwise comparisons indicated significant increases in Year 1, no significant increases were found in Year 2. Follow-up polynomial contrasts showed a significant linear effect with means increasing over time during the 2 years, $F(1, 11) = 27.4$, $p < .01$, partial $\eta^2 = .72$, indicating that scores continued to increase in Year 2, though at a considerably lesser rate.

Changes in Content Knowledge

ANOVA results revealed statistically significant changes in content knowledge over the 2 years, Wilks' $\Delta = .21$, $F(2,10) = 18.64$, $p < .01$, partial $\eta^2 = .79$. Post-hoc pairwise tests revealed that teachers' content knowledge scores increased significantly in both Year 1, $t(14) = 2.41$, $p < .05$, and Year 2, $t(11) = 2.45$, $p < .05$. A Wilcoxon nonparametric test confirmed this finding, showing a significant increase in content knowledge scores during Years 1 and 2 at the alpha = .05 level.

Correlations

Parametric and nonparametric correlation coefficients (using Pearson and Spearman tests, respectively) were computed across the three teacher measures. No statistically significant correlations were found, even though all of the measures rose at a significant rate in Year 1. A visual inspection of the data showed that the growth rate was steeper for the inquiry practice (RTOP) scores in Year 1 (Fall to Winter) than for the other two measures. The low subject number may have prevented a statistically significant finding.

Summary

Results indicated statistically significant increases in all measures across the 2 years. Post-hoc pairwise tests showed statistically significant changes in all three measures during Year 1; however statistically significant increases were found only in content knowledge scores in Year 2.

Qualitative Data Results

Qualitative data from interviews conducted with the teachers near the beginning of Year 1 and the middle of Year 2 were used to corroborate the quantitative data. These data revealed teachers' beliefs and understandings about inquiry teaching and learning, their reasons for joining the PSIA program, and their perceptions of changes in their science teaching practices.

Changes in Beliefs

Shifts in two types of teacher beliefs—how elementary teachers should teach science and how elementary students learn science best—are reported here because they align most closely to the belief constructs measured by the BARSTL instrument. Two interview questions (What is the role of a science teacher? How do teachers maximize students' science learning?), both taken from the Teacher Belief Instrument (Luft & Roehrig, 2007), elicited information on these belief types.

In developing their instrument, Luft and Roehrig (2007) placed responses from teachers in their study into a rubric, with categories that ranged from teacher-centered ("traditional") to more student-centered ("transitional") to the most student-centered ("reform-based"). Luft and Roehrig (2007) explained that "traditional responses reveal science as based on facts, rules and methods…; transitional responses represent science as a body of certain knowledge; while reform-based responses support science as a dynamic field that is subject to revision" (p. 42). This rubric was used to analyze the interview data collected for this study.

Change in beliefs regarding role as a science teacher. The increases found in the quantitative data were supported by the qualitative data. Ten of the twelve teachers interviewed in both years had perceived a change in their role as a teacher from more traditional views to more reform-based (inquiry-based) views. For example, in Year 1, Julie described her role as teacher-centered, even though she had been exposed to inquiry science teaching in her pre-service program and had a concept of student-centered classrooms. In her Year 1 interview, she explained:

> I give a lot of information. My role is to make sure that these kids are prepared for the CRTs, for what they'll be tested on for the end of the year. It's hard to do hands-on stuff because it takes a lot of time, but I try to incorporate that throughout the year. My job, I think, is to help them learn the things they need to be successful for their test and also to learn how to be a scientist. (Julie, Interview 1)

In contrast, in her Year 2 interview, she explained how she had created a more student-centered classroom and expressed her feelings of greater competency and confidence in her skills to do so successfully. She described her role as, "Helping them learn to ask questions, to make observations, things like that. Having them do an experiment and then write about it, write down their results or what happened or what they're observing" (Julie, Interview 2).

Another teacher, Michele, experienced a change in the specifics of how to create a science learning experience for her students that was more inquiry-oriented. In her Year 1 interview, her focus was mostly on trying to create an exciting learning experience for her students:

> One of the things I look at is to get kids excited about science. And I don't believe in science books. I've always been a hands-on teacher. So I look at my role as gathering activities and getting experiences for them, rather than they hear of it or read about it or watch it. So that's my role—to accommodate that. (Michele, Interview 1)

In her Year 2 interview, she was more specific about how she could foster a student-centered science learning experience:

> I want them to be able to think scientifically, but that's a huge process. I'm not as much interested that they know the right answer rather that they know how to get the right answer. To me it's a process rather than an end result because I think in science, you never can come up with the final answer. It keeps changing. So my role is to help them gain the skills to do the process of looking at things scientifically and looking at problems because I think a scientist is just a problem solver. (Michele, Interview 2)

Similarly, Danielle shifted from teacher-centered beliefs to more student-centered beliefs about her role as a science teacher. Her statements also revealed an accompanying shift from personal feelings of uncertainty and lack of confidence in her science teaching skills to greater confidence in her skills and use of instructional strategies. In Year 1, for example, she reported:

> I found that with the first unit, with weather, that I don't know how to make it inquiry-based. My role as a science teacher though…just trying to get them as much information in different ways that I can.… I'm trying to think of the curriculum that we teach in fourth grade, and to me, it is a memorizing type of thing. (Danielle, Interview 1)

In Year 2, her beliefs about her role had changed. She explained:

> Because of [PSIA] I'm definitely more open to [inquiry]. I'm willing to do it and try new things. We did an experiment this year too, which is so out of my comfort zone.… And [now] I go to the library and get books on, like we're doing magnetism, so I found 10 books on magnetism to bring in that extra little background knowledge.… PSIA helped me open my eyes that science is not a right and a wrong answer. Yes it is, but no it's also an investigation kind of thing. (Danielle, Interview 2)

Change in beliefs about how teachers maximize student learning. Ten of the twelve teachers who were interviewed in both years perceived a shift toward more reform-based beliefs in how they maximized student learning. In Year 1, for example, Rich explained his approach to maximizing student science learning prior to PSIA participation:

> My typical approach last year was 'Bill Nye, The Science Guy.' And I still use that because it's a valuable resource.... Last year, it was all up to me as the teacher to present and they had to filter through what was most important. Last year I had a science folder, and they would have homework on one side and completed [homework] on the other. They would move it from one side to the other.... I admit that a lot of it would become remedial. I'm sure they would get bored with it because of all the worksheets. (Rich, Interview 1)

Rich explained his change after the PSIA Summer Institute and several monthly Academy sessions:

> But now what I do is…an introduction, then I take it a step further and I go into the inquiry. We start to ask questions. We start to do experimentation and home research. I've really tried to focus more on shifting the accountability and the responsibility to them. (Rich, Interview 1)

Jen compared the difference in her beliefs between Years 1 and 2. "I think it is different this year than last year. I just feel more comfortable letting them see I don't know everything in science and that we, still even as adults, have to look things up and figure stuff out" (Jen, Interview 2). In describing her implementation of science in Year 2, she indicated:

> I'm not really great yet at making sure that everything I do in science is hands-on, but hopefully someday I'll be better.... Sometimes we do demonstrations, other times they'll just have something to investigate. In the beginning, I'll give them something that maybe they're not so familiar with and they have to look at it and record what they see. Relating it to real life, to the water cycle for example. (Jen, Interview 2)

In sum, the findings from the interview data on teacher beliefs about inquiry teaching and learning corroborated the belief changes found in the BARSTL instrument results.

Changes in Practice

An analysis was conducted on teachers' conceptualizations of their science teaching practice before and after PSIA participation. These data primarily stemmed from one interview question that queried teachers on how they believe students learn science best. Analysis of this item, through coding and development of themes, unexpectedly elucidated more about teachers' inquiry practice and understandings about inquiry science than about belief changes. The results are discussed in terms of changes in teachers' conceptualizations of their practice across the 2 years, PSIA program impacts, and the influence of previous inquiry training on the comprehensiveness of teachers' inquiry understandings and practice.

Changes in teachers' conceptualizations of inquiry practice. Many of the teachers who defined *inquiry* both before the PSIA year as "hands-on" or "discovery" learning, continued to do so after the program, indicating a lack of a thorough (or sophisticated) understanding of inquiry. There was an increase in Year 2, however, in the number of teachers who also incorporated reform-based terminology, such as "exploration" or "investigations," when discussing inquiry.

In Year 1, many of the teachers' descriptions of their science teaching reflected somewhat directionless instructional practices. These teachers seemed to lack specificity in how their teaching practices affected student learning. For example, in Year 1, Tanya and Julie described their teaching practice as follows:

> Because [my students] have such limited background knowledge, reading it out of a book is not going to help them. Silly little experiments, songs, they're learning the water cycle through music, and I think that really helps cement the actual learning that they are doing because they're involved in learning a song. (Tanya, Interview 1)

> I think any activity that gets them moving, not necessarily always hands-on experiments, but just trying to get them up moving around the room keeps their attention because their attention span doesn't last very long. I try to change it up so they're not always sitting in their seats, or they're not always reading. I just try to switch it up to keep it interesting. I try to bring in visual examples, things they can touch, things they can see. (Julie, Interview 1)

In Year 2, many of the teachers' descriptions of their teaching practice suggest that their practice had advanced to some degree. For most of these teachers, however, their practice was still limited to "exploration-type" and "hands-on" (rather than "minds-on") activities. This is evident in the following examples, again from Tanya and Julie:

> Because I think if [my students] discover how something works, they interact with it to remember it longer.… So I try to incorporate that in my lesson plans because I think if they are able to discover an answer, they're more apt to remember what they found. (Tanya, Interview 2)

> Helping them understand that science is about experience and experiments and that you don't always have to get an answer. It's more about hands-on learning and just going through the process of scientific observation and things of that nature. (Julie, Interview 2)

Impacts from the PSIA program on practice. Teachers understood and incorporated the *Engage* and *Explore* elements of the 5 E model (Biological Sciences Curriculum Study, 1997), but they often did not incorporate the rest of the model, which includes the *Explain*, *Elaborate*, and *Evaluate* components. The former elements include activities that engage students' interest, and facilitate student exploration of phenomena and collection of observations/data. If applied without skill and purpose, these elements could result in more superficial exposure to the content than the latter elements. The latter components involve students' explanations for their observations, application of this learning to a new situation, and evaluation of their own learning (along with teacher evaluation of learning).

Teachers exited the PSIA program with a better understanding of (a) how to establish student groups and have students work collaboratively, (b) how to facilitate students in grouping data into student-defined categories and making conclusions based on this grouping, (c) how to use science journals effectively, and (d) how to integrate science into other subject areas. This growth is reflected in the teachers' statements. For example, when asked what aspects of PSIA she had incorporated into her teaching, Mary indicated:

> For one thing, the journaling that we started doing in our breakout sessions. [The elementary science education specialist] showed me how to move a lot of what I do with my reading log into science. I had used foldables before, but not to keep them in the log as ways for kids to record. That's been one of my biggest frustrations is how do I have the students record or collect their materials in a meaningful way where they could go back or where they feel pride in it. And it's part of the learning, not just an assignment to hand in. That was really a nice next step. I was ready to go there, and we are using them. (Mary, Interview 1)

Gina, Julie, and Clair described similar gains in their teaching practice. Gina explained, "This year we keep a journal and that's a huge part of our assessment tool" (Gina, Interview 2). Julie described her changes:

> Well, I think I'm able to crowd control a little better. Being open to having experiments. I know for a lot of teachers that it's kind-of chaotic to do that, and I kind of invite the chaos. I like the kids to be able to discover and have fun. So, maybe just that I'm open to them exploring and finding things out for themselves, and not being afraid to mess up as a teacher. (Julie, Interview 2)

Clair reported:

> Probably 90 percent of science time we're breaking out into a small group, and it's more of a cooperative situation. Most of the time, it's a hands-on exploring type of situation. I give them parameters of what they're supposed to do, but they get to manipulate and mess around with it, and then we discuss afterward, of course, and debrief. (Clair, Interview 2)

Overall, the results indicated that, especially for the teachers with little previous inquiry training, PSIA contributed to their gain in a basic understanding of inquiry.

For example, many teachers shifted over the 2 years in their comfort level with conducting "hands-on" activities and they promoted more exploration in class. Many of the lessons, however, were not complete student-centered investigations; rather they incorporated select elements of student-centered learning.

Effects of previous intensive inquiry-based training on practice. Several of the teacher participants had previously completed a 2-year, technology-based professional development program called eMINTS (enhancing Missouri's Instructional Networked Teaching Strategies), which integrated inquiry-based teaching, high quality lesson design, and development of classroom community, with technology. Mary, Gina, and Michele from Woodshed; Louisa from Rivers; and Rachel from Sycamore, had completed this program.

These teachers' overall average RTOP (inquiry practice) scores were on average higher than those of teachers who had not participated in eMINTS, suggesting that this program may have provided a background for teachers in their conceptual understanding of inquiry and the skills to implement inquiry successfully. Additionally, the eMINTS teachers' were more specific in their descriptions of ways to implement inquiry and to make connections to student learning. These teachers may have self-selected into the eMINTS program because they were more receptive to inquiry than teachers who had not participated.

Rachel described the impact eMINTS had on her understanding of inquiry teaching and learning:

> [Inquiry] is good teaching practice! I guess the thing that probably has been the most pivotal [for my inquiry teaching] in the last several years has been the eMINTS program. That would probably be the big one because that is totally inquiry-based…. It was a two-year program. It's a hundred hours outside of your

> teaching day throughout the year.... So [inquiry] is real natural. (Rachel, Interview 1)

Louisa described the multiyear process of her change in practice during her eMINTS participation, “This is my fifth year [of follow-up training], because the trainers understand that it's a large process. It's a huge change…a total turnaround in our teaching style” (Louisa, Interview 2)

While past intensive inquiry-based training impacted teachers’ average RTOP scores, analysis showed no link to amount of *change* in practice across the two study years. Therefore, this factor is not considered to be an explanatory factor in teachers’ change scores.

In sum, the findings suggested that teachers differed in their level of inquiry preparation and training before PSIA, which likely impacted their understanding of inquiry. This exposure may have also impacted the ways in which teachers implemented inquiry in their classroom during the study years.

Changes in Content Knowledge

As Figure 4.2 shows, the MOSART tests (which measured physical science content knowledge) differed by grade level in difficulty. The fourth-grade average (Y1 Fall = 0.81, Y1 Spring = 0.86, Y2 Spring= 0.92. Average = 0.86) was higher than the fifth-grade average (Y1 Fall = 0.65, Y1 Spring = 0.70, Y2 Spring = 0.77. Average = 0.71), which was notably higher than the sixth-grade average (Y1 Fall = 0.45, Y1 Spring = 0.59, Y2 Spring = 0.67. Average = 0.57). While differential difficulty may not have impacted teachers’ overall score changes across the 2 years, this issue, combined with the

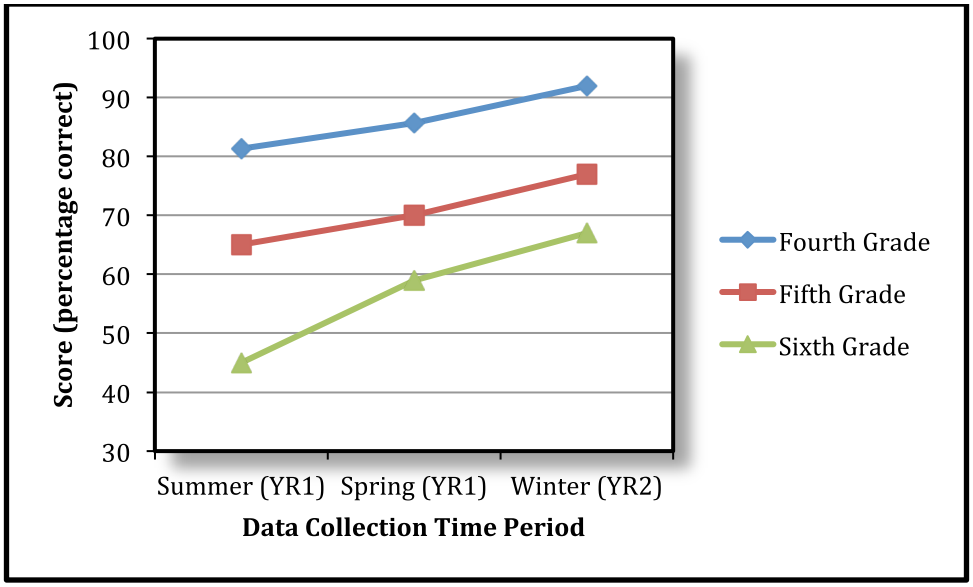


Figure 4.2. Differences in MOSART scores by grade.

low reliability coefficients for the study population, impacted the assertions that can be made from the MOSART data.

Discussion: Research Question One

The results from research question one revealed that inquiry-based practice, inquiry-based beliefs, and content knowledge increased at a statistically significant level across the two study years. In Year 1, all measures increased at a significant level. In Year 2, content knowledge increased significantly while the other measures only increased slightly.

Qualitative data indicated that the PSIA program impacted teachers' inquiry practice toward more student-centered teaching, and impacted teachers' beliefs and content knowledge. For example, teachers were more motivated to teach through inquiry and felt more comfortable "letting go" of control during science lessons. Many of the teachers felt they had gained the skills to develop collaborative student teams, and to use science journals.

Professional development, then, was shown to be an effective method of providing teachers with the necessary experiences to understand and enact some of the science teaching reforms, supporting similar findings in the literature (Duschl et al., 2007; NRC, 1996). The growth in teachers' practices, beliefs, and content knowledge is consistent with literature concerning reform-based professional development (Akerson & Hanuscin, 2006; Banilower et al., 2007). PSIA had many of the elements shown to be effective in promoting change toward reform-based practices and beliefs, including long-term engagement, collaboration with other teachers, a focus on student learning, and connectivity to classroom practices (Gess-Newsome, 2001; Loucks-Horsley et al., 2003; van Driel et al., 2001).

In concert with the results of this study, other research has shown that teachers often enter science professional development programs with positive notions of inquiry as effective for science learning, and wanting to learn how to apply inquiry in their classrooms (Marshall et al., 2009). The teacher participants entered the PSIA program with the recognition that inquiry teaching is good teaching. However, many teachers do not have or develop a clear or deep understanding of teaching and learning through inquiry, even after professional development (Marshall et al., 2009; Wee et al., 2007). The results of this study support this literature.

PSIA participants advanced from teacher-centered to more student-centered practices to different degrees. Teachers with previous intensive inquiry-based training through the eMINTS program were better positioned and prepared to incorporate more elements of inquiry and the 5 E model. This finding supports the research that has shown that it takes many years for teachers to implement new ways of teaching (Loucks et al., 2003), and supports the need for multiyear professional development on inquiry science (Akerson & Hanuscin, 2007).

Although a statistically significant correlation was not found among teachers' change in inquiry practices, inquiry beliefs, and content knowledge, the increases in all three measures across the 2 years suggest a relationship. Many researchers have found a relationship between these measures. Richardson (1996), for example, found that teachers' knowledge and beliefs (along with attitudes) are the components of teachers' cognitions most strongly linked to classroom practice.

There is little consensus in the literature about the order of change between practice, beliefs, and content knowledge. Some researchers contend that change in classroom practice comes first (Ball & Cohen, 1999; Guskey, 1986). Others have found that teachers' beliefs and knowledge must change in order for teachers' practice to change (Thompson & Zeuli, 1999; van Driel et al., 2000). Still others find little consistency in order (Fennema et al., 1996; Richardson, 1994). Richardson (1994) explained that determining the order might not be important. "Perhaps, in the long run, we are dealing with a change process that can begin with change in either beliefs *or* practices, depending on the particular teachers and the type of change…it may not be important to determine which comes first in the change process" (p. 102).

The results from this study suggest that the order of teachers' change and the magnitude of the change differed for each participant. All of the participants entered the program with the belief that inquiry is good teaching practice while also desiring improvement in their inquiry teaching skills. For some teachers, as their beliefs shifted toward more *informed* inquiry-based beliefs, their practice also shifted. For other teachers, observing their students' success with learning through inquiry altered their beliefs about the effectiveness of inquiry teaching. Further, teachers' content knowledge gains likely played a role in facilitating increases in the other measures.

Results: Research Question Two

While participants' change in practice, beliefs, and content knowledge in Year 1 can be attributed to their participation in PSIA, research question two investigated the impact of school-level and individual-level factors on the Year 2 results. In Year 2, teachers' scores in inquiry-based practice and beliefs increased slightly, and content knowledge scores increased significantly. As such, research question two asked:

> What impact do school-level factors have on the changes that occur in teachers' inquiry-based practices, inquiry-based beliefs, and content knowledge during the year after a professional development program?

The RTOP, BARSTL, and MOSART surveys were the primary quantitative data sources to answer this question. Interviews with the teachers and principals from each school were the primary qualitative data sources. One interview per year was conducted with the teacher participants with the intention of revealing: (a) the school-level factors that impacted changes in inquiry practices and/or beliefs in the year following PSIA, and (b) changes in teachers' personal beliefs and understandings about science teaching and learning. Interviews conducted in Year 2 with the principals were intended to elicit their understanding of the science reforms, prioritization of science as a subject, and support for their staff in their efforts to teach through reform-based methods.

Prioritization was given to providing explanations for changes in practice rather than changes in beliefs or content knowledge. This section begins with a description of the science culture at each school, followed by a cross-school comparison of each outcome measure. The section concludes with an analysis of school-level and individual-level factors that impacted teacher change in practice. A discussion of two additional individual-level findings ("secondary" findings) concludes this chapter.

School Culture

Rivers Elementary

Rivers had been in Title I: "In Improvement" for 2 years (Years 1 and 2 of the study) after failing to meet AYP for 2 successive years beginning in 2006. AYP in the study state is determined by math and language arts scores, and is not impacted by science scores. Rivers is the only study site with this status. There was a feeling of stress and concern at this school, most likely due to the threat of sanctions if it did not meet AYP again.

The concern over meeting AYP in math and language arts strongly and negatively impacted the science culture at the school. Each teacher from Rivers expressed several times that science was not a priority there, and cited their In Improvement status as the reason. The teachers explained that there was no designated science time like there was in the previous year (the PSIA year) and the administration discouraged them from allocating time for teaching science. The principal's statements corroborated the teachers' sentiments, explaining that because of being In Improvement, science should not be a priority at that time.

Sycamore Elementary

While the principal expressed his moral support for science and quality science instruction, his and the teachers' statements revealed that science teaching had been under-prioritized at this school in order to meet AYP. Sycamore had not passed AYP in the 2006-2007 school year, although it was not in In Improvement. There was an overall feeling that passing AYP was not guaranteed at this school, and attention therefore needed to be placed on student achievement in language arts and math. Further, the principal mentioned a significant teacher turnover in the following school year, explaining that integrating the new teachers would be a greater focus at the school than science education. Despite these pressures, however, there was a general atmosphere of satisfaction and contentment at Sycamore.

Watershed Elementary

Watershed had passed AYP every year since 2006. This school had a different atmosphere and attitude toward science than the other study schools. The principal had assigned an "Extended Learning Coordinator" staff member to administrate the school's science program. Further, the principal had a proactive stance about science materials and purchased a series of science books related to the State Science Core Curriculum the previous year.

Unlike the other two schools, Watershed did not focus exclusively on language arts and math achievement; rather, there was a culture of importance placed on science. The principal had told her staff that science teaching was a priority because it was assessed in standardized testing, and she did not overtly make a distinction as to whether science scores were used to establish AYP. The struggle to pass AYP and concern over the ramifications of failing, therefore, were not present at this school.

The principal showed her prioritization of science by encouraging teachers in their same-grade teams to collaboratively organize the order of their science curricula and the accompanying materials. She made clear her expectation that teacher teams work together to establish regular science teaching times and support one another in their science teaching. She entrusted teachers to create a successful science program according to the needs of each grade level.

Further, Watershed had established partnerships with a local university to conduct science activities for the school and with the District STEM high school to assist the elementary students in their preparation for the annual science fair (Rivers and Sycamore did not participate in a science fair and had not established partnerships with universities or high schools). Finally, many of the teachers had participated in the technology- and inquiry-focused eMINTS program (previously described).

Cross-School Results

Comparison of Instrument Outcomes Across Schools

A comparison of teachers' survey (quantitative data) results in practice, beliefs, and content knowledge across schools is presented in this section. These results provide a comprehensive picture of similarities and differences across the three study schools.

Inquiry practice (RTOP instrument). Inquiry practice scores increased significantly between Fall and Winter of Year 1 at all schools (See Figure 4.3), though Sycamore's teachers experienced greater growth than teachers at the other schools during this period. After the Winter Year 1 data collection period, the growth curve looked similar across all three schools, though Watershed showed a slight decline at collection period 5 (Winter of Year 2).

Watershed teachers' average scores were initially relatively high and ended high while Rivers teachers' scores started low and ended low. Sycamore teachers' baseline average inquiry practice scores started at the low level of the Rivers teachers and ended at the high level of the Watershed teachers at the final data collection period.

