De-Marginalizing Science in the Early Elementary Classroom: Fostering Reform-Based Teacher Change through Professional Development, Accountability, and Addressing Teachers' Dilemmas

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ABSTRACT

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To develop a scientifically literate populace, students must acquire the motivation and foundational skills for success in science beginning at an early age. Unfortunately, science instruction is often marginalized in elementary schools for reasons including teachers' lack of confidence in teaching science and an overemphasis on literacy and mathematics.

This study employed a case study design to examine the impact of teachers' dilemmas, career stage, coaching, and other forms of support on elementary teachers' abilities to teach science more often and in more reform-based ways. The conceptual lenses used to guide this dissertation include the theory related to teacher change, dilemmas, reform-oriented science teaching, and the professional learning continuum. Findings suggest that teachers' dilemmas must be addressed in order for them to move toward more reform-based science teaching practices. It was found that how teachers reconcile their dilemmas is due in part to their career stage, level of readiness, and access to a more knowledgeable other who can assist them in learning and enacting reform-based instruction. Moreover, the likelihood and extent of teacher change appears to be related to teachers recognizing a need to change their practice, developing the capacity to change, feeling accountable to change, and possessing the motivation to change.

Implications for teacher educators, professional development providers, and curriculum developers are presented. It is argued that teachers require support the length of their career and, to be effective, this support must be personalized to their diverse and changing needs and responsive to the context in which they teach.

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CHAPTER I

INTRODUCTION

Statement of Purpose

"Given that future innovation, global finance, and our very standard of living depend on mathematics and science knowledge, our students' unacceptable performance in these subjects constitutes nothing short of a national crisis" (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010, p. 6). It is crucial that we raise student performance in science and work to close the achievement gap that persists between students of low and high socioeconomic status. In the same vein, we must improve the science learning experiences of students, so that they are better prepared to navigate an increasingly complex world and we remain competitive in a global economy. To develop a scientifically literate populace, students must acquire the motivation and foundational skills for success in science beginning at an early age. Science education reform documents suggest that beginning in kindergarten students should be going through scientific processes in which they:

> ask a question about objects, organisms, and events in the environment, plan and conduct a simple investigation, employ simple equipment and tools to gather data and extend the senses, use data to construct a reasonable explanation, and communicate investigations and explanations. (National Research Council [NRC], 1996, p. 122)

Unfortunately, it is evident this is not common practice in elementary classrooms.

Teaching is a complex craft and effective teachers develop, draw on, and employ knowledge from a variety of domains (Barnett & Hodson, 2001; Magnusson, Krajcik & Borko, 1999; Shulman, 1986), including disciplinary knowledge, pedagogical knowledge, knowledge of the context in which they work, and pedagogical content knowledge (PCK). The student-centered pedagogical approaches advocated by social constructivists diverge significantly from the traditional lecture-based instruction to which most individuals have grown accustomed. “Fundamental change in practices and beliefs takes time, because there is much to unlearn and much that is complex to learn” (Loucks-Horsley & Matsumoto, 1999, p. 261). Oftentimes elementary teachers believe that engaging the learner in hands-on activities is sufficient to ensure student learning (Levitt, 2002). However, activities which are “hands-on,” without being “minds-on,” only lead to limited and superficial understandings. The knowledge base for science teaching is vast. Moreover, due to the fact that elementary teachers typically have inadequate backgrounds in science and are primarily held accountable for student performance in literacy and mathematics, it is no surprise that science is typically marginalized in elementary schools. Elementary teachers lack the necessary science content and pedagogical knowledge, and tend to have little confidence in teaching science (Cochran & Jones, 1998). As a result, Harlen (1997) found that elementary teachers often avoid teaching science or do not employ reform-based practices in teaching science.

Professional development is viewed as the key to reform. Loucks-Horsley and colleagues (2010) have found:

> widespread consensus regarding what constitutes effective professional learning: It is directly aligned with student learning needs; is intensive, ongoing, and connected to practice; focuses on the teaching and learning of specific academic content; is connected to other school initiatives; provides time and opportunities for teachers to collaborate and build strong working relationships; and is continuously monitored and evaluated. (p. 5)

Despite the agreement on these characteristics, teacher educators continue to grapple with how to design sustainable professional development (PD) experiences that effectively reform teacher practice (Putnam & Borko, 2000). Furthermore, Metz (2009) asserts that elementary science education reform is a comparatively under-researched area.