Inquiry beliefs (BARSTL instrument). Teachers from all three schools significantly increased their inquiry beliefs scores in Year 1 at approximately the same rate (See Figure 4.4). Sycamore had a slightly steeper curve, though only by a few points.

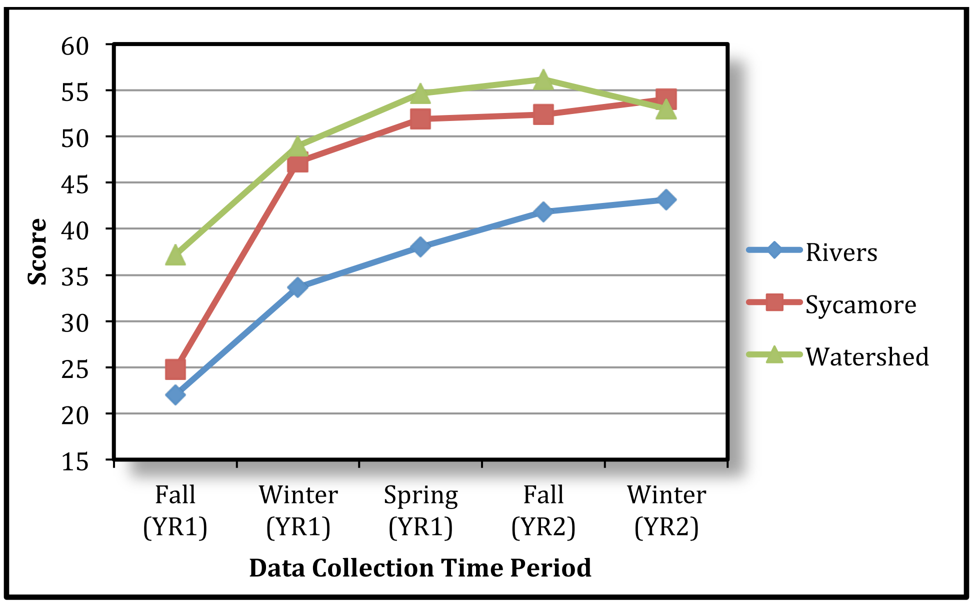


Figure 4.3. Teachers' average RTOP scores by school in Years 1 and 2.

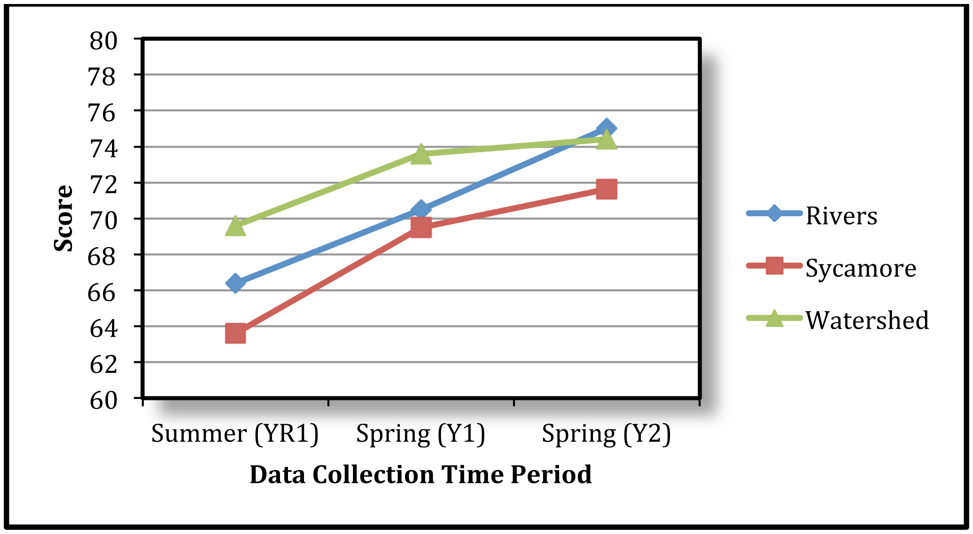


Figure 4.4. Teachers' average BARSTL scores by school in Years 1 and 2.

The growth curve in Year 2 is slightly different for each school, though again only by a few points. Watershed teachers showed incremental growth in this year, while Rivers teachers showed slightly more growth.

Physical science content knowledge (MOSART instrument). The growth curve for teachers' content knowledge was near equivalent across all three schools in both years (See Figure 4.5). Rivers and Sycamore teachers had slightly steeper growth curves in Year 1 than Watershed teachers. However, in Year 2, Watershed teachers showed slightly more growth than the other schools.

Rivers had the highest overall average percentage scores. However, as discussed above, the MOSART results should be interpreted with caution: Rivers had no sixth-grade teachers while both Watershed and Sycamore had two teachers taking the sixth-grade test. This is significant because the sixth-grade test appears to have been more difficult than the other tests.

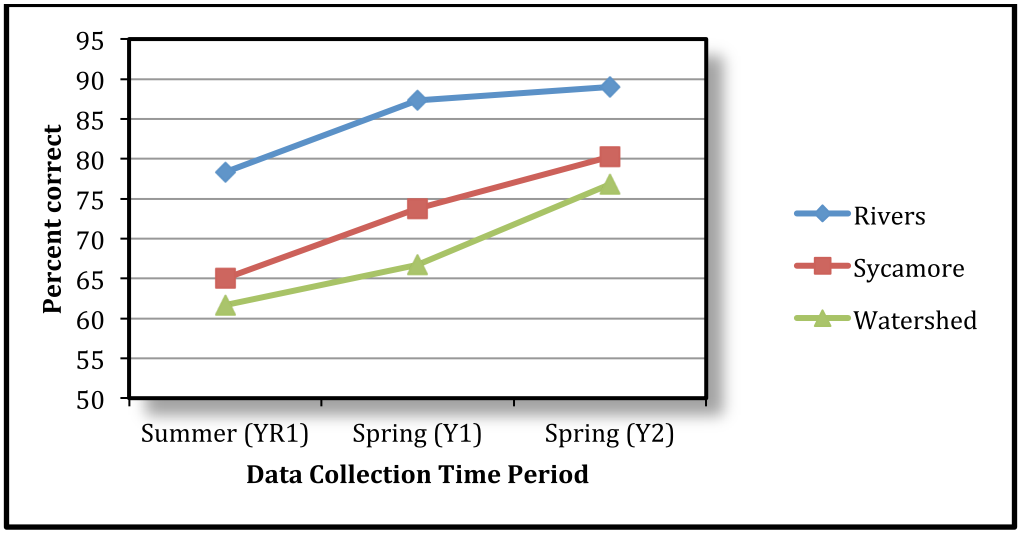


Figure 4.5. Teachers' average MOSART scores by school in Years 1 and 2.

In sum, Sycamore teachers experienced the most steady and continuous growth of the three schools across the 2 years in all measures. Watershed teachers showed the highest average scores on the inquiry practice and inquiry belief measures. Rivers teachers had the highest content knowledge scores. School-level and individual-level explanations for the changes, with a focus on changes in inquiry-based practice, are discussed next.

Factors That Contributed to Change in Practice

Survey data were used in concert with interview data to develop explanations for the changes in teachers' inquiry-based practices in the year following the professional development. In formulating these explanations, quantitative data were plotted for teachers by school and by individual teacher. Patterns were found at the school and individual levels.

Themes were also established in the teacher and principal interview data, which also revealed discrete school-level and individual-level differences between the teachers. Once these patterns and themes were established, trends in both data types were compared at the school and individual levels. The school-level factors are discussed first.

School-Level Factors

Three school-level factors were associated with changes in teachers' Year 2 practice. These were: (a) having supportive and collaborative same-grade teams that prioritized inquiry teaching and learning, and who prioritized science as a subject; (b) principal prioritization of science as a subject; and (c) having easy access to relevant materials and supplies, as well as receiving training in their use.

Factor 1: Having supportive and collaborative same-grade teams that prioritized inquiry teaching and science as a subject. Teachers' inquiry scores were more likely to continue to increase in the year following PSIA when one or more teachers in their same-grade team supported inquiry teaching and prioritized science as a subject. When asked about cross-grade interactions, each teacher explained that there was no interaction in science across grade levels. Almost all of their meetings, planning, and support occurred within same-grade teams. For example, Joanna explained, "Yeah, you talk to your grade level and you're just so busy you don't talk to other people…. What kind of school supports are there besides my team, what else is there? What do other people have? I mean I've got materials" (Joanna, Interview 2). The data supporting this finding are described by school.

The fourth-grade team at Sycamore was highly collaborative. PSIA participants, Rachel and Danielle, were close friends in addition to their collegial relationship. Rachel, an experienced teacher who had recently moved to Sycamore from Watershed, served as mentor to Danielle, who was younger and less experienced. The rest of Sycamore's fourth-grade team worked collaboratively, were supportive in their attitudes toward inquiry science, and prioritized science teaching. The data suggest that, in many ways, this group incorporated learning from PSIA as a team. As Danielle described:

> We exchange everything… all four of us. It's so nice. Because I didn't know anything about rocks and minerals, I was really excited when [another teacher] said that he would take that topic and share [his lessons] with us. I felt more comfortable with biomes, so I shared that with everybody. (Danielle, Interview 2)

When asked whether she felt other teachers at Sycamore were supportive of her efforts to incorporate her learning from the PSIA program, Rachel responded:

> Yeah. Danielle and I do it together because we took the program together, and we have two other people on our team. They're doing mock rocks this year with us because we did this last year at PSIA. I feel that our team is very receptive of anything that we brought back from [PSIA]. It's always the grade-level team…it's a good team. (Rachel, Interview 2)

It became apparent in her interviews that Rachel served as informal team leader. Her opinion, therefore, about science was especially important, and impacted the other team members, especially Danielle. When asked whether she prioritized science as a subject, Rachel explained:

> I think science is really important because we're tested on it on the CRT. Of course, reading and math always supersede it because you can't really do science unless you can read.... So I would say science takes a tertiary role…. I think it's all about learning about the world. I certainly think it needs to have a third of the day…. I impose on myself so many minutes of science and so many minutes of social studies. I feel that that is making a well-rounded child. (Rachel, Interview 1)

Further, Rachel supported inquiry teaching. “I think all of us as human beings learn best from inquiry-based learning, and it goes along so well with that kinesthetic approach that so many younger kids need” (Rachel, Interview 2).

The results suggested that Rachel’s support of inquiry teaching and science as a subject may have influenced Danielle in her inquiry practice. As Figure 4.6 shows, Rachel’s RTOP scores at baseline were higher, and ended higher, than all of the Sycamore teachers who participated in PSIA. Danielle’s scores were initially significantly lower than Rachel’s but rose steadily over the 2 years to surpass Rachel’s highest score. These results suggested that Rachel’s mentorship, along with the entire fourth-grade team’s support for inquiry and prioritization of science, impacted Danielle’s substantial increase in her inquiry practice scores.

Rachel’s scores increased over the 2 years, though not as substantially as Danielle’s. The results suggested that, although she had her team’s support for inquiry teaching, there may have been nobody on the team skillful or knowledgeable enough in inquiry to push her to raise her scores further.

In contrast to the collaborative fourth-grade team, the sixth-grade team at Sycamore had no interaction with one another about science or inquiry teaching in Year 2, despite both Clair’s and Rich’s participation in PSIA. Clair explained:

> Unfortunately, one member of our team is not a very good team player and wants to be more isolated…it's hard…. The other sixth-grade teacher has done her own thing too, I’ve tried to pull her in, but she's just kind-of an island of her own too. If you don't have buy-in from everybody, it doesn't work. (Clair, Interview 2)

When asked about team collaboration, Rich corroborated Clair’s statements. “I just kind of do my own thing” (Rich, Interview 2). Further, Clair reported that she did not know

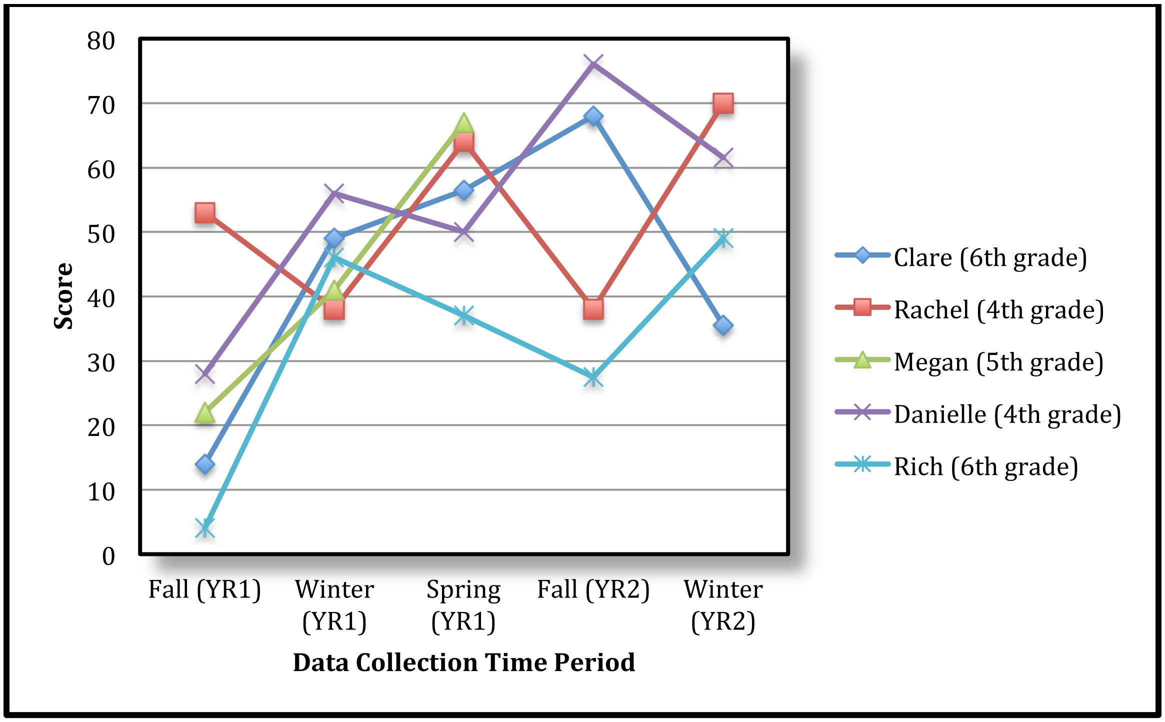


Figure 4.6. RTOP scores by teacher at Sycamore.

whether Rich had implemented any of the PSIA activities, evidencing the lack of communication about science in this same-grade team.

These teachers' RTOP scores suggested that this lack of collaboration had an effect on their Year 2 inquiry practices. As Figure 4.6 shows, all of the Sycamore teachers' scores rose in the 1st year. However, in the 2nd year, neither Clair nor Rich's scores showed substantial growth; rather, there was some decline in scores. In contrast, the fourth-grade team's RTOP scores continued to rise in Year 2.

Differences also were found between the teams at Rivers. The two Rivers fourth-grade PSIA teachers, Louisa and Tanya, supported one another and collaborated in teaching science. Both teachers indicated that they did not discuss science with other team members. When asked whether the other teachers on their team implemented inquiry, Louisa responded, “I don't know because we don't observe each other teaching--so I only know how Tanya teaches because she tells me what she's doing” (Louisa, Interview 2). Louisa explained, “Any support would come from colleagues like Tanya. She and I took [PSIA] together so I would take my notes and go, ‘Okay those are the notes I took, help me clarify what we're supposed to do for this activity’ (Louisa, Interview 2).

Interview data indicated that Louisa was in a leadership role in her relationship with Tanya. Further, as Figure 4.7 shows, Louisa’s RTOP scores were higher than Tanya’s at the beginning of the study, indicating she was implementing inquiry to a greater degree than Tanya. However, Tanya’s RTOP results over the 2 years revealed a score increase from low (relative to the other PSIA teachers) to the approximate level of Louisa’s scores at the end of the study period. These results suggested that Tanya’s gain may have been impacted by the supportive role Louisa played the year following the

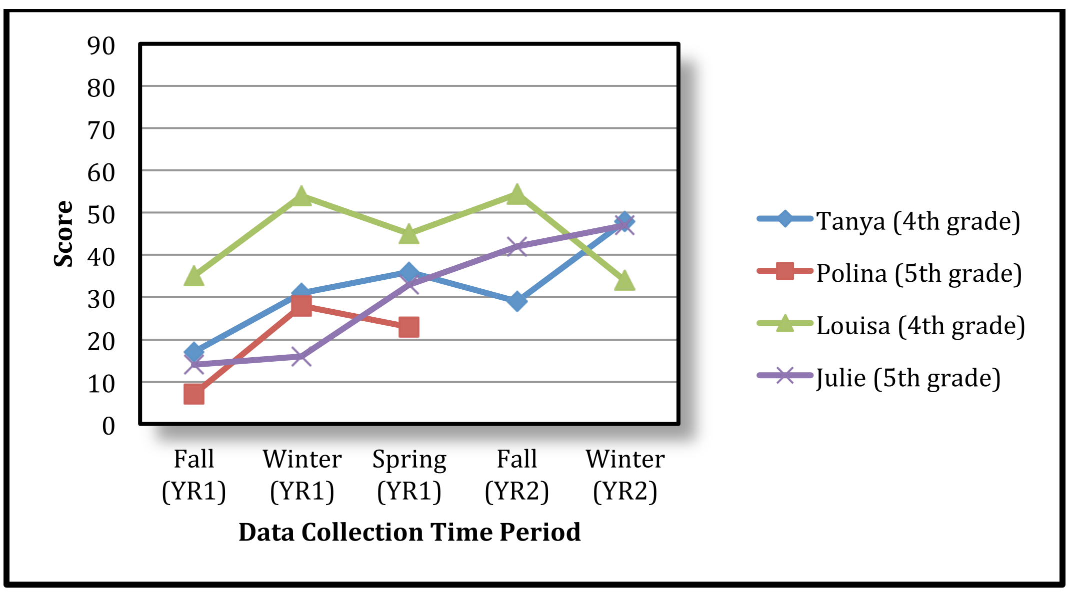


Figure 4.7. RTOP scores by teacher at Rivers.

professional development. In other words, these data suggest that Louisa's advocacy and prioritization of science may have influenced Tanya because Louisa was Tanya's same-grade support and collaborator.

Louisa believed science was an important topic, though she did not enjoy it and had no administrative support to teach it. She explained, "I have a responsibility to teach the core curriculum and to get the students excited about science.... I mean it's not like I hate, hate, hate teaching science. It's just hard for me to teach it" (Louisa, Interview 2).

Her scores oscillated over the 2 years, but did not increase notably. The data suggest this may have been due, in part, to the absence of same-grade collaborators to facilitate increases in her scores. Tanya may have lacked the skills to support Louisa's continued RTOP score increase, in addition to the absence of other school-based support.

Julie, a Rivers fifth-grade teacher, was entirely without same-grade collegial support in science. The other teacher who had participated in PSIA had left her teaching position before the beginning of Year 2, and the rest of Julie's grade team did not collaborate in science. She explained, "As far as having any support...in the school? Nobody. Nobody for science" (Julie, Interview 2). When asked what percentage of her same-grade meeting time was spent discussing science, she replied, "No time…like zero…it's just language arts and math" (Julie, Interview 2). As a result, Julie felt she had nobody to support her implementing the inquiry she had been exposed to at PSIA.

While Julie's RTOP scores did increase in Year 2 (see Figure 4.7), she taught science only three times that year, during researcher lesson observations. This result suggests that while she may have had personal motivators (that are discussed below) to facilitate the increase in her RTOP scores in Year 2, her lack of school-based support resulted in Julie placing a low priority on science teaching overall.

The data from Watershed revealed that both the fourth-grade and sixth-grade teams collaborated in science; however, the collaborative efforts were different for each grade level. This difference is likely a result of Principal H's trust in the teachers to organize and collaborate in the way they choose while adhering to her policy to prioritize science at the school.

Joanna, a fourth-grade teacher, explained how she, Jen (a 1st-year teacher and fourth-grade PSIA teacher participant), and their other team member who did not participate in PSIA, collaborated in science:

> We sat down at the beginning of the year and divided materials into unit one, two, and three. We went through anything we had from anywhere and put what we needed for unit one in a big tub, what we need for unit two, and what we need for unit three. (Joanna, Interview 2)

Joanna further explained their team's decision to use the district-wide science and social studies curriculum, which has inquiry-based elements, to teach science that year:

> There's a lot of collaboration, especially between grade-level teams. All three of us made the decision to use [the curriculum]. I thought of using it as just another resource and not just doing it step-by-step and then another teacher said I think I'm just going to do exactly how they say to do it and see what happens…. It's supposed to cover our core 100 percent. (Joanna, Interview 2)

However, although these teachers collaborated in their science teaching, the support for teaching through inquiry was not strong in this grade level. Some of Joanna's comments suggested that she was dubious about the value of inquiry. "I bought into [inquiry] probably less than the teacher who wasn't [at PSIA]. She's a more experienced teacher…. I'm getting to be more supportive of it" (Joanna, Interview 2).

Joanna, therefore, likely did not serve as a mentor to Jen to promote her inquiry teaching. Jen, in turn, may have been too new to be equipped to support Joanna in incorporating inquiry. Their RTOP scores reflect this lack of mentorship. As shown in Figure 4.8, Joanna’s scores decreased slightly in Year 1 and increased slightly in Year 2; perhaps this increase was due in part to the non-PSIA teachers’ support for inquiry. Although Jen’s scores increased notably in Year 1 (a result expected for a 1st-year teacher), they stayed at the same level across Year 2.

Watershed’s fifth- and sixth-grade team collaborated extensively on their science curriculum. They spent one-fifth of the time in their meetings discussing science. Fifth-grade teacher, Gina, described this collaboration:

> As far as interacting and teaming goes, it's big time fifth, sixth. As far as team meetings go, [science] is always part of it. It depends on where we're at in the school year. It's a huge part of the scheduling. It's a huge part of preparation for assessment…. Science is a huge focus here. (Gina, Interview 2)

Gina went on to describe this team’s process of analyzing standardized test data in order to plan and make adjustments in their science teaching to improve students’ test scores. She explained, “It's our team looking at that data…we pick that apart. The main driving force behind it is the team.”

The RTOP scores of two of the fifth/sixth-grade teachers increased notably in Year 1 then decreased slightly in Year 2 (see Figure 4.8). Still, their Year 2 scores stayed over 20 points higher than their baseline scores, indicating their change was mostly sustained in Year 2. Further, their baseline average RTOP scores were high compared to the entire group of PSIA participants, and PSIA may not have provided these Watershed teachers with the skills or knowledge needed to continue to grow beyond their already

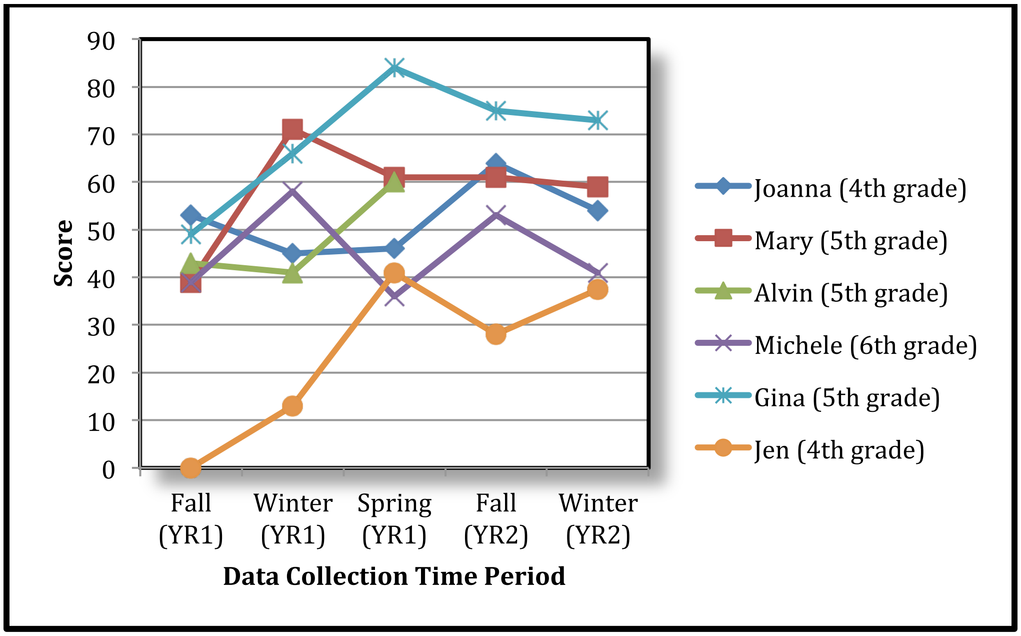


Figure 4.8. RTOP Scores by teacher at Watershed.

high growth rate in Year 1. The third teacher on this team, Michele, seemed to have been an exception in that her scores fluctuated over the 2 years, ending in Year 2 where she began in Year 1. Individual-level factors, discussed below, likely account for this pattern.

Supporting data for the importance of same-grade teams. Further evidence for the impact of same-grade teacher teams comes from data on team culture and practice across the three schools. The amount of time teachers spent discussing and planning science lessons varied by grade level within a school (see Table 4.3).

The amount of time that teachers met in same-grade teams was commensurate to the amount of time individual teachers spent teaching science (See Table 4.4). The exception to this finding was the fourth-grade teachers at Sycamore, where Rachel devoted 120 hours and Danielle devoted 75 hours a year to teaching science. These results suggest that the amount of time teachers allotted to the discussion of science

Table 4.3

Percentage of Time Spent Discussing Science in Same-Grade Meetings (Year 2)

School	Percentage of time teachers spent discussing science in same-grade planning meetings (average per week)
Rivers	* 4th grade: 0 - 5%, plus daily or weekly informal discussions with other PSIA teacher. * 5th grade: 0%
Sycamore	*4th grade: Before each new unit begins, about 50% of meeting time. Otherwise, 5%. Plus, weekly or occasional informal discussions with other PSIA teacher. * 6th grade: 0%
Watershed	* 4th grade: 25%, especially at beginning of the year to organize all materials and make yearlong lesson plans * 5th-6th grade: 20%

during same-grade team meetings is related to the amount of time they devoted to the teaching science. While time spent on science in meetings and time teaching science did not directly impact teachers' change in inquiry during the 2 years, they are important in understanding the contexts in which the participants taught. Overall, the results showed that same-grade teams impacted elementary teachers' inquiry instruction and the amount of time spent teaching science.

Factor 2: Principal prioritization of science as a subject. Principals' prioritization of science as a subject impacted teachers' RTOP scores more than did principals' understanding and support for reform-based science teaching. The principals had a fairly limited understanding of the science reforms, referring to them as "hand-on" or "active" learning. This section describes the effect of principal prioritization of science on change in teachers' RTOP scores and teachers' average RTOP scores. The effect of a school's AYP status on principal prioritization is also discussed.

Change in RTOP scores. The relationship between principals' prioritization of science and their teachers' change in RTOP scores in Year 2 was indirect rather than direct. The results suggested that principals influenced teachers' change in inquiry practice scores by encouraging or mandating same-grade collaboration for science, which, in turn, influenced teacher change scores.

Watershed's principal was the only principal who actively encouraged same-grade team collaboration. The Sycamore teachers perceived that their principal supported them to make good decisions for their students, but did not actively encourage same-team collaboration. Neither the Rivers principal nor any of her teachers mentioned encouragement for same grade-team science collaboration.

Average RTOP scores. The results revealed a direct and positive relationship between principal prioritization of science and teachers' average RTOP scores. A comparison between Watershed (with high principal prioritization of science) and Rivers (with low principal prioritization of science) showed that Watershed teachers had the highest average RTOP scores across both Years 1 and 2, while Rivers teachers had the lowest.

Further, the results suggested that the principals' prioritization of science was related to the amount of time teachers spent discussing science in same-grade meetings and the amount of time teachers spent teaching science. The Watershed teachers were higher on both of these measures, while the Rivers teachers were notably lower. See Table 4.5 for a comparison between all of these results.

Table 4.4

Average Number of Hours Spent Teaching Science Per Grade (Year 2)

School	Teacher	Grade	Number of hours teachers spent teaching science per year	Number of hours spent teaching science per grade level (average per year)
Rivers	Tanya	4	45 minutes per day, 3 times per week, 3 weeks a month = 61 hrs.	*4th grade = 71 avg. hrs per school year *5th grade = 5 avg. hrs per school year
	Louisa	4	1 hour per day, 3 times per week, 3 weeks a month = 81 hrs.	
	Julie	5	5 times during school year = 5 hrs.	
Sycamore	Danielle	4	3 times per week, 25 weeks = 75 hrs.	*4th grade = 97.5 avg. hrs per school year *6th grade = 45 avg. hrs. per school year
	Rachel	4	4 times per week, 30 weeks = 120 hrs.	
	Rich	6	1 hour per day, 2 times per week, 25 weeks = 50 hrs.	
	Clair	6	1 hour per day, 2 times per week, 20 weeks = 40 hrs.	
Watershed	Joanna	4	30 - 45 minutes per day, 2 times per week, 36 weeks = 36 - 54 hrs.	*4th grade = 36 – 54 avg. hrs. per school year *5th/6th grade = 120 avg. hrs. per school year
	Jen	4	30 - 45 minutes per day, 2 times per week, 36 weeks = 36 - 54 hrs.	
	Gina	5	1 hour per day, 4 times per week, 30 weeks (includes science fair preparation) = 120 hrs.	
	Michele	6	1 hour per day, 4 times per week, 30 weeks (includes science fair preparation) = 120 hrs.	
	Mary	6	1 hour per day, 4 times per week, 30 weeks (includes science fair preparation) = 120 hrs.	

The effect of AYP status on principal prioritization of science. A school's history of meeting AYP seemed to affect principals' prioritization of science. For example, the results suggested that being In Improvement for 2 years had a negative effect on the Rivers' principals' prioritization of science. When asked whether their principal prioritized science as a subject, Louisa from Rivers explained:

> No…I guess the reason is because we're in school reform… This is our second year in school reform and science is not counted towards adequate yearly progress, so our whole focus is reading and math and [science] is kind-of talked down. (Louisa, Interview 2)

The Rivers' principal confirmed these sentiments. When asked how science compared to other subjects in importance, she commented, "Most of the things that we do…goes to language arts because we have to pass CRTs in that area" (Principal N, Interview).

Sycamore did not pass AYP in 2006-2007, though it did pass in subsequent years, and therefore was not in In Improvement. It was clear, however, that the principal was pressured to focus on language arts and math even though he believed science was important for elementary students. When asked about the barriers at Sycamore to implementing inquiry science, he explained, "[Science] has been an ugly stepsister in [testing] because even if you do poorly, which we have done, you don't have heavy consequences or mediation support and training to do science" (Principal B, Interview).

Sycamore's teachers echoed these sentiments. For example, when asked whether Principal B prioritized science as a subject, Danielle responded, "No, I do not think so…it's reading and math…because that's what everybody looks at. When we have data studies, nobody looks at science. Honestly science isn't important here" (Danielle, Interview 2).

Table 4.5

Comparisons Across Schools of RTOP Scores, Number of Hours Spent Teaching Science, and Percentage of Time Discussing Science in Same-Grade Meetings

School	**Average RTOP scores (average per data collection period)**	**Number hours spent teaching science per grade level (average per school year)**	**Percentage of time spent discussing science in same-grade planning meetings per grade (average per week)**
Rivers	FallY1 = 22 WinterY1 = 33.7 SpringY1 = 38 FallY2 = 41.8 WinterY2 = 43.2	* 4th grade = 71 average hrs. *5th grade = 5 avg. hrs.	*4th grade: 0 - 5%. Plus daily or weekly informal discussions with other PSIA teacher. *5th grade: 0% * No 6th grade teachers
Sycamore	FallY1 = 24.8 WinterY1 = 47.3 SpringY1 = 51.9 FallY2 = 52.4 WinterY2 = 54	*4th grade = 97.5 avg. hrs. *6th grade = 45 avg. hrs.	*4th grade: Before each new unit begins, about 50% of meeting time. Otherwise, 5%. Plus, weekly informal discussions with other PSIA teacher. *No 5th grade teachers *6th grade: 0%
Watershed (without first-year teacher)	FallY1 = 37.2 (44.6) WinterY1 = 49 (56.2) SpringY1 = 54.7 (57.4) FallY2 = 56.2 (56.75) WinterY2 = 53 (56.75)	* 4th grade = 36 – 54 avg. hrs. *5th grade = 120 avg. hrs. *6th grade = 120 avg. hrs.	*4th grade: 25%, especially at beginning of the year to organize all materials and make yearlong lesson plans *5th/6th grade: 20%

In contrast, Watershed had passed AYP for the past 6 years. The principal had informed her teachers that science teaching was a priority since it was tested on the CRTs. Principal H explained her belief that science is important:

> I know a lot of the emphasis is just on language arts and math…we really feel like science is an important part of the curriculum…. We really encourage our teachers to make sure they're getting in the correct amount of time for science and getting that to the students. (Principal H., Interview)

When asked about the principal's prioritization of science, a Watershed teacher reported, "She expects the science to be going on. She expects things to be fit in" (Gina, Interview 2).

In sum, the results suggest the following. A relationship existed between principal prioritization of science and teachers' average RTOP. Principal science prioritization was more closely related to teachers' average RTOP scores than teachers' *change* in RTOP scores. Principal prioritization of science may be more closely related to teachers' RTOP scores than principals' support of reform-based instructional strategies. Finally, principal prioritization of science was influenced by a school's AYP status.

Factor 3: Having easy access to relevant materials and supplies and receiving training in their use. Receiving much-needed materials and training on the use of these materials contributed to the significant increase in teachers' inquiry practice scores in Year 1. This factor contributed more directly to inquiry change scores in Year 1 than in Year 2; however, the maintenance or continuation of improvement in scores from Year 1 through Year 2 would only be possible with appropriate materials and proper training in their use.

A number of findings were related to teachers' need for materials, supplies, and training at the Title I schools in this study. First, teachers from each school reported lacking in supplies in Year 1. Second, gaining relevant materials and training facilitated teaching through inquiry. Third, teachers were reluctant to ask principals for funds for science materials. Fourth, a yearlong professional development program was a recognized source of the necessary materials and training. Each of these findings is discussed in this section.

Teachers are lacking in science materials and supplies. All of the teachers reported that their school was in need of new supplies and replenishments of old supplies. For example, the teachers from Sycamore expressed frustration with their lack of materials and felt that they needed to gain new materials in order to teach science effectively. Clair, a sixth-grade teacher, explained:

> When I was the science teacher before…we did all kinds of really cool experiments. But that's not going to happen here.… It's hard to find the middle ground between being in a science lab [before] and now where I don't even have running water. (Clair, Interview 1)

Rich, another sixth-grade teacher, echoed Clair's comments, "We need science help. Get me a textbook, get me whatever because I know that this is a very inadequate way to present the material…I need more resources. I need manipulatives. I need charts" (Rich, Interview 1). Fourth-grade teacher Danielle explained her frustration with the lack of materials at Sycamore, "We're supposed to have all of these big giant tubs of all the books, and all the videos, and we have nothing in them" (Danielle, Interview 2).

Sycamore's Principal B provided an explanation for the lack of materials at his school and other Title I schools:

> The trouble is most of the hands-on stuff takes time to gather the resources and materials and some of the stuff we have to pay for. What we're seeing is as the budget crunches come out that a lot of times we're trying to do the teaching without the actual materials…. And they're wearing out and they're very expensive—ten times the cost now. So what we're finding is the physical cost of replacing microscopes and all the things needed for real, quality hands-on learning is not available for [elementary] schools anymore. [The District] is not giving priority to doing those things because it's not a part of the accountability assessments. (Principal B, Interview)

Although Watershed teachers had more and better-organized supplies than the other schools before the PSIA program began, the teachers acknowledged that one incentive for participating in the program was to the gain the materials they were lacking. Mary explained, "The idea that there would actually be materials available was a real big incentive [to join PSIA] because that's been one of my biggest frustrations is trying to get that science material together" (Mary, Interview 1). Joanna commented, "We're always lacking in money and materials" (Joanna, Interview 1).

Materials and supplies, and training to use them facilitates teaching through inquiry. Teachers entered PSIA claiming to be open to incorporating inquiry, but they felt limited by the few inquiry-appropriate resources at their schools. The results also indicated that teachers required training to effectively utilize materials through inquiry. When asked about obstacles to teaching through inquiry, Louisa responded:

> "I think the time it takes, the money it takes to get the materials…and it seems like so much of it is consumable. We made terrariums and sent them home. The stuff's gone. To make terrariums again, I have to buy all that stuff again" (Louisa, Interview 2).

Julie reported needing materials and supplies along with professional development support to implement the inquiry she knew from her preservice program. When asked in Year 2 whether she felt she now had the materials she needed, she replied:

> I do. Especially from the PSIA program. It's just a matter of pulling them out and shuffling through them and getting them ready to go. It's not hard, I've just got to do it… I got so many great materials from the PSIA program that I really have not been in need of any science materials at all. That might not be the case a couple of years down the road when I'm running out of supplies! (Julie, Interview 2)

In her Year 2 interview, Clair explained how obtaining materials through the PSIA program had enabled her to teach through inquiry:

> I have the supplies and stuff. For example, that's the tub for light, it's labeled, and so I was able to just grab it, and I had everything there. I would say this year I've done probably as much or more inquiry-based lessons as I did last year because…I finally had the supplies because I didn't actually have anything before. (Clair, Interview 2)

Mary reported how having materials contributed to whether she taught through inquiry:

> If I have materials readily available, that are easy to set up, and it's not a long complicated experiment, then I'm much more likely to do inquiry-type science

> than if I have to round up all of the stuff and there are a bazillion parts to it. (Mary, Interview 2)

Tanya described how she needed training in using materials in her inquiry teaching. “But I need to know, [for] the materials I have, how to use them more effectively” (Tanya, Interview 1). The Rivers principal explained that even though the teachers already had some science supplies, they were not using them. She reported, “I purchased all the [District-wide science and social studies curricula] stuff for them. The problem with that is it just sat there on the shelf and so I quit doing that” (Principal N, Interview). This lack of resource utilization likely occurred because the teachers were not trained in their use.

Teachers do not ask principals for funds for science materials. Teachers claimed feeling comfortable asking their principals for funds for materials. However, none of the teachers in either year had asked for money for materials or planned to do so. Danielle explained, “If we needed supplies, [Principal B] would get them no problem” (Danielle, Interview 2). However, the data showed she had never asked for funds, even though she had felt her school was lacking in supplies.

Louisa also felt she could ask her principal for money, though she did not do so for science. “To be honest, it's never even occurred to me. Because we ask for money for field trips and we ask for money for other things, so I don't know if I dare do one more thing” (Louisa, Interview 2). Clair, from Sycamore, echoed these sentiments:

> There's been so much focus on reading and math…. I think if I said ‘Can I have $20 worth of thermometers or something,’ as long as there was still money in my legislative funds, [Principal B] would have no problem with it. He probably would, but we haven't really approached him. (Clair, Interview 2)

Principal B provided an explanation for why teachers were not asking for materials and supplies money, “If we were putting a primary emphasis on science like we do in reading and math, they'd probably be asking. But honestly, I'm not asked about [purchasing science materials] anymore” (Principal B, Interview). These results suggest that elementary teachers do not ask for funds for science materials because it is just one subject of many they teach, and this subject is not a priority for most schools.

A yearlong professional development program can provide the necessary materials and training to implement inquiry. The teachers uniformly reported that they gained the materials and training they needed to teach using inquiry methods through participation in PSIA. For example, when asked how the PSIA program contributed to her stock of materials, Clair explained that she received exactly the supplies she needed for her classroom environment and her students’ specific needs:

> Like just the stuff [the elementary science specialist] gave us on Heat, Light, and Sound.... She got us the little plug-in kettle for hot water so that makes it so I can actually do things because I can have hot water. Just little things like that have made a big difference because of the availability of supplies—because I had no supplies. She asked us, ‘If you could have certain things, what things would you want?’ We listed things and she got [them]…. For us to able to list out what our specific needs are, that was good. (Clair, Interview 2)

Julie corroborated Clair’s statements, “I got so many great materials from PSIA that I really have not been in need of any science materials” (Julie, Interview 2).

In sum, these results suggest that materials and supplies, along with training in their use, facilitated teaching through inquiry. Elementary teachers tend not to ask principals for funds for science materials. Professional development programs can provide the necessary materials and training.

Summary. Three school-level factors were associated with changes in inquiry-based practice: (a) having collaborative same-grade teams that prioritized inquiry teaching and learning, and science as a subject; (b) principal prioritization of science as a subject; and (c) having easy access to relevant materials and supplies, and receiving training in their use.

The school-level factors differed in their impact on advancing change in teacher inquiry practice. The results suggest that, while principal prioritization of science is important, it plays less of a direct role than same-grade team support for inquiry. Access to materials and training were especially important in raising scores in Year 1, and contributed to the maintenance of these changes in Year 2.

Individual-Level Factor

This section describes the individual-level factor that relates most directly to inquiry practice changes in Year 2: the degree to which teachers were willing and ready to change their science teaching practice in fundamental, or paradigm-shifting, ways. This factor is belief-based, providing evidence for the strong relationship between beliefs and practice.

Factor 4: Degree of readiness and willingness to change in fundamental ways. All of the PSIA teachers joined the program with intentions of finding new and better ways to teach science. However, the teachers differed in their readiness and willingness to change their practice in fundamental ways. Qualitative analysis revealed three discreet levels of willingness and readiness to change. These levels are described below along with the teachers' individual RTOP scores across Years 1 and 2.

Level 1: Entering the program with a desire to gain new activities and resisting a paradigm shift toward inquiry. Several teachers entered the program wanting to gain new materials and activities to use in their classroom. Even though these teachers claimed to support inquiry, their descriptions of their experience during PSIA and the following year revealed that they were not willing (or yet willing) to changing their beliefs about teaching and learning to reflect inquiry ideologies. Their RTOP results indicated that these *level 1* teachers increased their scores by 20 points at some period during the 2 years; however, their scores at the end of Year 2 tended to return to where they began in Year 1.

For example, Louisa, a fourth-grade Rivers teacher, reported that she came into the program wanting a bank of activities. In her Year 1 interview, Louisa expressed displeasure with the program, indicating that it was not meeting her desire to gain new, effective activities:

> It seems like the [PSIA leaders] are trying to find stuff to meet our core instead of saying, 'This is what I did when I taught this lesson or when I taught this objective or content area.' Sometimes, as teachers we just want to know 'Well, what can we turn around and do with our kids tomorrow. What can we do next week?' Or, 'I'm teaching this in two weeks. What are some activities?' Sometimes we forget to take a step back and look at the bigger picture. (Louisa, Interview 1)

Although inquiry teaching and learning is effective in the retention of information, Louisa was not open to experiencing it as such. For example:

> I just would like more information on ways to successfully teach the students to get them to retain.... How do I get them to remember that [content] past the few minutes we're doing this lesson or activity? I wish I had just a really specific bank of activities.... Like, 'Here are three activities to teach this objective and here's this center.' (Louisa, Interview 1)

In her Year 2 interview, however, some of Louisa's statements suggested that she began recognizing her own need for a shift in her beliefs. Further, she recognized the difficulty of changing one's belief system and teaching practice. She began to reflect and talk about the change process, though she had not yet begun to undertake change:

> I think I am drawing a lot from the experience of last year, but I think it will take a while to process…. It's like every month, 'Okay, now you need to do this.' Are you kidding me? I've already changed so many other things or adapted.... A significant change like this takes years and years. So, there is no expectation at all [on my part] that it would have happened in just a year. (Louisa, Interview 2)

Louisa's inquiry practice scores, shown in Figure 4.9, reflected her resistance to changing her beliefs in fundamental ways. While her RTOP scores fluctuated over the 2 years, her practice did not change in a sustained way, and ended in the same place where she started at the beginning of the program.

Similarly, Joanna, a fourth-grade teacher from Watershed, was not ready or willing to shift her beliefs during the 2 years toward an inquiry orientation. Joanna was dubious about the effectiveness of inquiry and vacillated in her support of it as a teaching method, even though she had studied inquiry recently in her teacher preparatory program. "The big thing now is inquiry…. It changes all the time, the best way to teach kids, the best practices" (Joanna, Interview 1).

Joanna showed resistance to learning through the PSIA program and even requested that the elementary science specialist not visit her classroom because she felt nervous by her presence. When asked what aspects of the Academy she had incorporated into her teaching, Joanna was uncertain what had been covered in the Academy. She stated, "Well, unless I have my book with me, I forget what we've done. Definitely a

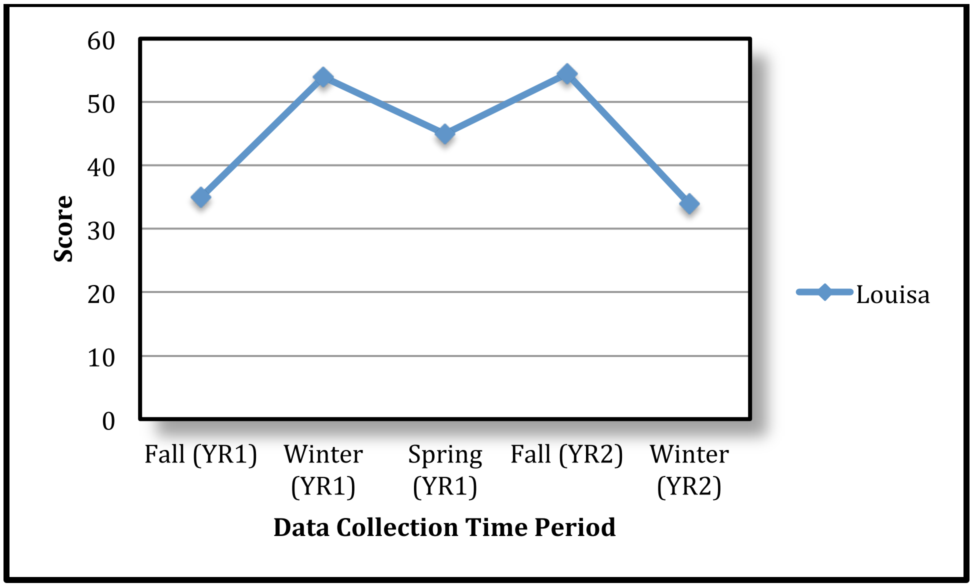


Figure 4.9. Louisa's RTOP scores in Years 1 and 2.

focus on inquiry, going about it that way…. I was pretty disappointed that I couldn't bring [activities] right back [to my classroom]" (Joanna, Interview 1).

As shown in Figure 4.10, Joanna's inquiry practice scores decreased slightly in Year 1, increased slightly in Year 2, and ended at her Year 1 baseline score. These scores reflected her skepticism about incorporating the inquiry beliefs and practices into her existing teaching paradigm.

Level 2: Entering the program with an interest in improving teaching techniques and expressing a willingness to reflect on one's own teaching practice. Teachers in the *level 2* category also entered the program desiring an improvement in their teaching practices by gaining new instructional techniques. However, they demonstrated a willingness to reflect on their practice. The RTOP scores of all three *level 2* teachers increased 30 points over the course of the 2 study years.

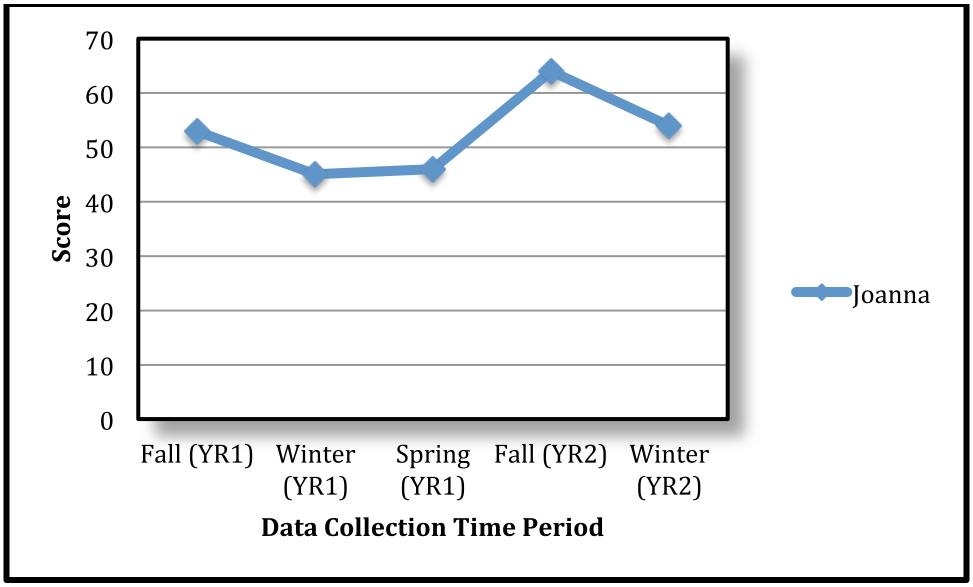


Figure 4.10. Joanna's RTOP scores in Years 1 and 2.

For example, Mary, a Watershed teacher, described her goals for the program as:

> I went into [PSIA] wanting a better foundation as far as a sequence of learning …I don't know if I wanted more confidence or if I wanted some time and the motivation to think through 'How do I involve [students] more?' [PSIA] has given me that.… I am more ready to bump [my teaching] to the next level. (Mary, Interview 1)

Mary's RTOP scores, as shown in Figure 4.11, increased substantially in Year 1, declined slightly and then remained steady during the rest of the study period. This suggests that her willingness and readiness to change influenced her RTOP score gains to a higher degree than occurred for the *level 1* teachers.