Teachers experience support from a number of different sources, such as curriculum materials, formal professional development, mentoring or coaching, and collaboration with colleagues; however, more research is needed to uncover what combinations of components are effective in transforming teachers' beliefs and practices (Putnam & Borko, 2000). Due to the fact that teacher change is a complex process, there is more to be learned in this area. For example, researchers are calling for additional studies into how teachers' beliefs and practices interact and are related to the implementation of reform-based instructional practices (Key & Bryan, 2001; Wilkins, 2008; Young & Lee, 2005). In addition, there is a scarcity of research on what effective coaches do and how they impact what teachers do (Vanderburg & Stephens, 2010; Walpole & Blarney, 2008). Furthermore, there is more to uncover about how to support teachers at various stages of their careers (Bevan, 2004; Kennedy & McKay, 2011).

In response to these gaps in the literature related to supporting elementary teachers to teach more science and to teach it in more reform-oriented ways, the purpose of this research study was to investigate the dilemmas perceived by a group of first-grade teachers at different stages of their career and how they went about reconciling them with the support of the researcher working in the role of a science coach. Moreover, I sought to explore the impact of receiving various forms of support on one of the teachers' beliefs and practices related to science teaching.

Factors that Determined the Origin of this Study

My interest in studying the impact of professional development on teachers' abilities to teach science in reform-based ways stems from my experiences as a student. It was back then that I learned how much of an impact a teacher can have their students. In high school, my chemistry classes left me feeling that academic success required pure memorization. On the other hand, in my physics classes I got to see the science we were learning in practice. We learned about waves and had to construct panpipes that could play the appropriate notes, we were able to see firsthand the anatomical structures of the eye when our teacher dissected a bovine eye to show us why we were learning about focal length, and we learned about center of gravity through an experiment showing that females, but not males, could kneel down and knock over a block of wood which had been placed an appropriate distance away by using their nose. It seemed there were real-world applications for every concept we learned in that class.

Having had two great physics teachers in high school led me to originally plan to major in this branch of science in college. To my dismay, however, first year undergraduate physics did not live up to my expectations. During the spring semester I had trouble grasping the concepts as they became more abstract and the labs did not seem to help since they did not follow the sequence of the class lectures. I was dispassionate about all of my science classes until a professor, who was a guest speaker in my chemistry class for the last three weeks of the year, reminded me of how the subject matter is related to my life. He did not lecture in the traditional way. He told stories, included personal bits of information he had learned about particular scientists, and connected the material to our lives. His lessons revived my enthusiasm for science. I later took two more classes with him, World of Chemistry: Food and World of

Chemistry: Environment. These classes were designed to teach laymen what they need to know about chemistry in order to be scientifically informed citizens. We learned to look with a critical eye at seemingly obvious solutions to our pollution problems. Everyone knows recycling is good for the environment, but before this class I never thought about all the pollution produced in the process, from the fumes emitted by the trucks that pick up the bottles, cans and paper products, to the chemicals used in the sanitation process. We learned interesting facts, such as an English sailor was often referred to as a "limey" because seamen frequently eat limes for their vitamin C in order to reduce incidents of scurvy while out at sea. I learned that although aspartame has been proven to have adverse side effects when ingested in large quantities, it is important to remember that artificial sweeteners can be hundreds of times more potent than sugar, and as a result there is only a very small amount in each can of diet soda. The toxicity is in the dose. Still, only time will tell the full story of the potential side effects. We learned that as new knowledge becomes available, scientists revise their thinking. The World of Chemistry courses are where I learned the importance of being a scientifically literate citizen. They made learning about the minutia of chemistry much more appealing, I could see why it was important. Scientists cannot do what they do without foundational knowledge.

Once I became a science teacher it became my responsibility to justify my course. Some students complained that they were not going to study science in college and therefore did not see the need to take chemistry. My goal was to ensure that by the time they left my class they would appreciate the value of science as a means of protecting themselves as well as being valuable, contributing members of society. While I felt that I developed a reform-oriented stance to science teaching from my pre-service master's program, I did not have the knowledge or skills to translate my ideas into practice. I desperately wanted to collaborate with a more experienced and knowledgeable other in order to find ways to teach the content standards through more authentic and meaningful approaches. Since I was unsure how to consistently teach in this manner on a daily basis, I opted to incorporate these ideas through research projects. I had my students choose from an open-ended list of chemistry-related topics that directly affect their lives. My students researched and presented their findings to the class on topics such as the pros and cons of water fluoridation and fluoride in toothpaste, the positive and negative physiological effects of participating in sports, how food is genetically modified and the implications of altering plant DNA, the benefits of consuming organically grown foods and the consequences of pesticide use, the differences between good and bad cholesterol for one's health, the differences between LCD and plasma television screens, and how common products work (e.g., sunscreen, diapers, CD players, etc.). While this was a first step, I still felt like I required assistance to make such topics part of the regular curriculum. Unfortunately, the only mentoring support I received as a new teacher was from a retired elementary teacher who had no science background. Moreover, I was the only chemistry teacher at the school. My experiences as a novice science teacher, led me to want to pursue ways to better support teachers to develop reform-based understandings and enact them in practice.