When asked about her goals for joining PSIA, Gina responded: "Do more inquiry. Raise CRT scores. Develop in the kids a real love of science so that, no matter what happens down the road, it will be something they are curious about and want to learn more about independently" (Gina, Interview 1). She described some of the changes she noticed in her own beliefs and science teaching practice:

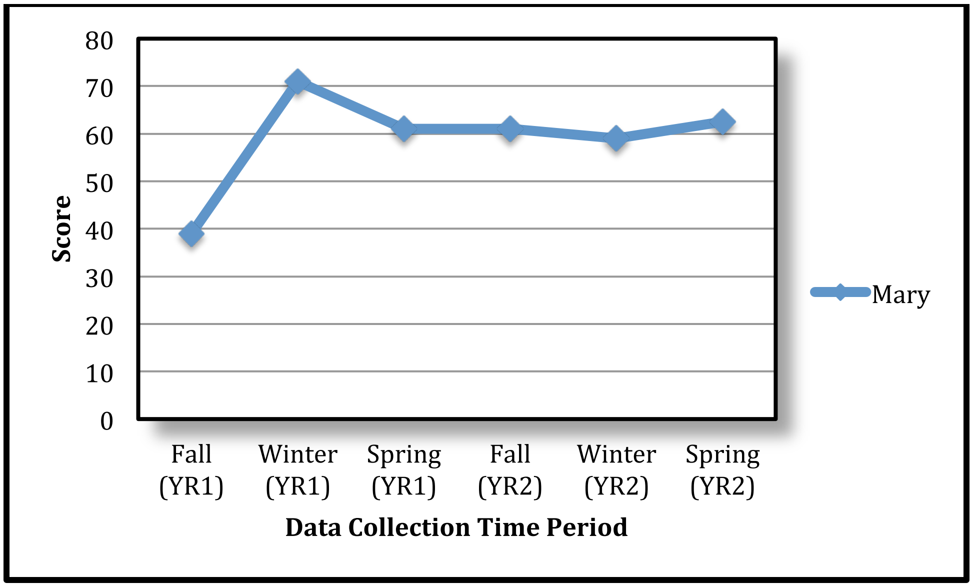


Figure 4.11. Mary's RTOP scores in Years 1 and 2.

> I try to do more inquiry now. Start with a question rather than jumping right into 'This is the content you need to know.' I am trying harder to do that.… [The program leaders] have spent quite a bit of time showing different strategies that follow the inquiry model. It's made it more evident to me that it's something I need to do more of. (Gina, Interview 1)

As shown in Figure 4.12, Gina's RTOP scores reflected her change over the 2 years. Her scores increased substantially in Year 1. While her scores declined slightly in Year 2, they were significantly higher (around 25 points) at the end of the study than at the beginning.

Tanya, a fourth-grade teacher from Rivers, was initially resistant to inquiry because of the preparation time. In Year 1 she explained, "I think the inquiry method is probably the ideal, but a lot of times I feel like I don't have the time—it's trying to get things set out, prepared. Preparation is overwhelming, especially as an elementary school teacher" (Tanya, Interview 1).

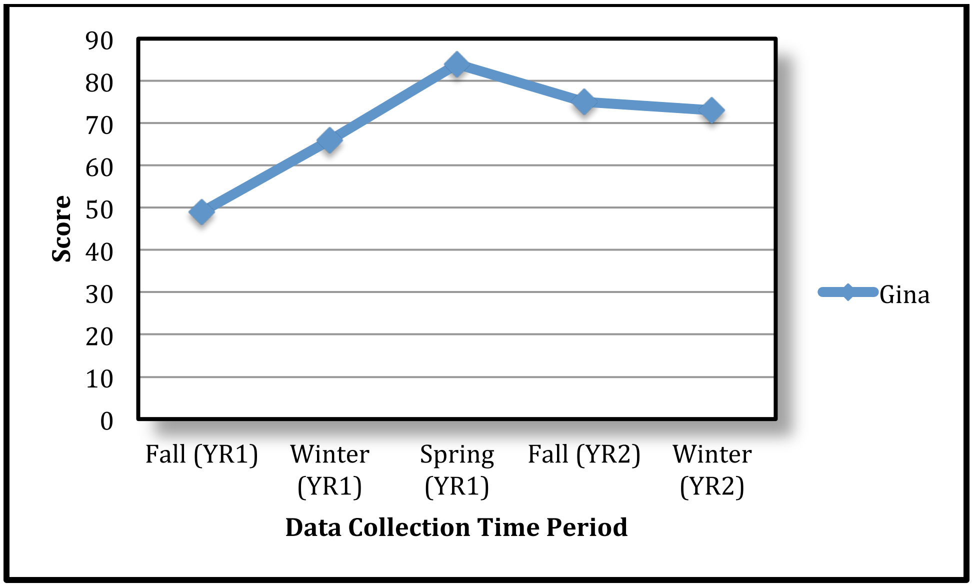


Figure 4.12. Gina's RTOP scores in Years 1 and 2.

As the PSIA program progressed, she shifted in her ideas about inquiry as an effective way to teach and learn science. Through reflection, in Year 2 she changed her beliefs about inquiry teaching as being suitable for her:

> I see that if they discover how something works, they interact to remember it longer.… I usually give them an opportunity to find the answer…and they have to be able to explain how they came up with that answer. I try to incorporate that in my lesson plans because I think if they are able to discover an answer or be able to back up that answer, justify that answer, they're more apt to remember what they found. (Tanya, interview 2)

Tanya's RTOP scores reflected her moderate shift over the 2 years toward a more inquiry-based practice (see Figure 4.13).

So, while Tanya, Mary, and Gina did gain some inquiry strategies that they incorporated into their practice, they did not experience a fundamental paradigm shift in their beliefs, which could influence inquiry practice substantially. The fundamental shift experienced by the *level 3* teachers is described next.

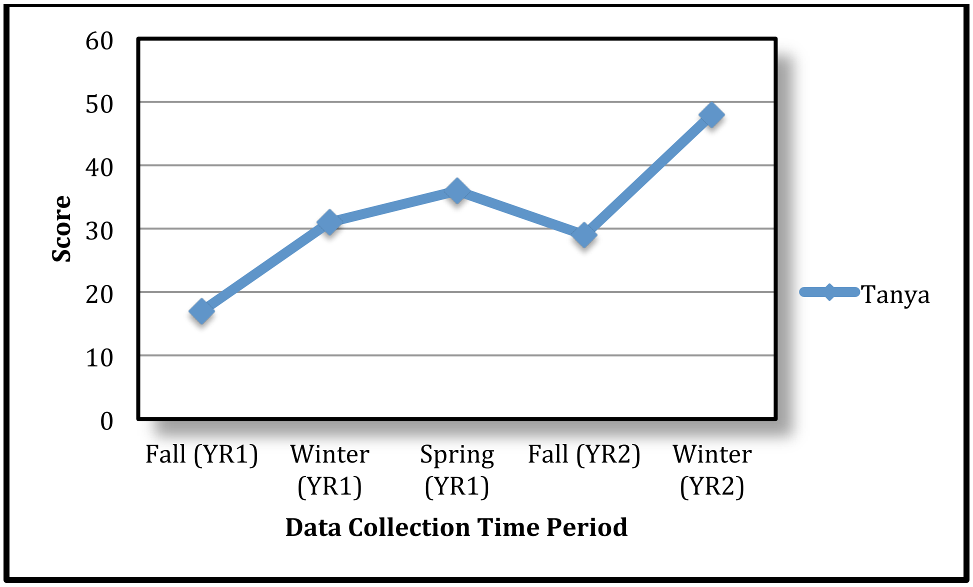


Figure 4.13. Tanya's RTOP scores in Years 1 and 2.

Level 3: Regardless of initial goals for the program, having a willingness and readiness to change in ways that resulted in a fundamental orientation shift toward inquiry. The *level 3* teachers came to the program with varying expectations; however, all of these teachers experienced a fundamental shift in their beliefs about student learning toward an inquiry orientation. These teachers were also successful in implementing inquiry into their practice, as reflected in RTOP scores that increased substantially at some point during the 2 years. The teachers in the *level 3* category increased in their RTOP scores between 20 points to nearly 50 points. While the RTOP scores of some of these teachers were similar to the *level 2* teachers, the quality of their belief change distinguished the two groups.

Danielle, a fourth-grade Sycamore teacher, was open and eager to gain content knowledge and change her teaching beliefs and practices through PSIA. In Year 1, she described her teaching practices as teacher-centered and her hopes for learning more about inquiry:

> I use direct instruction just because I think that's what science is for the most part. Of course there are the experiments to go with it, but most of it is direct instruction.... I don't know so much about science and how to get it ingrained in their head.... I found that with the first unit, with weather, that I don't know how to make it inquiry-based. (Danielle, Interview 1)

When asked what she hoped to gain from PSIA, she explained:

> I would like some help with science. I'm all about getting help because I need it and I know that I need it.... [I want] to learn more about [science], and I do want the kids to do it on their own just to see if they can justify it, right or wrong.... Enthusiasm for [science] is the main thing, and understanding [science content] a little bit more. And you know, I would like to do some experiments, (Danielle, Interview 1)

In Year 2, Danielle had changed in her beliefs about how students learn, and gained an understanding of how she could teach through inquiry. In reflecting about the changes she had experienced in her science teaching, she described more inquiry-based instruction and an increased enthusiasm for teaching the subject:

> Because of [PSIA] I'm willing to do [science] and try new things. I want the kids to like science, like to find the answer, know that it's okay to be wrong.... Science is...an investigation. (Danielle, Interview 2)

She also described her conscious effort to create a more student-centered classroom. "I'm starting to let them explore on their own. That was a big thing from last year, me letting go, which was such a big control issue for me. I think it's getting better for me personally" (Danielle, Interview 2).

As Figure 4.14 shows, Danielle's RTOP scores increased nearly 50 points during the 2 years. This substantial increase reflects her willingness to shift toward a more inquiry-based orientation.

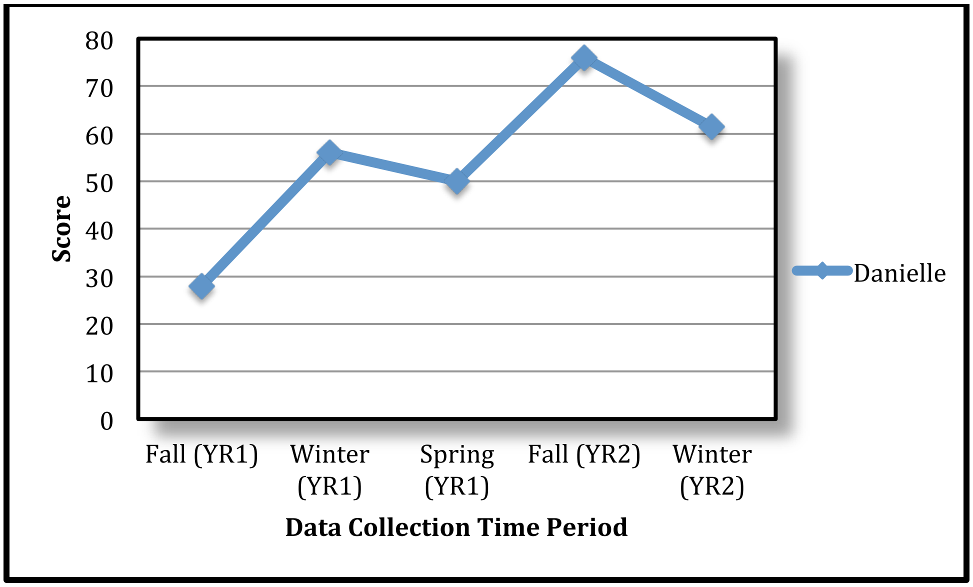


Figure 4.14. Danielle's RTOP scores in Years 1 and 2.

Having taught for over 30 years, Rachel was initially resistant to learning from the inquiry-intensive approach taken by the PSIA program. For example, she wanted PSIA to provide her with lessons that had the "wow" factor. In Year 1, she explained:

> I'd like to have some 'wow!' stuff that every day that I came back I can say, 'Oh wow! I learned this really new cool thing. Let's try it out.' Those were my expectations of what I was going to get to do..... Let me come back and say, 'I was away from you yesterday and look what we get to do now!' (Rachel, Interview 1)

When asked how she would like to change and what her goals for her learning through PSIA were, Rachel described the ideal lessons she would like to acquire rather than any changes in her beliefs or understandings:

> I just would like to have lessons that would be better and would explain science easier to the kids. There is a so much terminology with fourth grade. If there were just a cool way to introduce what we're doing, a cool way to play with what we're doing. (Rachel, Interview 1)

Judging by her statements in Year 1, Rachel felt that PSIA was not a success for her learning. However, her Year 2 interview reflected just the opposite sentiment. In this interview, she claimed that the program had made a significant improvement in her teaching and that she more completely understood and appreciated how to teach through inquiry. For example, she described an all-day inquiry experience she had organized early in Year 2 at her school:

> So we've done a really cool thing this year in our team in the fourth grade that I learned [in PSIA]. We have just started to do these big discovery days at the end of every unit. The first one was called 'Water Day,' and throughout the water unit, all of us on our team wrote down questions the children had. Like, 'Will ice melt faster in the shade than in the sun?' and, 'Will ice water get hot at the same rate as unfrozen water if we set them in the sun?' We did an entire day of their experiments.... Watching them be able to ask questions throughout [while] learning something…was phenomenal. (Rachel, Interview 2)

Although Rachel had claimed to support inquiry teaching before beginning PSIA, her interview data reflected a PSIA-influenced development in her understanding of inquiry and how to implement it. The results suggest that this increased understanding, in turn, fostered a paradigm shift toward greater beliefs about the effectiveness of inquiry. In Year 2, for example, she enthusiastically explained her implementation of investigative science in her classroom, "With the rocks cycle unit, of course, we're doing the mock rocks, and I feel like that's investigative, investigative the whole way along, and that's really fun" (Rachel, Interview 2).

Rachel's inquiry-based practice scores showed growth over the 2 years (see Figure 4.15), though not as substantially as Danielle's scores. An explanation for this may be that Rachel came into the PSIA program with high baseline scores and was already an effective science teacher before the program began. While her beliefs changed significantly, her already-high practice scores may have prevented a dramatic increase in these scores.

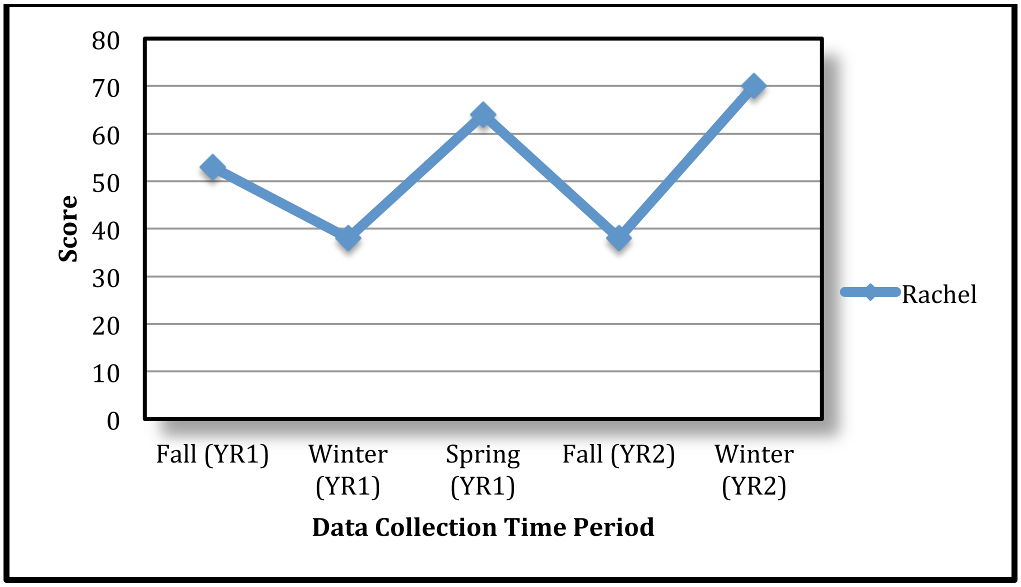


Figure 4.15. Rachel's RTOP scores in Years 1 and 2.

Julie, a fifth-grade teacher from Rivers, had studied inquiry science in her pre-service program 5 years prior. She reported coming into PSIA understanding how to implement inquiry and believing it was an effective way to teach and learn. "I had a good experience in my science methods class.… We kept a journal, went out to the Great Salt Lake, and came up with a science experiment. We went through all the different steps of the scientific process" (Julie F, Interview 1).

Still, in her Year 1 interview Julie described feeling that inquiry was not appropriate for her student population. Though she supported teaching through this method in theory, she did not teach this way in her classroom:

> A lot of these kids don't stay on task. They need a constant finger on them, and that's unfortunate because not every kid is like that, but a lot of them see [science time] as a time to play and goof around.… So I'm really hesitant to do a lot of the hands-on stuff, plus it takes so much time. If science was the only thing I was teaching, it wouldn't be a big deal, but it's very hard. (Julie, Interview 1)

When asked about her goals for her learning in the PSIA program, she explained wanting to learn to use inquiry-based practices:

> I would like to have a classroom that is more inquiry-based. I would like to be able to give the kids more responsibility and not just be the person that's up there saying, 'Yes, that's correct,' and 'No, that's wrong.' So I'm trying to move in that direction, but I'm hesitant just because of past experiences I've had at this school. I know how much energy it takes to do in-depth science with these kids, so a lot of times, just for the classroom management issues, I just stick to very controllable things…. [Participating in PSIA] would be a fun opportunity to learn more. Get more out of science. (Julie, Interview 1)

Further, she expressed a willingness to change her beliefs about the appropriateness of this method for her student population.

By Year 2 Julie had changed in fundamental ways in her beliefs about the feasibility of implementing inquiry with her students, indicating that she now believed that inquiry was possible with them. When asked about her role as a science teacher and the changes she had experienced in her teaching since PSIA, she explained:

> My role is to help them understand that science is about experience and experiments and that you don't always have to get an answer. It's more about hands-on learning and just going through the process of scientific observation and things of that nature. (Julie, Interview 2)

She went on to describe further changes in her teaching:

> Well, I think I'm able to crowd control a little better.... I know that for a lot of teachers it's kind-of chaotic to do that, and I kind-of invite the chaos. I like the kids to be able to discover and have fun. So, maybe I'm more open to them exploring and finding things out for themselves, and not being afraid to mess up as a teacher because, for me, that's a lesson to teach them to just say, 'this is part of science.' (Julie, Interview 2)

As shown in Figure 4.16, Julie's scores increased steadily by greater than 30 points across the 2 years. She experienced continued growth from baseline to the end of Year 2, reflecting the change in her beliefs about inquiry as effective for her student population.

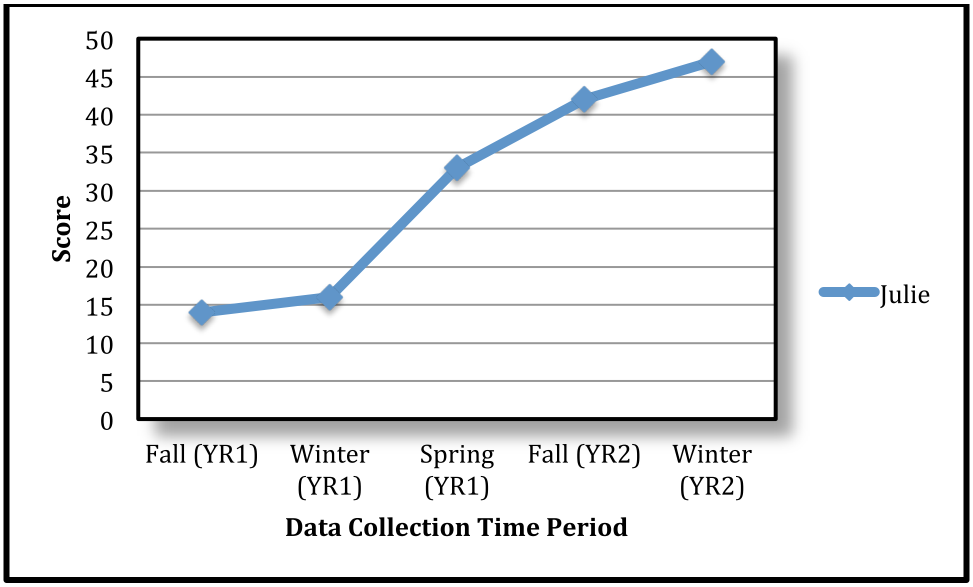


Figure 4.16. Julie's RTOP scores in Years 1 and 2.

Rich, a sixth-grade teacher at Sycamore, experienced fundamental change in his inquiry beliefs over the study period. He entered PSIA desperate for science help, and reported being open to any type of assistance. Before the program, he had taught using traditional, teacher-centered practices. Rich's Year 2 interview data demonstrated the turnaround in his beliefs and approach to teaching that were more inquiry-oriented:

> I have changed my whole approach to the scientific process and my *modus operandi* has changed completely because I've been willing to take more risks but it's a lot more responsibility and effort on my part. [Inquiry teaching] is very labor intensive and it requires an incredible amount of procedural practice, modeling.... I was not willing to risk anything [last year]. (Rich, Interview 2)

He described his buy-in for inquiry after participating in PSIA:

> This inquiry method is completely revolutionary in my opinion because it's not the traditional approach.… Now through inquiry you put things in their hands. Literally, they play with it. They can manipulate it. You know if they are kinesthetic they get the hands on [experience]. The ESL kids are accommodated. You get the different personalities and the different ways that the brain functions as far as learning styles are all accommodated. (Rich, Interview 2)

Rich's inquiry scores at baseline reflected his traditional, teacher-centered instructional approach (See Figure 4.17). His scores increased by greater than 45 points across the 2 study years, though they declined significantly from the Winter of Year 1 to the Fall of Year 2, then increased again. The decrease may have been due to school-based factors.

In sum, all of the teachers joined PSIA in order to find new and better ways to teach science. The study data revealed that the level of teachers' readiness and willingness to change their pre-existing beliefs about effective teaching and learning in *fundamental* ways varied across the participants. Fundamental belief changes can result in significant changes in practice.

Secondary Findings

The data revealed other, related findings that were either not directly addressed by the research questions in this study, or indicated suggestive rather than conclusive

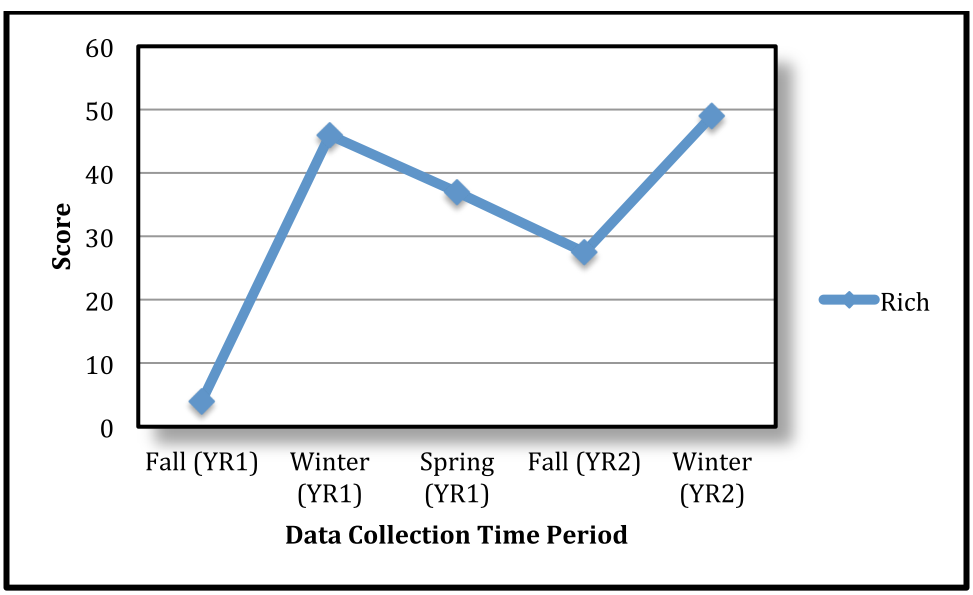


Figure 4.17. Rich's RTOP scores in Years 1 and 2.

findings. They were increases in teachers' self-efficacy and outcome efficacy beliefs, and teachers' enjoyment of science as a subject. These increases may be related, as efficacy beliefs in teaching can bring added enjoyment of the subject.

Efficacy beliefs. Teachers' efficacy beliefs are common in the education literature. Self-efficacy beliefs refer to one's own competence to teach science, while outcome efficacy beliefs are teachers' expectations that they can influence student learning (Pajares, 1997). Although investigating changes in efficacy beliefs was not part of the original research questions for this study, the results from an efficacy beliefs survey administered to the study participants will be briefly described with the goal of providing a more comprehensive picture of the factors involved in teacher change.

Teacher participants had completed the Science Teaching Efficacy Belief Instrument (STEBI) (Riggs and Knochs, 1990) survey at the same time as the BARSTL and MOSART surveys (Fall of Year 1, Spring of Year 1, and Spring of Year 2). A one-way within-subjects analysis of variance was conducted to uncover changes in teachers' efficacy beliefs over the 2 years. The results revealed statistically significant increases across Years 1 and 2, Wilks' $\Delta = .24$, $F(2,10) = 15.61$, $p < .01$, $n^2 = .76$). Follow-up pairwise tests indicated statistically significant increases during Year 1, $t(14) = 5.13$, $p < .001$. While scores increased in Year 2, the increase was not statistically significant.

The relationship between teachers' efficacy scores and their inquiry practice scores (RTOP scores) was not clear across both study years. In Year 1, the relationship between efficacy beliefs scores and inquiry practice was clear and direct—teachers' efficacy scores increased dramatically during the professional development year, as did their inquiry practice scores. However, in Year 2, when individual participants scores were analyzed, some teachers' efficacy scores increased steadily, but their inquiry practice scores did not (for example, Rich and Clair). For others, both practice and efficacy scores increased significantly across both years (for example, Gina and Tanya), or both their practice and efficacy scores fluctuated across the 2 years (for example, Louisa and Joanna).

A brief analysis of the qualitative data supported a positive relationship between efficacy beliefs and practice scores across both years. For example, both Danielle and Julie, whose RTOP scores increased significantly in both years, described greater feelings of efficacy in their science teaching from their participation in PSIA.

Teachers' enjoyment of science. All of the teachers who participated in PSIA believed that science was important as a subject; therefore, this belief type did not distinguish the teachers from one another. Differences were found in whether teachers reported enjoying science as a subject, and may be related to change in practice scores in Year 2.

The following descriptions show a relationship between teachers' enjoyment of science and their RTOP scores. Teachers were not directly asked about their enjoyment of science during the interviews; rather many of them offered it as one of their strengths as a science teacher. Danielle, who experienced significant change in practice in both years, did not enjoy science at the onset of PSIA. In Year 1, she explained, "I guess the thing I struggle with the most about science is that I don't find it interesting" (Danielle, Interview 1). By Year 2, she claimed she was enjoying science and science teaching considerably more. She explained:

> The Academy has shown me that science can be fun and that I can teach it.… It's funny, I was walking with my dad and I'm like, 'Dad, that's a cumulus cloud,'

> and he's like, 'Why do you care?' 'Because I have to teach it!' It's so funny that I look at clouds now in a whole different way. (Danielle, Interview 2)

Julie, whose inquiry scores also increased significantly across both years, explained, "I like science and therefore I hope that my [enthusiasm] gets to my students too" (Julie, Interview 1). Gina, a Watershed teacher who experienced growth in her inquiry practice scores over the 2 years, reported, "I love the subject. I used to be a science major for three years in England before I came here" (Gina, Interview 2).

However, while some teachers who enjoyed science experienced growth in their inquiry practice scores in Year 2, other teachers who enjoyed science did not experience substantial or even incremental growth in Year 2. For example, Joanna reported loving science, especially her grade-level core, but her scores remained approximately the same during the 2 years of the study. Clair, whose favorite subject is science, experienced substantial growth in her scores in Year 1, then a decline in Year 2.

The study findings suggest, therefore, that enjoying science as a subject may play a role in teachers' inquiry practice score increase. However, this factor alone did not have conclusive explanatory or predictive value for change in inquiry practice.

In sum, teachers' enjoyment of science and teachers' efficacy beliefs contributed to some degree to changes in their inquiry-based practice scores. Additionally, enjoyment and efficacy are likely related to one another.

Discussion: Research Question Two

The results from research question one revealed that, as a group, teachers' inquiry-based practice, inquiry-based beliefs, and physical science content knowledge scores increased significantly during the professional development year. The PSIA professional development program was a yearlong, reform-based experience during which teachers received inquiry training, support, and materials. In the year following the professional development, only content knowledge scores increased significantly, while practice and belief scores increased slightly.

Research question two examined the school factors that impacted the participants' change in the three measures in the year following the professional development program. While all three measures were examined, explanations for change in practice were the focus of the analysis.

The results from research question two indicated that a combination of school-level and individual-level factors impacted changes in practice in the year following PSIA. This finding supports previous research concluding that both contextual and personal factors influenced the implementation of reform-based teaching practices in novice teachers' science (Appleton & Kindt, 1999) and math instruction (Steele, 2001). Research on novice teachers provides a useful and appropriate parallel to understanding the experiences of teachers following an intensive professional development experience.

Finding 1: Collaborative Same-Grade Teams

The most influential school-level factor for continued teacher change in inquiry practice for participants in this study was having collaborative same-grade teams and/or a supportive mentor who advocated inquiry science and prioritized science as a subject. Much literature has shown the influential role colleagues in elementary schools play on one another's practice.

Ishler et al. (1998) explained, "The degree to which [elementary] teachers learn new practices depends on who socializes with whom (e.g., the extent to which there is a learning community) and what they do together (the content of their social interactions and how it affects learning to teach)" (p. 361). In a review of the teacher change literature, Richardson and Placier (2001) described research that placed collegial support second in importance only after the influence of students in teacher socialization. Further, the authors reported that teachers in effective schools were more likely to receive help and information from other teachers than teachers from ineffective schools.

Research has demonstrated that teacher change in the workplace was associated with collaborative rather than individualistic practices. Appleton and Kindt (1999) found that collegial support was related to novice elementary teachers' willingness to try non-traditional instructional methods. In many of these studies, however, it was unclear whether the collegial collaboration described was specific to same-grade teams.

Recognizing the importance of collegial support and collaboration, some schools have organized "professional learning communities," also known as "communities of practice," in which staff provide "meaningful and sustained assistance to one another to improve teaching and student learning" (Sparks, 2002, p. 6-2). These are formal groups that meet regularly and provide assistance to one another on a technical and social level. Oftentimes, however, these groups are enforced by administration, without buy-in from teachers, resulting in forced groups instead of "community-building approaches to generate energy and sustain long-term commitment" (Sparks, 2002, p. 6-2).

The study results speak to the need for administrators and professional development providers to recognize the importance of same-grade team collegiality in elementary schools. These leaders can support teachers in their learning and change process through encouraging team building. Further, they can establish expectations for same-grade collaboration, establishment of shared goals, and productive same-grade team meetings that organize and plan the science curriculum. Additionally, if it is culturally appropriate at their school, administrators can place a teacher or specialist who is knowledgeable about inquiry in a leadership position to support the rest of the team.

Finding 2: Degree of Willingness to Change in Fundamental Ways

The willingness and readiness of teachers participating in this study to change in their inquiry beliefs was found to relate to change in their inquiry practice. This finding lends further support for literature that has found that changes in teacher beliefs are explanatory factors in teacher change in practice (Pajares, 1992; van Driel et al., 2000).

More specifically, the study results indicated that the *degree* to which teachers were ready and willing to change their inquiry beliefs in fundamental ways was related to the amount of change in their inquiry scores in the year following professional development. This finding supports Richardson and Placier (2001), who concluded that teachers' willingness to change in practice might depend on their attitudes and beliefs toward teaching and learning.

Interestingly, teachers' statements prior to the professional development did not always reflect their willingness to change their beliefs or the extent to which their practice scores changed in the PSIA year or in the following year. These findings suggest that teachers' comments prior to beginning a professional development program are not enough to predict who might benefit the most from such a program. Teachers may be influenced by numerous experiences that may alter their beliefs and practices during and after professional development. They may be influenced, for example, by the ways in which their students respond to the new instructional practices (Loucks-Horsley et al., 2003), by their colleagues, or by their administration, among other influences.

Finding 3: Materials and Training

The results revealed that providing teachers with materials and training on their use was critical for inquiry practice change in Year 1 and contributed to the maintenance or increases in scores in Year 2. The teachers from all three schools reported having a significant need for materials before the program began.

This finding supports Appleton and Kindt (1999) in their investigation of the impacts of elementary school contexts on the science teaching practices of novice teachers. They found that availability and accessibility of resources for science and organization of the resources at the teachers' schools determined the instructional practices they used to teach certain topics within science. Further, the researchers found that resource availability determined the types of science topics covered. Similarly, Schoeneberger and Russell (1986) reported that elementary principals found it difficult to make equipment and materials available to teachers. This finding highlights the need for professional development programs serving teachers from Title I schools to provide materials and training on these materials.

Finding 4: Principal Prioritization of Science

Principal prioritization of science was also found to impact teachers' inquiry practice scores. This impact, however, was on teachers' *average* practice scores rather than on their *change* scores. Nonetheless, principal prioritization indirectly influenced teacher change in practice through mandating or encouraging same-grade team collaboration in science. Interestingly, principal understanding and support of the science reforms did not appear to impact teachers' inquiry scores.

Principal prioritization of science was impacted by their school's history of meeting AYP, and the ramifications of being in Title I: In Improvement. Principals at the schools where science was not a priority cited pressure from the district to focus on the subjects required for making AYP (math and language arts). Because principals have a large impact on their school culture (Guskey, 2002b), making AYP therefore had a significant effect on the science culture at each school.

These findings are consistent with other research advocating strong alignment between the goals of professional development, school administration, and the district in order for teachers to successfully implement reform-based practices (Sparks, 2002). Johnson (2007) concluded that in order for middle school teachers to successfully change their science instruction to more reform-based practices, administrators must provide resources and protection from outside forces (including district pressures) that can hinder teachers' attempts to improve their practice. Guskey (2002a) explained that a "lack of organizational support and change can sabotage any professional development effort, even when all the individual aspects of professional development are done right" (p. 47).

Finally, the results suggested that while principal prioritization of science is an important school-level factor, same-grade collaboration may be more influential in inquiry practice change. Having effective same-grade teams with strong team leaders can mitigate the effects of an unsupportive administrator.

Secondary Findings

Two additional study findings provide a more comprehensive picture of the many factors involved in teacher change in inquiry practices. These findings indicated that increases in teachers' efficacy beliefs and enjoyment of science were, to some extent, related to increases in inquiry practice scores. These findings combined with the other findings demonstrate the complex nature of teacher change, and the many school-level and individual-level factors involved in this process.

Summary

The Physical Science Inquiry Academy professional development program impacted teachers' inquiry-based practice, inquiry-based beliefs, and physical science content knowledge. Teachers' scores in all three outcome measures rose significantly during the professional development year, indicating that the PSIA program influenced teachers to change during the year.

This difference was sustained or increased in the year after the program ended. For the participants in this study, a combination of school-level factors and individual-level factors were shown to influence the maintenance or continuation of these changes. Same-grade collaboration, support, and/or mentorship in teaching through inquiry along with having a personal willingness to change in fundamental ways appeared to impact change the most in the year immediately following the professional development.

Materials, and adequate training in their use, were essential for growth in inquiry implementation in Year 1 and contributed to the maintenance of the growth in Year 2. While the influence of school administration was an important school-level factor, having effective same-grade teams can mitigate the effects of an unsupportive principal. In this study, lack of full principal support seemed to have stemmed from concerns over meeting Adequate Yearly Progress (AYP).

These results demonstrated the importance of determining the contextual factors in teachers' schools that might facilitate or hinder the impacts made by professional development in the year following the program. Further, it is important to determine the personal factors that influence teachers' learning during and following professional development. The study conclusions, recommendations for elementary professional development providers and school administrators, and suggestions for future research are presented in Chapter 5.

CHAPTER 5

CONCLUSIONS AND IMPLICATIONS

This study examined the impact of a yearlong reform-based professional development program on teachers' inquiry-based practice, inquiry-based beliefs, and physical science content knowledge. Specifically, the study investigated: (a) Whether changes in these three characteristics were advanced, maintained, or reversed in the year following the program, and (b) the school and individual factors that influenced these changes.

This chapter will first present the study conclusions, along with their implications for practice and research. The study limitations and suggestions for future research conclude the chapter.

Summary of Results

The study results indicated that the PSIA professional development program was effective in advancing teacher change during the program year, as scores in all three measures (practice, beliefs, and content knowledge) increased at statistically significant rates. Further, scores increased in all three measures during the year following the professional development program; however, only the content knowledge scores increased significantly. Qualitative data from teacher interviews corroborated the survey findings about teachers' beliefs and practices.

A combination of school-level and individual-level factors impacted the Year 2 changes. School-level factors were: (a) having supportive same-grade teams and/or a supportive mentor who advocated inquiry science and who prioritized science as a subject, (b) principal prioritization of science, and (c) having easy access to and training in the use of relevant materials. The primary individual-level factor that impacted change was degree of teachers' willingness and readiness to change beliefs in fundamental ways.

Conclusions

Based on the study results, the following conclusions can be drawn about the impacts of professional development during a program year, and the impacts of school-level and individual-level variables on teacher change in the year following professional development:

1. A yearlong, reform-based professional development program can foster changes in elementary school teachers' inquiry-based practice, inquiry-based beliefs, and content knowledge during the professional development year.
2. Materials and training in their use are *critical* for change toward inquiry teaching and learning in schools that have few science materials and supplies and/or training in using them.
3. Fundamental change in teacher beliefs and practice is a gradual process. As a result, 1 year of professional development is not sufficient to advance comprehensive and thorough change in all teachers.
4. Changes in teacher practice and beliefs during a professional development program can be sustained and continued once the program is over. School supports are required to maintain or enhance this learning.

5. Effective same-grade teams with strong team leaders can mitigate the effects of an unsupportive administrator.
6. Not all teachers are open or willing to change. For these teachers, it is unlikely that professional development will result in substantial changes. However, it is not always clear at the beginning of a project which teachers will embrace change from their demographic profile or self-described goals.
7. Participation in previous high-quality inquiry-based programs appears to enhance the comprehensiveness and skillfulness of teacher inquiry implementation, fosters deeper understandings of inquiry, and may be an indicator of willingness to change.
8. NCLB Title I: In improvement status negatively affects principal prioritization of science and, therefore, the science learning in elementary schools.

Implications for Practice

The implications of the study findings for professional development providers and school administrators are presented in this section.

Professional Development

To change teacher beliefs and practice, professional development needs to include specific features. Professional development should:

1. Focus on providing a comprehensive understanding of inquiry. If the program uses the 5 E model, for example, it is important to focus time and resources on all five elements. Without such an understanding, teachers may only implement selected aspects of an inquiry-based lesson. However, this result may also be an

indication that change takes time, and incorporating all five elements may not be possible in 1 or 2 years.

2. Provide support and encouragement for belief and practice change to occur. Teachers must be supported during the professional development sessions and in their classrooms in order to undergo significant transformations in their beliefs about teaching and learning, and in their practices. Such transformations result in an increased focus on student learning, one of the goals of the science reforms.

3. Provide materials and supplies, and training in their use. Teachers must have relevant science materials easily accessible in order to implement the inquiry-based approaches they experience during professional development. Further, they must know how and when to use certain materials in order to achieve specific content area learning goals.

4. Offer a support structure for same-grade teams. Grade level support appears to be more important than cross-grade support. Professional development providers should encourage same-grade teams from each school to participate together in professional development.

5. When funds are limited, schools should be selected to participate based on administrative support for science as a subject and school features such as same-grade collaboration and support, or the potential for such collegial support. This will provide a greater opportunity for the investment in science professional development to pay off and be successful. Further, professional development programs can provide education for principals about how to maintain the reform-based changes after a professional development program ends.

School Administration

To maintain or enhance the changes in teacher beliefs and practice following professional development, school administrators (principals) should do the following:

1. Encourage or set expectations for same-grade teams to work collaboratively on inquiry-based science planning and implementation. Additionally, they can encourage or mandate same-grade team participation in professional development.
2. Prioritize science teaching. By prioritizing science, principals foster a culture of favorable attitudes toward science and implementation of reform practices. Principal prioritization of science enhances the quality of teachers' inquiry implementation and the amount of time they allot to science teaching.
3. Support reforms through developing staff expertise. Principals do not need to understand the reforms in order to impact inquiry practices. They can hire or assign knowledgeable staff members to leadership positions. Principals can establish partnerships with local universities that can assist in science education at that school.
4. Provide materials and access to training in using the materials. Principals should be aware that teachers tend not to ask for funds for science materials, so an understanding that funds will be available for science should be established. Further, principals should encourage teachers to participate in reform-based science professional development in which training on inquiry-based materials is provided.

5. Participate in professional development. Principals can participate in some aspects of science professional development programs in order to create alignment between program goals and school-level goals.
6. Be aware of the deleterious effects of AYP status on science teaching and learning. Awareness of the detrimental results of prioritizing math and language arts over science could encourage principals to re-consider the type of culture they establish in their school. To counteract this, principals could encourage teachers to participate in science professional development, establish a culture of prioritization of science despite district pressures, and facilitate same-grade support in the school for teaching science.

Implications for Research

The implications of the study findings and conclusions for research are discussed in this section. Specifically, implications for instrument use and methodology are presented.

Instrumentation

The difficulty of the MOSART physical science tests varied by grade level. Because of this discrepancy, it was inappropriate to draw conclusions about the relationship between content knowledge and practice. Pilot testing the MOSART tests with a similar population and making the appropriate item adjustments would have resolved these issues. Further, the reliability coefficient on this instrument was low.

Methodology

1. What teachers report they do and what they actually do in practice can differ. Some researchers describe a strong correlation between teachers' self-reports about their teaching practice and others' observations of their teaching practices (Desimone, 2009). In this study, however, teachers often reported using inquiry methods in the classroom that could not be supported by classroom observations. Teachers' actions, therefore, may not have caught up to their beliefs or desires. Teachers may begin to have beliefs about change and can verbalize these beliefs but the skills or actions are not yet in place.
2. The timing for conducting the lesson observations should be carefully planned to reflect authentic practice. In the study state, the state-wide criterion-referenced testing occurred in late March and early April for schools with traditional calendars and in March through June for year-round schools. Most teacher participants did not want to be observed more than 3 weeks before the testing began because they were reviewing. Likewise, observations conducted after the testing may not have reflected teachers' regular teaching practice because students were deemed to be fatigued after testing. Based on this finding, it is recommended that observations be planned to respond to teachers concerns surrounding the state's standardized testing schedule.
3. Using multiple *types* of data is effective in understanding trends in outcomes across teacher participants. In this study, using multiple types of data enabled analyses of patterns in different ways that were systematic. This allowed for the recognition of patterns and for the development of explanations for them.

4. Using multiple *sources* of data enhanced the validity of the study findings. In this study, data were collected from numerous sources: teachers, principals, and researcher observations. Pajares (1992) and Richardson (1996) also recommend using multiple data sources to study the complex nature of teacher beliefs.

Limitations

The findings from this study suggest that reform-based professional development can significantly impact change in teachers' inquiry practice, inquiry beliefs, and content knowledge. Further, school and individual factors can impact the continuation or maintenance of increases in these outcomes in the year following the professional development.

The limitations of this study include the following. The study population was small and they were volunteers. This situation, however, is typical of inservice professional development programs and is difficult to avoid in professional development research. The small subject number, only 15 teachers in Year 1 and 12 teachers in Year 2, reduces the statistical significance of the quantitative data.

Only three schools were investigated in this study. Because each school is unique (Ishler et al., 1998), and because the number of schools studied was small, it is difficult to generalize the conclusions to other schools. In other words, the conclusions about contextual influences may not apply uniformly to Title I elementary schools.

Single RTOP scores (scores for one data collection period) should not be considered in isolation; rather, patterns across the five data collection periods should be used in data interpretation. A single lesson may receive a low score for many reasons and may not necessarily reflect a teachers' skill level or willingness to teach through inquiry.

Explanations for a low RTOP score include unexpected occurrences that prevented inquiry preparedness, being observed when teaching a topic not conducive to inquiry, or being observed in Year 1 before the topic had been covered in PSIA.

The MOSART physical science test varied in difficulty by grade level and had a low reliability coefficient. It was difficult, therefore, to make conclusions about the relationship between content knowledge and practice.

The PSIA program was a new program during study Year 1. Lessons learned from this initial year were used to improve and enhance the program in the subsequent two years of PSIA. Improvements included monthly classroom support visits from the elementary science specialist instead of visits that occurred only three times during the year (or more upon request). While PSIA had elements of high quality professional development, results may have differed if teachers from the second two cohorts were study participants instead of the first cohort.

Finally, two members of the program staff were involved in data collection: the researcher and the elementary science education specialist. The researcher also served as the program evaluator for PSIA and as a result became familiar and friendly with the teachers in the program. The researcher was in an observer role throughout the study period and was not in a position of teaching or authority. The researcher was involved in 75% of the program planning meetings. The use of quantitative data and the triangulation of qualitative data sources served to decrease the researcher bias that may have developed over the course of the study. Still, it should be recognized that the presence of the researcher and the elementary science education specialist in teachers' classrooms may have influenced the teachers. For example, the research activities likely promoted more reflection and inquiry implementation than if the research and the classroom observations had not been conducted.

Future Research

This study demonstrated that a reform-based professional development program can result in significant increases in teachers' practice, beliefs, and content knowledge. By following teachers through the year subsequent to a professional development program, this study highlighted the importance of school variables (grade-level support, prioritization of science, and access to and training in materials and supplies) and individual variables (a willingness and readiness to change beliefs and practice) in fostering continued change.

Several future avenues for research are suggested by this study:

1. *Study continuation*. How will changes in study participants' practice, beliefs, and content knowledge evolve in future years? What are the differences in the maintenance of changes in schools where principals deemphasize science compared to schools where principals prioritize science?
2. *Teachers' demographic beliefs*. What impact can science professional development have on teachers' demographic beliefs about student science learning (teachers' beliefs in the abilities of their students to learn science)? What impact does school science culture have on teachers' demographic beliefs about student science learning? Researchers advocate conducting more research into the relationship between teachers' demographic beliefs and inquiry practice (Duschl et al., 2007; Lee, 2004).

3. *Same-grade teams in the presence of an unsupportive administrator*. Do same-grade teams require the presence of a strong teacher who has taken on a leadership position in order to counteract the effects of the lack of principal support? How do teachers change the culture in their schools instead of the school culture socializing them (Richardson & Placier, 2001)? What qualities do teachers who change school culture possess that makes this possible?
4. *Impact of previous inquiry-based programs*. What are the elements of previous professional development programs that affect the quality of teachers' inquiry implementation during a current program? What is the relationship between time that has passed since previous professional development and level of inquiry implementation? Can participation in previous inquiry-based programs act as an indicator of readiness and a predictor of success for future professional development programs?
5. *Impact of professional development on student achievement*. What is the impact of professional development on students' science standardized test (CRT) scores? Does professional development in science impact math and reading scores? Many researchers suggest that the relationship between professional development and student achievement merits further investigation (Guskey, 2003; Lee, 2004; Richardson & Placier, 2001).

Future research into these topics could contribute to knowledge of how to design and implement successful professional development programs. Such programs would lead to sustained teacher changes in beliefs and practices, and most significantly, to increased student achievement and science understanding.

APPENDIX A

LETTER TO TEACHER PARTIPANTS FOR MEETING CHECKING

Dear PSIA teachers,

I hope all is wonderful with each of you. I'm working hard on analyzing the data I've collected over the past two years about the PSIA program, its impacts on your teaching, and your science teaching experiences in the year following your PSIA participation.

I have completed a preliminary analysis of all of your surveys and interviews for the past two years. Attached is what I have found so far.

Could you please take a look at the attached one-page paper and let me know what you think of my conclusions? An important part of understanding whether my results are accurate is your feedback. The first part of the paper is an explanation of the results. The second part is the summary section, which is where you may want to focus your feedback.

In short, do you think these findings are accurate and reflect your experience of the last two years? If not, please explain how your experience is different that what is written in the paper.

I also have graphs that I've made for each of you on the results of the surveys you took over the past two years. Please let me know if you'd be interested in seeing your graph. I would be extremely interested in your reaction and in any comments you would have on the patterns of change over the two years.

Thank you, in advance, for your time.

Best,

Dina

APPENDIX B

LETTER TO PRINCIPAL PARTICIPANTS

FOR MEMBER CHECKING

Dear Principal X,

I hope you are having an enjoyable summer so far!

I have completed a preliminary analysis of the survey and interview data I collected from the teachers at your school who participated in the PSIA science professional development program in 2008-2009. This is the program for which I conducted an interview with you approximately 6 months ago.

The attached document includes a summary of my findings to date. Could you please take a look at this one-page paper and let me know what you think of my conclusions so far? An important part of validating the results is your and your teachers' feedback.

In short, do you think these findings are accurate and reflect your understanding of teachers' experiences during and following professional development in science?

Thank you, in advance, for your time.

Best,

Dina

APPENDIX C

SUMMARY OF FINDINGS FOR MEMBER CHECKING

RESULTS

Year 1 = 2008-2009 school year, the PSIA year
Year 2 = 2009-2010 school year, the year following PSIA participation

Findings: Surveys and Content Knowledge Tests

Inquiry practice survey. There was a substantial increase during the PSIA year (Year 1) and a slight increase during the year following PSIA (Year 2).

Inquiry beliefs survey. There was a substantial increase during Year 1 and a slight increase in Year 2.

Physical science content knowledge tests. There was a substantial increase during Years 1 and 2.

These results also showed that there were differences between schools and between same-grade teams within schools: the number of hours spent teaching science, average inquiry-based practice scores, and the number of hours spent discussing science in meetings.

Explanations for Findings

Year 1: The PSIA program was effective in raising teachers' scores during this year.

Year 2: A combination of school-level and individual-level factors was responsible for changes in teachers' practice.