During my first year at Teachers College, I began working in an urban high school where I realized that the students lacked the background knowledge and foundational skills necessary to successfully learn the science material for their grade. Catching students while they are young and innately inquisitive and motivated to learn science, and developing those foundational skills early on can help set the stage of continued interest and achievement in the field of science. I subsequently worked with teachers at the middle school and elementary school levels.

Elementary teachers, who lack science knowledge and have often had poor science experiences themselves, must be supported to do this. While elementary teachers have greater access to onsite and off-site support and reform-oriented curricula than high school teachers, professional development for science pales in comparison to the supports made available to them for literacy and mathematics as a result of No Child Left Behind.

Currently, researchers are calling for professional development that is ongoing and embedded in the school context (Lumpe 2007), as it is a complex process through which teachers take what they experience in off-site staff development and modify and incorporate it into their own classrooms (Putnam & Borko, 2000). One highly regarded form of such situated supported is teacher learning communities. However, elementary teachers do not usually possess a science background or the knowledge necessary to critique and move their practice forward in reform-based ways, as a result working with a more knowledgeable other is key. Literacy and mathematics coaches are beginning to become a common feature of elementary schools, thus this is a prime context for the introduction of science coaches as well.

The biggest issue with science at the elementary level is getting teachers to actually spend time teaching it. From there it is imperative that these generalist teachers learn the content, curricular, and disciplinary knowledge necessary to teach it well. It is the teacher who has the greatest impact on what students learn in their classroom. As a result, I felt compelled to focus my efforts for this study on supporting teachers so that they could better support students in developing a strong foundation in science. With the introductory skills and knowledge to be successful in science, students will be less likely to fall behind and become disinterested in science as they progress through their schooling. Having a strong base in science increases the likelihood of academic success in science as students move forward in their schooling and promotes the development of a scientifically informed population.

As a former high school teacher, it was a big leap for me to begin working with and supporting the learning of early elementary teachers and students. While I had a firm grasp on the science content and an understanding that elementary students are capable of thinking critically about phenomena and learning relatively sophisticated science content, supporting these teachers and students in the actual classroom required a steep learning curve on my part. I approached the professional development work with the teachers from the perspective that they were the experts on their students and I was the more-knowledgeable one in terms of the science content. I viewed my role as a science coach as parallel, not senior, to the role of the teachers. I wanted our work together to be a collaborative effort to improve student learning experiences in science, where we capitalized on the particular knowledge each teacher—and me as the coach—brought to the partnership.

I had a lot to learn from the teachers about teaching first-grade students and they had a lot to learn from me, their curriculum materials, and other resources about how to teach elementary science. Specifically, I had to familiarize myself with the unique elementary school environment before I could offer helpful advice about how to teach science in this context. I also had to learn what their particular students were capable of, what kinds of knowledge and experiences they brought with them into the classroom, what they were learning in the other subject areas, what challenges and constraints the teachers had to work around, and what the teachers' knowledge base and experiences were related to science. In essence, there were steep learning curves for both the teachers and me, and we assisted each other's development in our respective areas of expertise.

Research Questions

The purpose of this research study was to investigate the dilemmas that three elementary teachers, at various stages of their careers, perceived related to science teaching and how they reconciled their dilemmas. I also sought to uncover the impact of a science coach on how the teachers reconciled their dilemmas. Additionally, I studied the impact of receiving multiple forms of professional development on one of the teachers' beliefs and practices related to reform oriented science teaching. It was hoped that investigating these questions would shed light on the reality of what elementary teachers face in attempting to teach science, since lack of science instruction in elementary schools is such a pervasive issue (Appleton, 2007). Moreover, it was hoped that through coaching and other forms of support, teachers would not only begin to teach science more often, but would also move toward teaching science in more effective ways. Specifically, the research questions guiding this study were:

1. What dilemmas did three teachers at various stages of the professional learning continuum perceive related to teaching and learning science?
2. How did the three teachers reconcile the dilemmas they perceived related to science teaching?

a) What were the differences and similarities in how the teachers at different stages of their careers reconciled the dilemmas they perceived related to teaching science?

b) What impact, if any, did the researcher—in the role of a science coach—have on the teachers' reconciliation of their dilemmas?