School-level factors

(a) Same grade teams. Having supportive and collaborative same-grade teams that prioritized the teaching of science were related to increases in inquiry teaching in Year 2.

(b) Having a principal who prioritizes science as a subject.

(c) Having easy access to relevant materials and supplies, and receiving training in their use.

Individual-level factors

(d) Having a willingness and readiness to change beliefs and practice in fundamental ways

Summary

(1) The PSIA program was effective in advancing teacher change in inquiry practice, inquiry beliefs, and content knowledge.

(2) Both school-level and individual-level teacher factors were necessary for continued change in inquiry practice in Year 2.

(3) The factors that most influenced changes in inquiry teaching in Year 2 were:

- Same-grade support and/or mentorship for science as a subject and inquiry science instruction.
- Principal prioritization of science.
- Easy access to relevant materials and training in their use.
- A willingness/openness to change beliefs and practice in fundamental ways.

APPENDIX D

RTOP SCALES WITH SCORING RUBRIC

Teacher Name ___________________________
Lesson Topic/Grade Level____
Date of Tape RTOP Date Score

	ITEM	0	1	2	3	4
	Lesson Design					
1	**The instructional *strategies and activities* respected students' prior knowledge and the preconceptions inherent therein.**	No evidence	Teacher asks students to write or describe their previous knowledge of a topic before starting instruction.	In addition to asking for previous knowledge, class time is spent discussing student ideas and how they relate to the current or previous activity.	The teacher actively solicits student ideas and discussion of these ideas takes place **throughout** the lesson. Students' prior knowledge is built upon throughout the lesson.	The teacher actively solicits student ideas and builds the lesson from their starting point. The direction of the lesson is shaped by student ideas.

	ITEM	0	1	2	3	4
2	**The lesson was *designed* to engage students as members of a learning community**	No evidence	Teacher-led interactions are limited to student-teacher exchanges. No ideas or understanding of concepts developed between students.	Teacher-student interactions develop concepts. Some student-student interactions (groups involved in hands-on but not minds-on activities); however little conceptual understanding is developed between students.	Good teacher-student interaction and development of concepts, which includes group construction of knowledge. Students interact with each other to construct some conceptual understanding.	Students interact with each other to construct understanding of concepts. Student-student interaction, group to group as well as whole group interaction to reach (or prior to) final consensus.
3	**In this lesson, student exploration preceded formal presentation**	No evidence	Students engage in exploration through teacher-led discussion or questioning with no activity and no negotiation of meaning between students.	Students engage in exploration through discussion, questioning, or activity prior to a formal presentation but teacher tells content to students before they discover it for themselves. Little negotiation of meaning occurs between students. Students rely on teacher for meaning.	Students engage in exploration through discussion, questioning, or activity prior to a formal presentation. Teacher and students negotiate meaning together with final teacher consensus.	Students engage in exploration through discussion, questioning, or activity prior to a formal presentation. Students negotiate meaning through the entire community of learners

	ITEM	0	1	2	3	4
4	**This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.**	No evidence	The teacher asks for student to share at least one other approach to the investigation, but this approach is not valued (condemned or does not receive further discussion)	The teacher encourages a variety of approaches to the problem, but then asks students to consider only his/her direction.	The teacher actively solicits a variety of approaches to the problem and shows respect to the suggestions by considering their feasibility. Students are not allowed to pursue their ideas through further discussion or action.	The teacher actively solicits a variety of approaches to the problem and shows respect to the suggestions by considering their feasibility. Students are encouraged to pursue their own investigation directions through discussion or action.
5	**The focus and direction of the lesson was often determined by ideas originating with students**	No evidence	Very teacher-directed lesson. The instructor answers questions that the students raise, but the teacher does not let the questions change the direction of the lesson.	*Somewhat teacher directed.* *The instructor answers questions that the students raise that may take the lesson in another direction. Discussion is allowed to follow the students' ideas.*	Somewhat student-directed. Students are allowed to direct their own participation in small groups or during a segment of the lesson.	Student-directed lesson. Student ideas set the focus and direction of the entire lesson.

Content: Propositional		0	1	2	3	4
6	**The lesson involved fundamental concepts of the subject**	No evidence	Most of the lesson not based on grade level appropriate, state or national standards.	Lesson is standards-based, but not presented at an appropriate level for the class being taught.	Lesson standards-based, taught at the appropriate level, significant scientific ideas not the main focus.	Lesson based on grade level appropriate standards, the scientific ideas covered are central to scientific knowledge.
7	**The lesson promoted strongly coherent conceptual understanding**	No evidence	Lesson presented concepts as un-connected pieces of knowledge.	Lesson did not encourage students to develop understanding of the inter-relatedness of concepts more than once.	Lesson encouraged students to make connections about the inter-relatedness of concepts several times.	Lesson clearly made evident the inter-relatedness of concepts throughout and involved **whole class discussion.**
8	**The teacher had a solid grasp of the subject matter content inherent in the lesson**	No evidence Many content errors.	Few content errors. Teacher could not answer with confidence many of the questions posed by students. Teacher hesitated or ignored many questions.	Few content errors. Teacher answered most questions with confidence, and answers were appropriate. Teacher answers did not help students form conceptual understanding.	No content errors. Teacher answered all questions posed by students correctly, but elaborated on only a few in order to aid students in developing conceptual understanding.	No content errors. Teacher demonstrated thorough mastery of content knowledge through the addressing of students' misconceptions and inaccurate responses, to the point of aiding students in developing conceptual understanding.

	ITEM	0	1	2	3	4
9	**Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so**	No evidence	The teacher and/or students did not use any drawings or props, and the teacher gave only verbal concrete examples of theory.	The teacher and/or students used drawings, props, and concrete examples only once or twice during the lesson. The examples were not used to build theory from the phenomenon.	The teacher and/or students used drawings, props, and concrete examples **throughout** the lesson, but the examples were not consistently used to build theory from the phenomena.	The teacher and/or students used drawings, props, and concrete examples throughout and used these examples to **consistently build theory** from the phenomenon.
10	**Connections with other content disciplines and/or real world phenomena were explored and valued**	No evidence	Only one real world application presented.	The teacher presented several everyday examples, but students do not make meaningful connections between the phenomena and everyday life and/or other content disciplines.	The teacher uses multiple applications and circumstances from everyday life. Students make some connections between the phenomena and everyday life and/or other content disciplines. Little development of conceptual understanding.	The teacher uses applications and circumstances from everyday life throughout the lesson. Students make multiple connections between the phenomena and everyday life and/or other content disciplines and use these connections to develop conceptual understanding.

Content: Procedural		0	1	2	3	4
11	**Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives) to represent phenomena**.	No evidence	Students used one approach to articulate ideas, but no analysis of information took place.	Students used at least one means to articulate their ideas and analyze their information. Some experimentation and data collection.	Students used at least two different means or two varieties of means to articulate ideas, analyze information. Little or no critical analysis of ideas.	Students used at least two different means or two varieties of means to articulate ideas, analyze information, and critique their idea.
12	**Students made predictions, estimations, and/or hypotheses and devised means for testing them (collecting and analyzing data) Conjecture evident.**	No evidence Teacher gives students informat ion needed to solve problem.	Students were given a hypothesis to test or discuss. Step by step process. No prediction. (Cookbook activity).	Students made predictions, but these predictions were followed up by classroom discussion and teacher directed explanations Method provided.	The students made predictions, devised a means to test the prediction, and collect data with some teacher guidance	The students explicitly made predictions, devised a means to test the predictions, and collected data without teacher guidance.

	ITEM	0	1	2	3	4
13	**Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.**	No evidence	Students engaged about how to do the activity (following procedures), but **do not question how or why**.	Students engaged about how to do the activity. Students **offer commentary** on the procedures.	Students knew what they were doing and why. Students could clarify steps in their investigations. Student **questions** and discussions exhibit their attempts to **construct conceptual understanding** from the activity. **No explicit** critical assessment of procedures.	Students knew what they were doing and why. Students could clarify steps in their investigations. Student questions/discussion evidenced their attempts to make connections and make meaning of their learning. **Explicit critical assessment** of procedures.
14	**Students were reflective about their learning.**	No evidence	Teacher asks **at least one** question, but it does not facilitate discussion or analysis.	Teacher asks questions that lead students to some discussion or analysis of ideas, but discussion is not critical of student knowledge.	Teacher's questions stimulate **critical** analysis of student knowledge. Students do exhibit **little to no independent reflection** exhibited by their questions.	Teacher's questions stimulate critical analysis of student knowledge. Students ask questions that are reflective, demonstrating that they are thinking about their learning.

	ITEM	0	1	2	3	4
15	**Intellectual rigor, constructive criticism, and the challenging of ideas were valued.**	No evidence	No competing ideas presented. Argumentation was not modeled or encouraged. Students were asked if they reached the correct conclusion, with explanation following by the instructor. Students do not present (report) findings.	At least two competing ideas were presented. Students reported their data, explained their conclusions, but received no critical questioning or challenge from the instructor.	The instructor asked students to provide evidence to support their conclusions, and that students explain how they reached their conclusion. Challenge and negotiation of conclusions was not encouraged. Findings presented by groups and discussed.	A variety of ideas was presented by the students and whole class or cross-group critique occurred. The instructor encouraged challenge and negotiation, and the instructor asked students for evidence to support their ideas. The instructor modeled argumentation.
Classroom Culture		**0**	**1**	**2**	**3**	**4**
16	**Students were involved in the communication of their ideas to others using a variety of means and media.**	No evidence Students did not share ideas. Alternative articulation not encouraged.	Communication between student and teacher consists of responses to teacher prompts. No variation. One medium used.	Communication is between students and teacher; may include varied media **or** group to group or whole group, but not all.	Variety of media used to communicate ideas, however, whole group or group to group communication may be missing.	Negotiation of meaning and alternative articulation of ideas encouraged. Whole class and group to group communication. Rationale presented; discussion/debate of ideas.

	ITEM	0	1	2	3	4
17	**The Teacher's questions triggered divergent modes of thinking.**	No evidence	Divergent thinking is not encouraged but is tolerated.	Divergent thinking encouraged, but *correct* answer sought.	Divergent thinking encouraged open answers directed to whole class.	Divergent thinking and open answers directed to groups of students.
18	**There was a high proportion of student talk and a significant amount of it occurred between and among students.**	No evidence. No talk among students. **Answering questions is not scored.**	Teacher talk is significantly greater than student discussion. Lesson is mostly teacher talk.	Students engaged in discussion, but teacher contributes significantly.	Student discussion is significantly greater than teacher talk	Lesson consists mostly of talk between and among students. Critical portions of the lesson were developed through student discourse.
19	**Student questions and comments often determined the focus and direction of classroom discourse.**	No evidence No student questions/comments.	Teacher answers student questions; however, discourse is teacher-determined and directed. No student-student discourse.	Student questions in groups or in whole class instruction are answered. Questions do not change focus or direction of discourse, but some student-student discourse occurs.	Students discuss in groups and with the instructor. Students are encouraged to ask questions. Teacher answers all questions and students may determine focus of some discourse.	Discussion includes group-to-group; student ideas are elicited at beginning of class and determine direction of discourse throughout the lesson.

	ITEM	0	1	2	3	4
20	**There was a climate of respect for what others had to say.**	No evidence	Teacher only acknowledges student remarks, but does not encourage elaboration.	Teacher actively encourages student remarks, however, elaboration is not encouraged and ideas are not explored freely.	Within groups, students share ideas and share ideas with the instructor; most ideas explored freely.	Ideas are shared and considered between groups and with the entire class. Students are allowed to explore ideas freely.
Student/Teacher Relationships		**0**	**1**	**2**	**3**	**4**
21	**Active participation of students was encouraged and valued.**	No evidence	Students answer questions, but provide no direction to questioning and do not contribute to development of description or explanation. Students simply follow directions (hands-on only)	Minimal minds-on. Teacher gives information. Students encouraged to answer and ask questions; teacher describes and explains.	Minds-on activity. Students actively participate in describing and explaining.	Students actively participate in describing and explaining. Student questions and remarks frame final description or explanation. Students have voice in how activity occurs.
22	**Students were encouraged to generate conjectures, alternative solution strategies, and/or different ways of interpreting evidence.**	No evidence	Students are encouraged to find the "right" answer.	Students are encouraged to think of different ways to solve a problem, however, emphasis is placed on "right" answer.	Students are encouraged to think of other ways to solve problems and to critique strategies. Discussion is primarily within groups.	The balance of responsibility for thought is shifted from teacher to student. Whole class discussion is evident. Critique of alternative solutions is evident.

	ITEM	0	1	2	3	4
23	**In general, the teacher was patient with students.**	No evidence. Teacher informs student “don’t go there, that’s for a later lesson” or ignores the student.	Teacher may provide “wait- time”, but does not allow students to explore phenomena. Teacher gives short answers to student questions.	Teacher provides good wait-time when directing questions to students. Teacher allows some student exploration, but directs student thinking and may tell correct answer.	In addition to good wait-time, the teacher allows students to explore phenomena and asks questions that promote student understanding. Teacher questions directed toward groups of students.	Teacher understands the gap between novice and expert and works to bridge the gap by providing students the opportunity to explore on student terms. Teacher incorporates use of data and gives priority to use of data to find answers.
24	**The teacher acted as a resource person, working to support and enhance student investigations.**	No evidence No student investigation or activity.	Teacher tells students how to complete the activity. Questions direct students to “right” answer. Teacher initiated activity and questioning.	Teacher answers questions. Student initiative tolerated but not encouraged.	Teacher does not “tell” students what to do. Teacher encourages student inquiry, but may be answering questions rather than asking probing questions.	Teacher does not “tell” students what to do. Initiative comes from student. Teacher encourages inquiry through probing questions.

	ITEM	0	1	2	3	4
25	**The metaphor “teacher as listener” was very characteristic of this classroom.**	No evidence No attempt to check initial knowledge or incorporate student ideas into lesson or to assess final understanding.	Teacher arbitrarily checks initial understanding. Lesson is directive.	Teacher checks initial understanding but does not allow students to develop understanding. Teacher check for final understanding is missing or minimal.	The teacher helps students construct further understanding, but teacher talk is directive. Student – teacher talk develops understanding. Teacher check for final understanding is substantial.	The teacher helps students use what they know to construct further understanding. Talk is centered around student ideas. Teacher and students are both actively listening.

Gates, H. A. (2008). Middle school science teachers' perspectives and practices of teaching through inquiry. Unpublished Doctoral Thesis. University of South Carolina.

Ruth, L. (2007). Impacts of project-based science in middle school classrooms. Unpublished Doctoral Thesis. University of South Carolina.

APPENDIX E

RTOP CATEGORIES WITH GUIDING CRITERIA ADAPTED

FOR ELEMENTARY SCHOOL SETTINGS

<u>LESSON DESIGN</u>

1.) The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.

- *Does the lesson involve evoking student misconceptions (what students know and don't know)?*
- *Does the lesson address what students know at the beginning of the lesson?*
- *Is an explicit connection made to other ideas that teachers have worked on in class (including in other subject areas and/or to the outside world)*

2.) The lesson was designed to engage students as members of a learning community.

- *Does the lesson at some point involve students working in groups/talking to their neighbors?*
- *Are students making decisions together?*
- *Are students sharing their ideas with their class members?*

3.) In this lesson, student exploration preceded formal presentation.

- *Are students given opportunities to explore before the material is presented as new knowledge for the students to understand?*
- *Is there opportunity for student ownership of the knowledge?*

4.) This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.

- *Is there opportunity for students to make their own decisions on how to find information?*

5.) The focus and direction of the lesson was often determined by ideas originating with student.

- *Is there opportunity for students' ideas and interests to influence teaching of the core curriculum?*

- *Is there skillful negotiation between teacher and student in what is covered in the lesson?*

CONTENT: PROPOSITIONAL

- *What the teacher knows/understands about the subject along with his/her ability to facilitate learning of abstract ideas in understandable ways to students.*

6.) The lesson involved fundamental concepts of the subject.

- *Is the lesson covering core content?*

7.) The lesson promoted strongly coherent conceptual understanding.

- *Does the lesson connect concepts, making evident their interrelatedness?*
- *Does the lesson tie to previous instruction in either science or to instruction/skills that can be productively used in science class?*

8.) The teacher had a solid grasp of the subject matter content inherent in the lesson.

- *Does the teacher thoroughly understand the subject matter covered in the lesson?*
- *Has the teacher resolved his/her own misconceptions?*
- *Has the teacher prepared for the lesson (e.g., worked with colleague, talked through content, studied, practiced teaching lesson, worked with coach?) before teaching lesson?*

9.) Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.

- *Is the teacher using or facilitating students' use of representations (e.g., pictures, graphs, models)?*
- *Is the teacher using and/or facilitating students' use of representations to build theory?*

10.) Connections with other content disciplines and/or real world phenomena were explored and valued.

- *Does the lesson cover how concepts/phenomena fit in the real world?*
- *Is teacher finding ways to show students that concepts/phenomena can be used/are seen outside of the classroom?*

CONTENT: PROCEDURAL

- *The process of using an inquiry model: Is the lesson set up well enough so that students can generate questions/answers on their own? Is there enough structure within the lesson where students can choose successfully what to explore and what to study? Is the lesson structured so students are interested and able to retrieve the information?*

11.) Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives) to represent phenomena.

- *Are students seeking and using structures (e.g., models, drawings, graphs) to represent data?*
- *Are students using structures to organize data, analyze data, and report on the data?*

12.) Students made predictions, estimations, and/or hypotheses and devised means for testing them (collecting and analyzing data) conjecture evident.

- *Are students making predictions/hypotheses based on their student exploration?*
- *Are students finding ways to test their predictions/hypotheses?*

13.) Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.

- *Are students aware and able to fully understand why they are undertaking the activities?*
- *Are students engaged in the critical assessment of the procedures used in the activities?*

14.) Students were reflective about their learning.

- *Do students form ideas and questions based on what they investigated?*
- *Do students evaluate their own learning processes (e.g., we wanted to know if...)?*
- *Do students evaluate their own attempts to find answers (e.g., since we tried it this way we found that…)?*
- *Are students given opportunities to recognize contrasts between what they thought would occur to actual results?*
- *Can students connect exploration to the focal concept?*

15.) Intellectual rigor, constructive criticism, and the challenging of ideas were valued.

- *Do class conversations/group conversations occur about the content of the lesson? Is the teacher encouraging these discussions?*
- *Does the teacher encourage thought-provoking questions from students based on evidence from student investigations?*
- *Do the teacher's questions promote classroom conversations where student ideas/ways of problem solving are skillfully challenged by others (i.e., how do you know?)?*

CLASSROOM CULTURE

- *Teacher pedagogy/management: What is the teacher's ability to organize "chaos," student interactions, student-centered learning?*

16.) Students were involved in the communication of their ideas to others using a variety of means and media.

- *Are students working and discussing ideas with one another in partnerships, groups, and as whole class?*
- *Are students using a variety of media in their communication of ideas to the teacher and/or one another (e.g., technology, something from real world)?*

17.) The teacher's questions triggered divergent modes of thinking.

- *Do the teacher's questions promote different ways of student thinking/solving problems?*

18.) There was a high proportion of student talk and a significant amount of it occurred between and among students.

- *Are students planning amongst themselves?*
- *Are students making discoveries together?*
- *Are students coming up with a plan of investigation together?*

19.) Student questions and comments often determined the focus and direction of classroom discourse.

- *Do student questions and ideas direct some of the learning in the classroom? (it is not possible to address all questions, but teacher can skillfully choose some that can be fruitful and direct students to find the answers, e.g., "so, how can we find out? ask a NASA representative…)*

20.) There was a climate of respect for what others had to say.

- *Is there equal partnership/give and take/balance in the room between the students and the teacher and between the students and other students.*

STUDENT/TEACHER RELATIONSHIPS

- *Teacher demeanor/teacher focus/lesson direction*

21.) Active participation of students was encouraged and valued.

- *Is there active student participation in describing and explaining the concept/phenomenon covered in the lesson?*
- *Is the "80% rule" of student on-task behavior present?*

22.) Students were encouraged to generate conjectures, alternative solution strategies, and/or different ways of interpreting evidence.

- *Do teachers skillfully challenge students to figure out alternative ways to understand/assess scientific phenomena, including during data collection, analysis and during the interpretation of the data?*

23.) In general, the teacher was patient with students.

- *Does the teacher act as facilitator?*
- *Does the teacher thank students for staying on task and for sharing ideas?*
- *Does the teacher monitor classroom behavior while allowing students to perform individual/group tasks?*

24.) The teacher acted as a resource person, working to support and enhance student investigations.

- *Does the teacher provide encouragement, feedback, and reinforcement during student investigation?*
- *Does the teacher provide encouragement and monitoring while students do investigations instead of the teacher being in charge of the investigations?*

25.) The metaphor "teacher as listener" was very characteristic of this classroom.

- *Is the teacher responsive to the direction in which the students are taking the discussions and activities?*

APPENDIX F

BELIEFS ABOUT REFORMED SCIENCE TEACHING AND

LEARNING (BARSTL)

Name __________________
Date __________________

How People Learn About Science

The statements below describe different viewpoints concerning the ways students learn about science. Based on your beliefs about how people learn, indicate if you agree or disagree with each of the statements below using the following scale…

1: Strongly Disagree 2: Disagree 3: Agree 4: Strongly Agree

	SD	D	A	SA
1. Students develop many beliefs about how the world works before they ever study about science in school.	1	2	3	4
2. Students learn in a disorderly fashion; they create their own knowledge by modifying their existing ideas in an effort to make sense of new and past experiences.	1	2	3	4

3. People are either talented at science or they are not, therefore student achievement in science is a reflection of their natural abilities.	1	2	3	4
4. Students are more likely to understand a scientific concept if the teacher explains the concept in a way that is clear and easy to understand.	1	2	3	4
5. Frequently, students have difficulty learning scientific concepts in school because their beliefs about how the world works are often resistant to change.	1	2	3	4
6. Learning science is an orderly process; students learn by gradually accumulating more information about a topic over time.	1	2	3	4
7. Students know very little about science before they learn it in school.	1	2	3	4
8. Students learn the most when they are able to test, discuss, and debate many possible answers during activities that involve social interaction.	1	2	3	4

Lesson Design and Implementation

The statements below describe different ways science lessons can be designed and taught in school. Based on your opinion of how science should be taught, indicate if you agree or disagree with each of the statements below using the following scale…
1: Strongly Disagree 2: Disagree 3: Agree 4: Strongly Agree

	SD	D	A	SA
9. During a lesson, students should explore and conduct their own experiments with hands-on materials before the teacher discusses any scientific concepts with them.	1	2	3	4
10. During a lesson, teachers should spend more time asking questions that trigger divergent ways of thinking than they do explaining the concept to students.	1	2	3	4

11. Whenever students conduct an experiment during a science lesson, the teacher should give step-by-step instructions for the students to follow in order to prevent confusion and to make sure students get the correct results.	1	2	3	4
12. Experiments should be included in lessons as a way to reinforce the scientific concepts students have already learned in class.	1	2	3	4
13. Lessons should be designed in a way that allows students to learn new concepts through inquiry instead of through a lecture, a reading or a demonstration.	1	2	3	4
14. During a lesson, students need to be given opportunities to test, debate and challenge ideas with their peers.	1	2	3	4
15. During a lesson, all of the students in the class should be encouraged to use the same approach for conducting an experiment or solving a problem.	1	2	3	4
16. Assessments in science classes should only be given after instruction is completed; that way the teacher can determine if the students have learned the material covered in class.	1	2	3	4

Characteristics of Teachers and the Learning Environment

The statements below describe different characteristics of teachers and classroom learning environments. Based on your opinion of what a good science teacher is like and what a classroom should be like, indicate if you agree or disagree with each of the statements below using the following scale…

1: Strongly Disagree 2: Disagree 3: Agree 4: Strongly Agree

	SD	D	A	SA
17. Students should do most of the talking in science classrooms.	1	2	3	4
18. Students should work independently as much as possible so they do not learn to rely on other students to do their work for them.	1	2	3	4
19. In science classrooms, students should be encouraged to challenge ideas while maintaining a climate of respect for what others have to say.	1	2	3	4
20. Teachers should allow students to help determine the direction and the focus of a lesson.	1	2	3	4
21. Students should be willing to accept the scientific ideas and theories presented to them during science class without question.	1	2	3	4
22. An excellent science teacher is someone who is really good at explaining complicated concepts clearly and simply so that everyone understands.	1	2	3	4
23. The teacher should motivate students to finish their work as quickly as possible.	1	2	3	4
24. Science teachers should primarily act as a resource person; working to support and enhance student investigations rather than explaining how things work.	1	2	3	4

The Nature of the Science Curriculum

The following statements describe different things that students can learn about in science while in school. Based on your opinion of what students should learn about during their science classes, indicate if you agree or disagree with each of the statements below using the following scale…

1: Strongly Disagree 2: Disagree 3: Agree 4: Strongly Agree

	SD	D	A	SA
25. A good science curriculum should focus on only a few scientific concepts a year, but in great detail.	1	2	3	4
26. The science curriculum should focus on the basic facts and skills of science that students will need to know later.	1	2	3	4
27. Students should know that scientific knowledge is discovered using the scientific method.	1	2	3	4
28. The science curriculum should encourage students to learn and value alternative modes of investigation or problem solving.	1	2	3	4
29. In order to prepare students for future classes, college, or a career in science the science curriculum should cover as many different topics as possible over the course of a school year.	1	2	3	4
30. The science curriculum should help students develop the reasoning skills and habits of mind necessary to do science.	1	2	3	4
31. Students should learn that all science is based on a single scientific method—a step-by-step procedure that begins with 'define the problem' and ends with 'reporting the results.'	1	2	3	4
32. A good science curriculum should focus on the history and nature of science and how science affects people and societies.	1	2	3	4

APPENDIX G

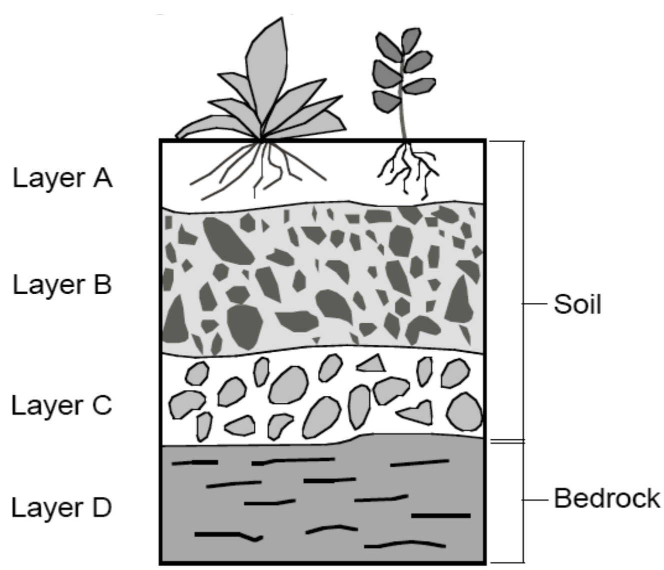
COMPILED MOSART TESTS

PHYSICAL SCIENCE TEST
GRADE 4

NAME ________________________________
DATE ________________

For some questions, there may be more than one correct answer. However, each question has only one best answer. Choose the single best answer from the five choices from each question.

1. Below is the diagram of a soil profile. Which layer contains organic material?



Which layer contains the most organic material?

a. A
b. B
c. C
d. D
e. They all have the same amount of organic material.

2. If mountains erode over long period of time, what can happen?
   a. The mountains decrease in height.
   b. Parts of the mountains become steeper.
   c. Valleys decrease in depth.
   d. Only two of the above can happen.
   e. a, b and c can all happen.

3. A metal pan of water is left on a counter. After a few days, there is less water in the pan. What most likely happened?
   a. Some water became part of the pan.
   b. Movement of the air pulled water out of the pan.
   c. Some water turned into oxygen and hydrogen.
   d. Some water went into the air as a gas.
   e. Some water no longer exists.

4. What is true about the evaporation of water?
   a. It happens only in the daytime when the sky is clear.
   b. It happens only when water boils.
   c. It happens when water changes from liquid to gas.
   d. Only two of the above are true.
   e. a, b and c are true.

5. Which is always true about a day when there are strong winds?
   a. There are lots of clouds.
   b. The air temperature is low.
   c. It is raining.
   d. The air is moving.
   e. All of the above.

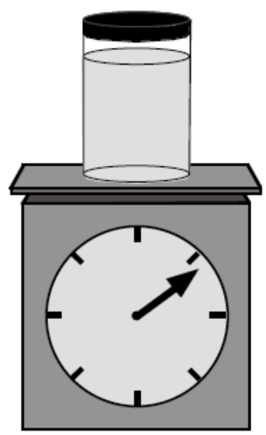
6. Minerals are in our water supply because:
   a. minerals are part of the chemical makeup of water.
   b. water evaporates from the ocean.
   c. people put minerals in water.
   d. water dissolves minerals in rock and soil.
   e. No one know why there are minerals in water.

7. What is true about all soils?
   a. They are the same color and texture.
   b. They contain weathered rock.
   c. They contain no air.
   d. They are very young.
   e. All of the above.

8. If you were flying inside a puffy looking cloud, you would see:
   a. smoke.
   b. fog.
   c. dust.
   d. cotton.
   e. All of the above are possible.

9. If there were no weathering and erosion, which type of rock would be least common?
   a. Sedimentary rock.
   b. Molten rock.
   c. Intrusive igneous rock.
   d. Extrusive igneous rock.
   e. Metamorphic rock.

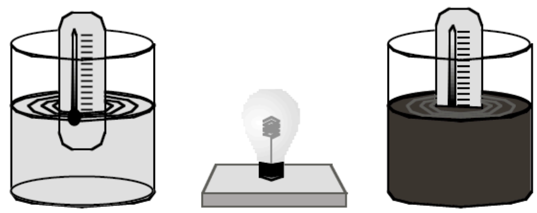
10. Hot water in a sealed container is weighed on a scale.



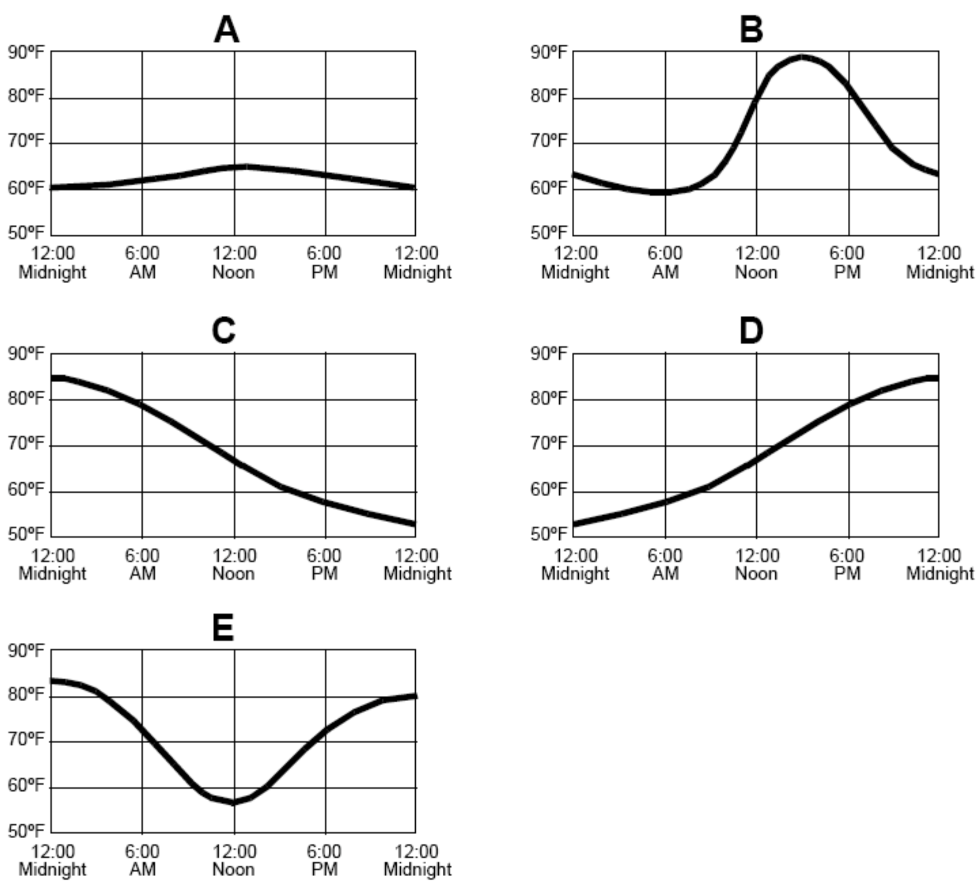
When the water cools to room temperature, the weight of the water:
   a. stays the same.
   b. will change.
   c. depends on how long it take to cool.
   d. depends on its initial temperature.
   e. depends on the room temperature.

11. Two identical jars are placed on a table with a light bulb between them. The bulb is turned on. One jar is filled with water and the other jar is filled with black ink. There is a thermometer hanging in each jar. What do you think will happen?

a. The jar with water will be hotter than the jar with black ink.
b. The jar with black ink will be hotter than the jar with water.
c. There will be no difference in the temperature of the two jars.
d. The temperature in both the jars will drop.
e. The temperature in the jar with black ink will first drop and then increase.

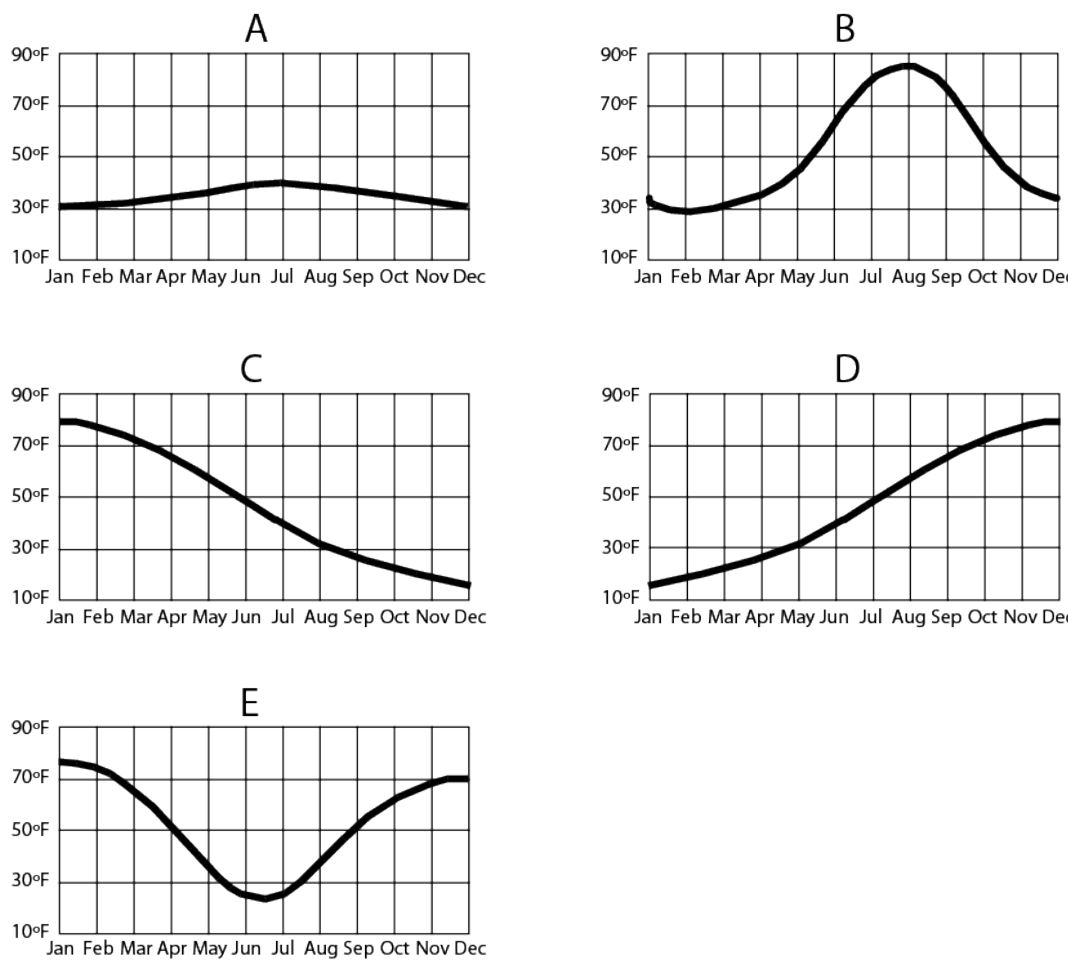


12. The graphs below show the air temperature reading for five different days. On which day was the sky most likely covered by clouds daytime and nighttime?



13. Which of the following is not part of water cycle?
   a. Snow falling from the clouds.
   b. Water evaporating from the ocean.
   c. Water absorbed by plants.
   d. Water in the ground.
   e. All of the above are part of the water cycle.

14. The graphs below show the highest air temperature reading every day for one year at five different locations. Which graph most likely is for a town in the middle of a large continent?



15. On a hot day, Paul left a glass of ice water outside. After a while, the outside of the glass was wet because:
   a. the water in the glass seeped through the glass.
   b. the ice in the glass became the water on the outside.
   c. the water is the air became cooler and became liquid.
   d. the ice in the glass melted and overflowed.
   e. No one knows why the glass is wet.

16. As part of an experiment, Jason mixes 2 cups of water at 200 F with 10 cups of water at 50 F. The temperature of the combined water is:
   a. 200 F.
   b. closer to 200 F than to 50 F.
   c. 125 F.
   d. closer to 50 F than to 200 F.
   e. impossible to estimate.

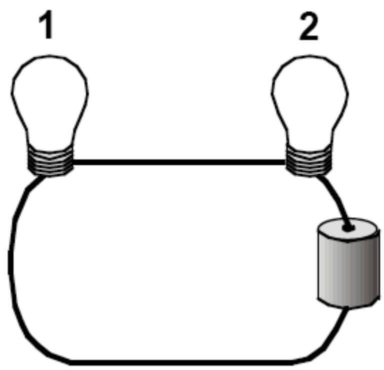
PHYSICAL SCIENCE TEST
GRADE 5

NAME ________________________________

DATE ________________

For some questions, there may be more than one correct answer. However, each question has only one <u>best</u> answer. Choose the <u>single best answer</u> from the five choices from each question.

1. Identical lights 1 and 2 are connected to the battery in the circuit below.



When connected as shown:

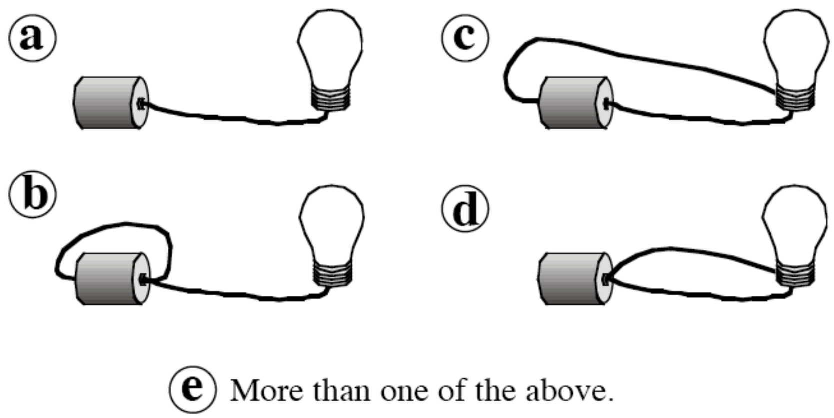
a. light 1 is brighter than light 2.
b. light 1 is dimmer than light 2.
c. light 1 is the same brightness as light 2.
d. one of the lights remains until the other lights up.
e. There is no way to tell if lights' brightness would be the same or difference.

2. If you cut a bar magnet in half, each half will:
a. no longer attract objects.
b. attract from both ends.
c. attract objects only at one end.
d. have two north poles or two south poles.
e. be more powerful that the original.

3. Mike thinks that he can turn copper into gold. He mixes a small amount of gold with a large amount of copper and heats them up until they melt. What do you think has happened?
a. All the copper has turned into gold.
b. Some of the copper has turned into gold.

c. The copper has not changed into gold. It's just a mixture of gold and copper.
d. Copper and gold have turned into something completely new.
e. Not enough information to answer the question.

4. Each of the arrangements below includes a battery, light bulb, and wire. Which arrangement will light the bulb?



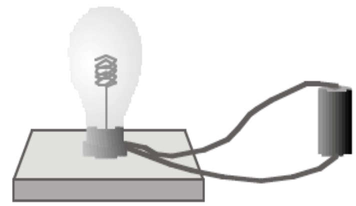
5. Imagine that you go to leave a room with an overhead light. The light is on. You move the wall switch to turn off the light, but the light stays on. What is probably wrong?
   a. The battery that powers the switch is dead.
   b. There is a break in the wire to the light bulb.
   c. The switch can no longer stop the flow of electricity through the wires.
   d. The light fixture is broken.
   e. A surge of electricity is occurring in the building.

6. Helium gas is used in balloons. When helium gas is cooled enough, it become a liquid. What do you think happens when helium turns into a liquid?
   a. The helium has turned into water.
   b. Some of the helium has turned into water.
   c. The helium has turned into a different liquid.
   d. Some helium has turned into water, some into another liquid and the rest is helium.
   e. It is all still helium, but in a liquid form.

7. A light bulb is connected to a battery by wires. The bulb is lit up. Nadia wants to know what is flowing through the wires. If a scientist were to cut the wire and look at it with a powerful magnifying glass, what do you think she would see?

a. Chemicals from the battery flowing through the wire.

b. Light flowing through the wire.



c. The wire will be hollow with nothing flowing through it.

d. Tiny sparks flowing through the wire.

e. The wire will be solid.

8. Scientists think which of the following has affected Earth for billions of years?
   a. Flowing water, such as rivers.

   b. Weathering processes.

   c. Earthquakes and volcanic eruptions.

   d. a, b and c have all affected the Earth.

   e. None of the above has affected Earth for that long.

9. If mountains erode over long periods of time, what can happen?
   a. The mountains decrease in height.

   b. Parts of mountains became steeper.

   c. Valleys decrease in depth.

   d. Only two of the above can happen.

   e. a, b and c can all happen.

10. Scientists think that the primary cause of mountain building is:
    a. the cooling and shrinking of the Earth.

    b. the heating and expanding of Earth.

    c. the Moon's gravitational pull.

    d. local climate factors.

    e. plate tectonics.

11. Suzanne is baking a cake and has placed several ingredients on the countertop to use. She has scooped some baking soda into a measuring

spoon. She accidentally knocks over a cup of vinegar and several drops spill onto the spoon with the baking soda. The baking soda begins to fizz where the vinegar spilled on it. When the fizzing stops, Suzanne notices that about half of the baking soda in the spoon is gone and there is now a liquid on the spoon. The baking soda "disappeared" because it:

a. melted.

b. combined with the vinegar, but is still in the liquid.

c. dissolved in the vinegar, but is still in the liquid.

d. evaporated.

e. was pushed off of the spoon by the fizzing.

12. Jack opens a can of soda pop and lets it sit on his kitchen countertop. He goes off to do some chores and forgets about the opened can. When he returns several hours later, the weight of the opened can of soda pop will:

a. be more that the unopened can.

b. be less than the unopened can.

c. be the same as the unopened can.

d. depend on the relative humidity.

e. depend on the type of soda pop.

13. Someone claims to have invented a system that converts sound energy into electrical energy. The inventor plans to put this system into a portable CD player so that the player's own sound can be used to recharge the player's own batteries. What do you think will happen when this CD player system is tested?

a. The system should work fine, allowing unlimited running time for the layer.

b. The system will work, but the player's volume will have to be kept in a narrow range, not too low, not too loud.

c. The system will work, but the player's volume will vary from low to high depending on whether or not the battery is being charged.

d. The system will be limited by the design of the battery: if it takes too long to fully charge, the battery may go dead.

e. The system will not work and the CD player will stop running after the battery is fully discharged.

14. Scientists think that compared to today, in the past Earth's climate has:
    a. always been the same.
    b. cooled only during the Ice Age.
    c. warmed and cooled many times.
    d. warmed only since humans stared burning fossil fuels.
    e. been much less stormy.

15. Which of these is a piece of scientific evidence for plate tectonics?
    a. The location patterns of earthquakes.
    b. The path of the Gulf Stream.
    c. The Earth's magnetic field.
    d. The tilt of Earth on its axis.
    e. There is not scientific evidence.

PHYSICAL SCIENCE TEST
GRADE 6

NAME ________________________________
DATE ________________

For some questions, there may be more than one correct answer. However, each question has only one best answer. Choose the single best answer from the five choices from each question.

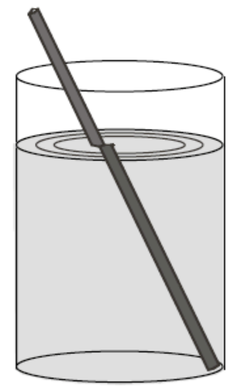
1. Scientists say a metal doorknob indoors often feels cold to you because:
   a. cold from the doorknob goes into your hand.
   b. heat from your hand goes into the doorknob.
   c. cold moves from the doorknob to your hand.
   d. heat is pulled form the doorknob by your hand.
   e. metals are always colder than air.

2. As Earth and Mars move they:
   a. exchange position with one another.
   b. both get farther from the Sun than Jupiter.
   c. move randomly through the solar system.
   d. travel around the Sun with Earth always closer.
   e. This isn't a good question because planets don't move.

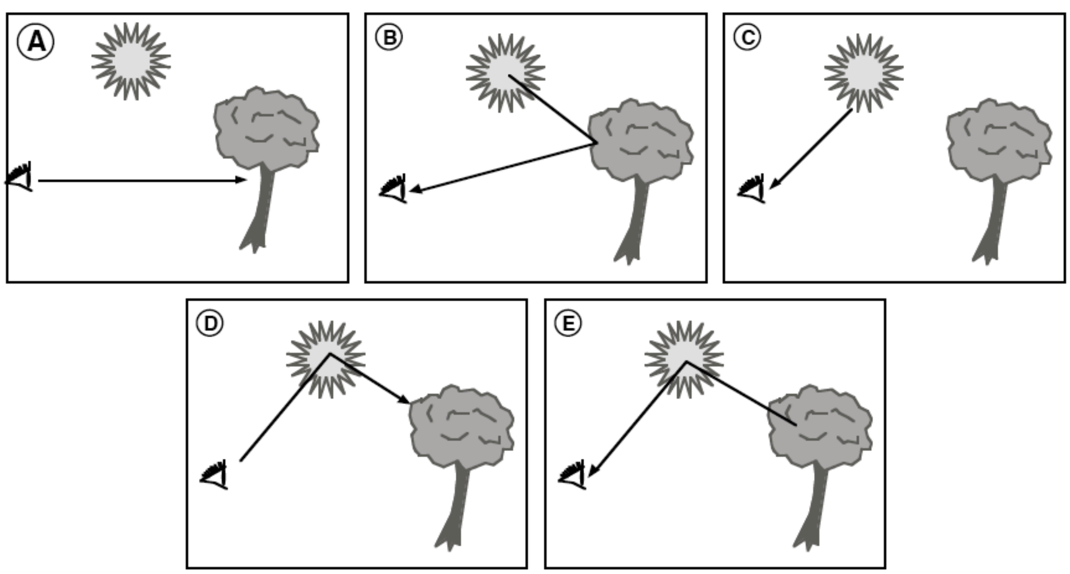
3. How long does it take for Earth to turn once on its axis?
   a. One day
   b. One week
   c. One month
   d. One year
   e. It never happens.

4. Our solar system contains:
   a. one average star.
   b. several stars spread across space.
   c. one older, dimmer star, and one younger, brighter star.
   d. three stars.
   e. no stars.

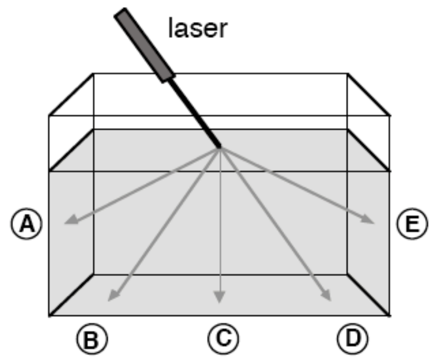
5. If you place a drinking straw in a glass filled halfway with water, the straw looks like it is in two pieces (see picture). This is because water:
   a. changes the direction of light of the straw.
   b. reflects some light back into the straw
   c. increases the amount of light off the straw.
   d. actually bends the straw.
   e. dissolves light off the straw.



6. Zahra is sitting in her backyard, looking at a tree. With which of the following statements about how she is able to see a tree do you agree?
   a. Light from her eye reaches the tree and she sees the tree.
   b. Light from the Sun reaches the tree and then her eye and she sees the tree.
   c. Light from the Sun reaches her eye and she sees the tree.
   d. Light from her eye reaches the Sun and then the tree and she sees the tree.
   e. Light from the tree reaches the Sun and then her eye and she sees the tree.



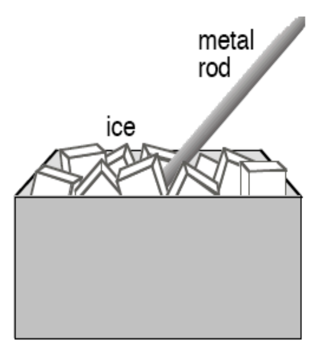
7. Look at the set up below. It shows a fish tank filled with water; the sides and bottom of the tank are all clear glass. If a red laser pointer were aimed into the tank as shows, at which lettered point do you think the laser beam would hit the glass?



8. It is a sunny day. Sean sits by the window and enjoys the sunshine. His mother tells him not to sit there for too long. However, Sean does not agree with her. Which one of the following statements do you agree with?
   a. Sean can get skin cancer from the ultraviolet radiation coming in with the sunlight.
   b. Ultraviolet radiation is completely blocked by the window glass.
   c. Ultraviolet radiation will not affect Sean in any harmful way.
   d. Sean's risk depends upon the amount of sunlight.
   e. The thickness of the window is important.

9. How long does it take for the Moon to go around the Sun?
   a. One day
   b. One week
   c. One month
   d. One year
   e. It never happens

10. Sue sticks one end of a metal rod into a box filled with ice. The end of the rod that is covered with ice becomes cold. After a while Sue places her hand on the upper end of the rod outside the box and feels that it is cold. What do you think has happened?



   a. Cold has transferred from the lower end of the rod to the upper end.
   b. The rod gave up heat to the ice.
   c. Cold moved from Sue's hands toward the rod.
   d. Heat moved from the rod to Sue's hand.
   e. It depends on the original temperature of the rod.

11. How far away is the closest star to us beyond our Sun?
    a. About the same distance as the Sun.
    b. Ten times farther.
    c. One hundred times farther.
    d. One thousand time farther.
    e. More than a thousand times farther.

12. How many planets have orbits between Earth and the Sun?
    a. None; Earth is the closest planet to the Sun.
    b. 1
    c. 2
    d. 3
    e. More than three planets.

13. An eclipse of the Moon can only occur:
    a. when the Moon passes between Earth and Sun.
    b. when the Sun passes between Earth and the Moon.
    c. when Earth passes between the Sun and the Moon.
    d. when the Moon is closest to Earth.
    e. when the Moon is farthest from Earth.

14. What is true about the source of any sound?
    a. A living thing had to be involved.
    b. Something had to vibrate.
    c. Air had to be involved.
    d. More that one of the above.
    e. None of the above.

15. Calcutta, India, is half way around the Earth east of Chicago. If it is noon in Chicago, in Calcutta it would be about:
    a. sunrise
    b. sunset
    c. noon
    d. midnight
    e. noon the next day.

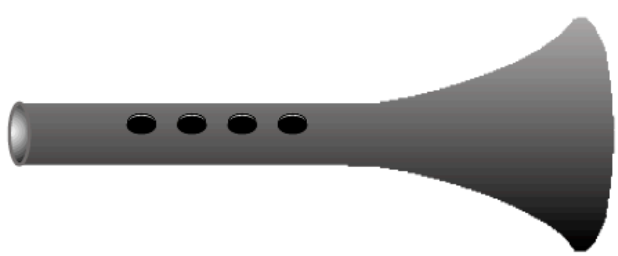
16. John has built a special greenhouse in his brickyard. By turning a special dial, John can choose which type of sunlight can enter the greenhouse. When only ultraviolet light is allowed to enter the greenhouse, what do you think will happen while John is standing inside the greenhouse?
    a. John can see objects inside the greenhouse.
    b. It is warmer inside the greenhouse that it is outside.
    c. After a few hours, John begins to sunburn.
    d. John can see objects outside the greenhouse.
    e. John can only see a few objects.

17. Which answer shows the most accurate pattern of the three objects in order from closest object to Earth to farthest from Earth?
    a. Center of Milky Way→Andromeda galaxy→North Star
    b. Center of Milky Way→North Star→Andromeda galaxy
    c. Andromeda galaxy→North Star→center of Milky Way
    d. North Star→Andromeda galaxy→center of Milky Way
    e. North Star→center of Milky Way→Andromeda galaxy

18. If the Sun stopped shining right now, the soonest it could be noticed on Earth would be:
    a. a few seconds
    b. a few minutes
    c. a few hours
    d. a few days
    e. a few years

19. Which answer shows the most accurate pattern of the three objects in order from closest object to Earth to farthest from Earth?
    a. Space Shuttle in orbit→Stars→Pluto
    b. Pluto→Space Shuttle in orbit→Stars
    c. Stars→Space Shuttle in orbit→Pluto
    d. Stars→Pluto→Space Shuttle in orbit
    e. Space shuttle in orbit→Pluto→Stars

20. Michael made a low pitch sound on a horn (below) and wants to make a high pitch sound.

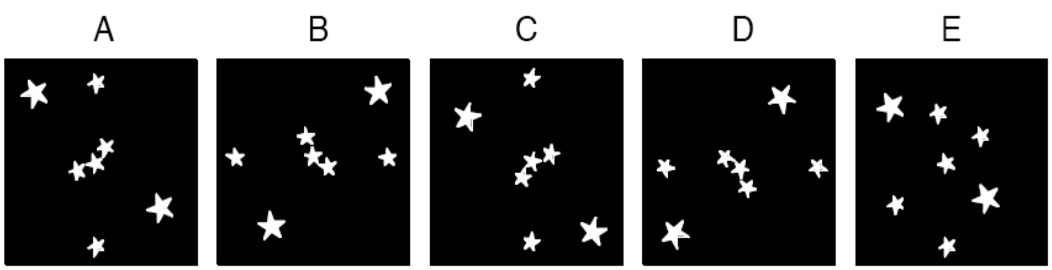


To make the high pitch sound, Michael must:

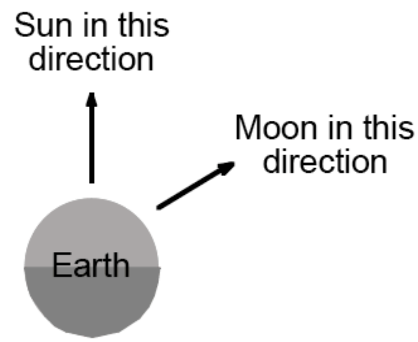
a. cover more holes with his fingers.
b. blow into the horn with more force.
c. blow into the horn for a longer time.
d. make the air vibrate faster.
e. hold the horn more firmly.

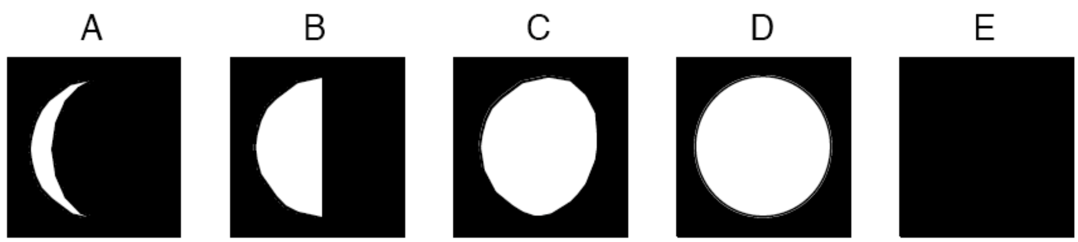
21. You go outside one night and see the pattern of stars in the southern sky below.

Which of the views below shows how the stars would look like 6 hours later?



22. If you could look down from space at Earth from far above its north pole, the Sun and Moon would be in the directions shown by the arrows in the picture below. What would the Moon look like to a person on Earth facing the Moon?





APPENDIX H

TEACHER BELIEFS INTERVIEW (YEAR 1)

Teacher: ________________________
Interviewer: _____________________
Date: __________

Note: Question focus, listed in parentheses, was added by the researcher.

1. How do you describe your role as a science teacher? (Beliefs)*
2. How do you know when your students understand a scientific concept? (Content Knowledge, Beliefs, and Practice)*
3. How do your students learn science best? (Beliefs)*
4. How do you maximize student science learning in your classroom? (Practice)*
5. What do you believe are your main strengths as a science teacher? (Beliefs)*
6. In what areas would you like to improve as a science teacher? (Beliefs)*
7. Why did you decide to participate in the PSIA program? (Beliefs and Context)
   Prompts:
   Was it your choice, principal/administrator encouragement, or another source?

8. What aspects of the PSIA program have you incorporated into your teaching so far? (Practice)

9. How positive or negative have your experiences been in implementing the inquiry science that was the focus of PSIA? (Beliefs and Practice)

10. What are your goals for YOUR learning in the PSIA program? (Beliefs)

11. What types and amounts of classroom science support have you sought? Did you receive this support? How helpful did you find it? (Beliefs and Practice)

* Luft & Roehrig, 2005, Taken from Salish [TPPI]

APPENDIX I

TEACHER BELIEFS, PRACTICES, AND INFLUENCE OF

CONTEXT (YEAR 2)

Teacher: ________________________
Interviewer: _____________________
Date: __________

Note: Focus of question, listed in parentheses, was added by the researcher.

1. How do you describe your role as a science teacher? (Beliefs)*

    Probe: What are your desired student outcomes for your students' science learning?

2. How do you know when your students understand a scientific concept? (Knowledge, Beliefs, and Practice)*
3. How do your students learn science best? (Beliefs)*
4. How do you maximize student science learning in your classroom? Is it different this year than last year? (Practice)*
5. What do you believe are your main strengths as a science teacher? (Beliefs)*
6. What is the role of science in 4-6 grade education? How important is science compared to other subjects? (Beliefs)
7. Please list a couple of ways in which your teaching practices relate directly to what you know about how students learn science? (Beliefs and Practice)***
8. How positive or negative have your experiences been in implementing the inquiry science that was the focus of PSIA? Are your experiences different this year than last year? (Beliefs and Practice)
9. What challenges do you face when teaching inquiry science in your classroom? What role does your student population play in this? (Beliefs and Context)

Probe: Do you believe standards-based (inquiry) instruction helps you prepare *your* students for state assessments? (Beliefs)***

10. What types and amounts of classroom science support have you sought from the PSIA staff this year? Did you receive this support? How helpful did you find it? Compare this to last year's support. (Beliefs and Practice)

11. What school supports do you have when teaching inquiry science in your classroom? (Context)
12. Does your principal prioritize science as a subject?
13. Was your principal supportive of your participation in PSIA last year? (Context)
14. Do you feel supported by your principal to teach science according to the inquiry methods you experienced in PSIA last year? (Context)***

    Probes:
    Does your principal accept the noise that comes with an active classroom?**
    Does your principal encourage the implementation of reform-based (inquiry-based) practices in science education?**
    Does your principal encourage innovative instructional practices?**
    Does your principal enhance the science program by providing you with needed science material and equipment?**

15. Do you feel other teachers at your school are supportive of your efforts to incorporate your learning from the PSIA program? (Context)***
16. How does collaboration between teachers happen in your school? How much of this time is spent on science? (Context)***

* Luft & Roehrig, 2005, Taken from Salish [TPPI]
** Adapted from Supovitz & Turner, 2000
*** Adapted from Johnson, 2007

APPENDIX J

PRINCIPAL INTERVIEW (YEAR 2)

Principal: ___________________
School: _____________________
Date: __________

1. Were you involved in encouraging/supporting teachers at your school to participate in the Physical Science Inquiry Academy professional development program last year?
2. What do you believe is the role of science education in grades 4-6? How does science compare to other subjects in importance in these grades?
3. How do you believe upper elementary students learn science best?
4. What do you believe is the teachers' role in elementary science teaching?

    Probes:
    What is the teacher's responsibility in elementary science teaching?
    What should teachers' desired student outcomes for their students' science learning be?

5. What do you believe are the supports in your school to implementing the inquiry science that was the focus of PSIA?
6. What do you believe are the barriers in your school to implementing the inquiry science that was the focus of PSIA?
7. Do you feel the teachers who participated in PSIA have made an impact on the school culture of your school?
8. What do you know about the national science reform in education?

    Probes:
    What are your understandings about the science education reforms?
    What are your impressions of the science education reforms?

9. How do you encourage the implementation of reform-based (*Standards*-based) science practice in your school? What do you believe this looks like in the classroom?*

   Probes:
   Active learning in the classroom is often noisy. Is this a concern for you?*
   How do you encourage innovative instructional practices?*
   How are funds allocated in your school for needed science material and equipment?*

15. What role do school demographics play in your answers?

16. Are there any additional concerns or issues that you want to talk about regarding science at your school?

* Adapted from Supovitz & Turner, 2000

APPENDIX K

TEACHER CONSENT FORM (YEAR 1)

PHYSICAL SCIENCE INQUIRY ACADEMIES for ELEMENTARY TEACHERS

CONSENT DOCUMENT

You are invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and ask us if there is anything that is not clear or if you would like more information. Please take time to decide whether or not you wish to take part in this research study.

BACKGROUND

The Genetic Science Learning Center (GSLC) at the University of Utah and the Granite School District invite you to participate in a study to evaluate the effectiveness of the Physical Science Inquiry Academies for Elementary Teachers program.

The Academy is designed to support you in teaching physical science. You will have opportunities to enhance your content knowledge, explore inquiry-based teaching and learning, modify lessons to increase the level of inquiry, learn to utilize inquiry-based kits, and collaboratively examine student work. An Education Specialist will provide classroom support as you implement what you are learning in your classroom.

STUDY PROCEDURE

Participants in the Physical Science Inquiry Academies for Elementary Teachers program will be involved in an Academy for one year. During this time you will be asked to engage in the following activities:

1. **Participate in a 3-day summer institute.** During this institute you will explore inquiry-based teaching and learning. As part of this institute you will be asked to complete three questionnaires: beliefs about science teaching, attitudes toward science teaching, and intent for participation. You also will be asked to complete a content knowledge survey and a daily feedback survey. The institute will be audio-taped. In no way will your answers to these surveys or what you say

during the institute affect your standing in the Academy or at your school. This information is strictly for research purposes.

2. **Participate in monthly Academy sessions during the school year.** These sessions will build on and extend the learning and experiences begun during the summer institute. In addition, you will enhance your physical science content knowledge, learn to utilize inquiry-based kits and collaboratively examine student work. The sessions will be audiotaped. You will be asked to complete a feedback survey at the end of each session. During the final monthly Academy session you will be asked to complete three questionnaires and a content knowledge survey, similar to those completed on the first day of the summer Academy. You also will be asked to respond to an end-of-Academy feedback survey.

3. **Implement inquiry-based science lessons and discuss student work.** You will receive training on implementing an inquiry-based physical science kit that addresses one Standard in the Utah Science Core Curriculum for the grade level you teach. You will be asked to implement the lessons from this kit with your students. You also will be asked to implement additional inquiry-based lessons that address other Standards. You will be asked to collect student work samples from these lessons, which will be discussed during the monthly Academy sessions.

4. **Work with an Education Specialist to enhance your inquiry-based science teaching.** The Education Specialist will be available to teach model lessons, examine student work with you, provide coaching, and support you in your teaching. You will be expected to work with the Education Specialist on a weekly basis.

5. **Participate in interviews.** You will be asked to participate in one interview near the beginning of the school year and one interview at the end of the school year with the same researcher. These interviews will last 20-30 minutes.

6. **Allow a researcher to observe in your classroom.** The researcher will observe three science lessons, one of which will be using a lesson from the kit for your grade level. Observations will occur three times during the school year. The researcher will be the same one who conducts the interviews.

RISKS

Risks to participants in this study are minimal. You may experience the normal discomfort of learning or teaching new curriculum materials.

BENEFITS

We cannot promise any direct benefit from taking part in this study. However, the Academy is intended to enhance your physical science content knowledge and your understanding of inquiry teaching, to provide you with practice with teaching using inquiry methods, and to provide you with science teaching materials to use in your classroom.

CONFIDENTIALITY

All information collected about you during the course of the study will be kept confidential. Only researchers Louisa A. Stark and Dina Drits of the Genetic Science Learning Center will see the information you provide. The exception is the anonymous feedback surveys collected at the end of each Academy session. These surveys will be shared with all of the leaders/presenters who participated in that session Summarized information that does not have your name associated with it may be shared as appropriate for Academy planning and evaluation with the Granite District Science Specialist, Stephanie Wood, and with the Education Specialist. All collected data will be stored in a locked filing cabinet. Results of the study may be published; however, your name and other identifying information will be kept private. Because you will be interacting with a group of other teachers throughout the program, the confidentiality of individual teacher's opinions cannot be assured.

PERSON TO CONTACT

If you have questions, complaints or concerns about this study, you can contact Louisa A. Stark, Ph.D., at 801-585-0019 or Dina Drits at 801-573-6939. If you feel you have been harmed as a result of participation, please call Louisa Stark at 801-585-0019 or Dina Drits at 801-573-6939. Louisa Stark or Dina Drits can be reached at their respective numbers between 9:00 a.m. and 6:00 p.m. weekdays.

INSTITUTIONAL REVIEW BOARD

Contact the Institutional Review Board (IRB) if you have questions regarding your rights as a research participant. Also, contact the IRB if you have questions, complaints or concerns which you do not feel you can discuss with the investigators. The University of Utah IRB may be reached by phone at (801) 581-3655 or by e-mail at irb@hsc.utah.edu.

VOLUNTARY PARTICIPATION

Participation in this study is voluntary. It is up to you to decide whether or not to take part in it. If you do decide to take part you will be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. This will not affect the relationship you have with the Genetic Science Learning Center staff or the Granite School District and its staff. Refusal to participate or the decision to withdraw from this research will involve no penalty or loss of benefits to which you are otherwise entitled. This will not affect your relationship with the investigators.

COSTS and COMPENSATION for PARTICIPANTS

There is no cost for you to participate in this research study.
Participating teachers will be able to count the summer institute as their 1.5 days of District-required professional development, and will receive a stipend of $300 for participating in the institute. Substitute teachers will be provided for the monthly,

school-day Academy sessions. Participating teachers will be able to earn five graduate science credits from the University of Utah for a $40 recording fee.

CONSENT

By signing this consent form, I confirm I have read the information in this consent form and have had the opportunity to ask questions. I will be given a signed copy of this consent form. I voluntarily agree to take part in this study.

____

Printed Name of Participant

______________________________ __________________

Signature of Participant Date

____

Printed Name of Researcher

______________________________ __________________

Signature of Researcher Date

____

Printed Name of Researcher

______________________________ __________________

Signature of Researcher Date

APPENDIX L

TEACHER CONSENT FORM (YEAR 2)

PHYSICAL SCIENCE INQUIRY ACADEMIES for ELEMENTARY TEACHERS

CONSENT DOCUMENT

You are invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and ask us if there is anything that is not clear or if you would like more information. Please take time to decide whether or not you wish to take part in this research study.

BACKGROUND

The Genetic Science Learning Center (GSLC) at the University of Utah and the Granite School District invite you to participate in a study to evaluate the effectiveness of the Physical Science Inquiry Academies for Elementary Teachers program.
The Academy you participated in last year (2008 – 2009) was designed to support you in teaching physical science. The Academy provided you with opportunities to enhance your content knowledge, explore inquiry-based teaching and learning, modify lessons to increase the level of inquiry, learn to utilize inquiry-based kits, and collaboratively examine student work.

STUDY PROCEDURE

Participants in the Physical Science Inquiry Academies for Elementary Teachers program will be asked to participate in a follow-up study for one year, during the 2009 – 2010 school year. During this time you will be asked to engage in the following activities:

1. **Complete surveys during the last month of the school year.** As part of this follow-up study, you will be asked to complete the same questionnaires you took during the beginning and end of the Academy year. These are: the beliefs about science teaching, the attitudes toward science teaching, and three content knowledge surveys. In no way will your answers to these surveys affect your standing with Academy staff or at your school. This information is strictly for research purposes.

2. **Allow a researcher to observe in your classroom.** The researcher will observe three inquiry science lessons. Observations will occur three times during the school year.

3. **Allow a researcher to administer a student survey in your classroom**. The researcher will administer a survey to your students three times during the school year. This is the same survey the researcher administered to your students during the Academy year. The researcher will be the same one who observes the science lessons.

RISKS

Risks to participants in this study are minimal. You may experience the normal discomfort of learning or teaching new curriculum materials.

BENEFITS

We cannot promise any direct benefit from taking part in this study. However, the Academy is intended to enhance your physical science content knowledge and your understanding of inquiry teaching, to provide you with practice with teaching using inquiry methods, and to provide you with science teaching materials to use in your classroom.

CONFIDENTIALITY

All information collected about you during the course of the study will be kept confidential. Only researchers Louisa A. Stark and Dina Drits of the Genetic Science Learning Center will see the information you provide. All collected data will be stored in a locked filing cabinet. Results of the study may be published; however, your name and other identifying information will be kept private. Because you will be interacting with a group of other teachers throughout the program, the confidentiality of individual teacher's opinions cannot be assured.

PERSON TO CONTACT

If you have questions, complaints or concerns about this study, you can contact Louisa A. Stark, Ph.D., at 801-585-0019 or Dina Drits at 801-573-6939. If you feel you have been harmed as a result of participation, please call Louisa Stark at 801-585-0019 or Dina Drits at 801-573-6939. Louisa Stark or Dina Drits can be reached at their respective numbers between 9:00 a.m. and 6:00 p.m. weekdays.

INSTITUTIONAL REVIEW BOARD

Contact the Institutional Review Board (IRB) if you have questions regarding your rights as a research participant. Also, contact the IRB if you have questions, complaints or concerns which you do not feel you can discuss with the investigators. The University of Utah IRB may be reached by phone at (801) 581-3655 or by e-mail at irb@hsc.utah.edu.

VOLUNTARY PARTICIPATION

Participation in this study is voluntary. It is up to you to decide whether or not to take part in it. If you do decide to take part you will be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. This will not affect the relationship you have with the Genetic Science Learning Center staff or the Granite School District and its staff. Refusal to participate or the decision to withdraw from this research will involve no penalty or loss of benefits to which you are otherwise entitled. This will not affect your relationship with the investigators.

COSTS and COMPENSATION for PARTICIPANTS

There is no cost for you to participate in this research study.

CONSENT

By signing this consent form, I confirm I have read the information in this consent form and have had the opportunity to ask questions. I will be given a signed copy of this consent form. I voluntarily agree to take part in this study.

____
Printed Name of Participant

____________________________________ ___________________________
Signature of Participant Date

____
Printed Name of Researcher

____________________________________ _________________________
Signature of Researcher Date

____
Printed Name of Researcher

____________________________________ ____________________________
Signature of Researcher Date

APPENDIX M

PRINCIPAL CONSENT FORM (YEAR 2)

PHYSICAL SCIENCE INQUIRY ACADEMIES for ELEMENTARY TEACHERS

CONSENT DOCUMENT

You are invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and ask us if there is anything that is not clear or if you would like more information. Please take time to decide whether or not you wish to take part in this research study.

BACKGROUND
The Genetic Science Learning Center (GSLC) at the University of Utah and the Granite School District invite you to participate in a study to evaluate the effectiveness of the Physical Science Inquiry Academies for Elementary Teachers program (PSIA). Teachers in your school participated in the PSIA program during the past school year.

The Academy is designed to support teachers in your school in teaching physical science. Teachers had opportunities to enhance their content knowledge and to explore inquiry-based teaching and learning. An Education Specialist provided classroom support as teachers implemented what they learned in their classrooms.

STUDY PROCEDURE
As part of the evaluation of the PSIA program, we would like to ask you to participate in a 20 - 30 minute interview with a researcher/evaluator about the science education in your school. The interview will last no longer than 30 minutes. The interview will be audio-taped.

RISKS
Risks to participants in this study are minimal. You may experience the normal discomfort of participating in an interview.

BENEFITS
We cannot promise any direct benefit from taking part in this study. However, the Academy is intended to enhance the science teaching of teachers in your school.

CONFIDENTIALITY
All information collected about you during the course of the study will be kept confidential. Only researchers Louisa A. Stark and Dina Drits of the Genetic Science Learning Center will see the information you provide. All collected data will be stored in a locked filing cabinet. Audio tapes will be destroyed after the study is complete. Results of the study may be published; however, your name and other identifying information will be kept private.

PERSON TO CONTACT
If you have questions, complaints or concerns about this study, you can contact Louisa A. Stark, Ph.D., at 801-585-0019 or Dina Drits at 801-573-6939. If you feel you have been harmed as a result of participation, please call Louisa Stark at 801-585-0019 or Dina Drits at 801-573-6939. Louisa Stark or Dina Drits can be reached at their respective numbers between 9:00 a.m. and 6:00 p.m. weekdays.

Institutional Review Board: Contact the Institutional Review Board (IRB) if you have questions regarding your rights as a research participant. Also, contact the IRB if you have questions, complaints or concerns which you do not feel you can discuss with the investigator. The University of Utah IRB may be reached by phone at (801) 581-3655 or by e-mail at irb@hsc.utah.edu.

Research Participant Advocate: You may also contact the Research Participant Advocate (RPA) by phone at (801) 581-3803 or by email at participant.advocate@hsc.utah.edu.

VOLUNTARY PARTICIPATION
Participation in this study is voluntary. It is up to you to decide whether or not to take part in it. If you do decide to take part you will be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. This will not affect the relationship you have with the Genetic Science Learning Center staff or the Granite School District and its staff. Refusal to participate or the decision to withdraw from this research will involve no penalty or loss of benefits to which you are otherwise entitled. This will not affect your relationship with the investigators.

COSTS AND COMPENSATION TO PARTICIPANTS
There is no cost or compensation for you to participate in this research study.

CONSENT

By signing this consent form, I confirm I have read the information in this consent form and have had the opportunity to ask questions. I will be given a signed copy of this consent form. I voluntarily agree to take part in this study.

____
Printed Name of Participant

____________________________________ ______________________
Signature of Participant Date

____
Printed Name of Researcher

____________________________________ ______________________
Signature of Researcher Date

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