3. What was the impact of receiving various forms of support on one first-grade teacher's beliefs and practices related to reform-oriented science instruction?

4. What mediating factors enabled or hindered one first-grade teacher's development of reform-oriented practices?

Organizational Overview of the Chapters

In the following section (Chapter II), I review the existing research literature relevant to this study, including a discussion of my conceptual framework. In the literature review, I outline current research related to elementary science education and professional development, including multi-component models of PD, coaching as a form of PD, and curriculum materials as a form of support. The conceptual framework outlines the theory on reform-oriented science instruction, teacher learning and change, career stages, and dilemmas.

Chapter III details the methods used in this study. This research is a yearlong qualitative case study of three first-grade teachers who worked at an urban public elementary school. The researcher assumed the role of participant observer (Guba & Lincoln, 1981). Primary sources of data included: teacher interviews, teacher meetings (as a team and individually), and classroom observations. Secondary sources of data included: interviews with the principal and assistant principal, and the researcher's journal. Aspects of constructivist grounded theory (Charmaz, 2006) were employed to analyze the data, which are described herein. Issues of trustworthiness are also discussed.

Chapters IV and V describe the findings of this research study and are written in the format of two separate publishable research papers. Chapter IV explores dilemmas the three teachers perceived in teaching science and how they reconciled them. This paper looks at the impact of career stages and coaching on how teachers reconciled these tensions.

Chapter V investigates the impact of multiple forms of support on one of the teacher's beliefs and practices related to reform-oriented science teaching. Supports included a kit-based curriculum, a summer institute, and collaboration with the teacher's grade-level team, the researcher, and the school's literacy coach. The lenses of teacher change and reform-oriented instruction guide the inquiry.

Finally, Chapter VI synthesizes the main findings across the studies and discusses the implications for curriculum developers and teacher educators, including mentors, coaches, and other professional development providers who support teacher learning at all stages of the teacher professional continuum.

CHAPTER II

LITERATURE REVIEW

Elementary Science Education

Mensah (2010) stated, “Nothing is comparable to [the elementary school] structure in terms of how time is allocated for subject-matter learning, how resources are used and teachers are supported, and how relationships are built” (p. 979). The job of an elementary school teacher is distinct from that of a middle school, high school, and college educators, in that elementary teachers are generalists, responsible for instructing students in all the core subject areas. Consequently, to be effective, these teachers must develop some level of expertise in all of these areas, instead of just one.

Preparing for four different subjects on a regular basis requires elementary teachers to spend a considerable amount of time planning (Levitt, 2002). Additionally, the time dedicated to science instruction in elementary schools is more limited, even absent at times, due to the fact that instruction in this area takes a back seat to literacy and mathematics—an unintended consequence of the No Child Left Behind legislation (Appleton, 2007). Moreover, elementary teachers are not likely to have a science background (Fulp, 2002; Tilgner, 1990) and, as a result, their confidence in teaching science pales in comparison to their confidence in teaching the other core subjects (Cochran & Jones, 1998). In fact, Harlen (1997) found that elementary teachers employed avoidance strategies, such as following instructional guides step-by-step, focusing on transmitting information rather than discussion and questioning, teaching science as little as possible, teaching topics with which they are most comfortable, sticking to the simplest activities, and avoiding the use of equipment that may not work smoothly. Many elementary teachers have had prior experiences with science that left them with a bad taste in their mouth. They may not have done well in this subject area academically and may believe that science is challenging and reserved only for the elite (Fetter, Czerniak, & Shawberry, 2002). Negative experiences in science can lead individuals to avoid taking science when these courses are no longer requirements for a diploma.

Even if teachers are motivated to teach science, despite negative experiences with the subject and its low priority in schools relative to mathematics and literacy instruction, the quality may questionable. Teachers may hold beliefs about teaching and learning that are not aligned with the vision of science teaching and learning outlined in current reform documents (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996, 2000, 2007, 2011). The student-centered pedagogical approaches advocated by such documents diverge significantly from the traditional lecture-based instruction to which most individuals have grown accustomed. Incongruent beliefs about teaching for understanding, developed through years of experience as a student, are likely to hinder a teacher's success in the classroom. Many teachers believe that what worked for them should also work for their students. "Fundamental change in practices and beliefs takes time, because there is much to unlearn and much that is complex to learn" (Loucks-Horsley & Matsumoto, 1999, p. 261). Oftentimes teachers believe that engaging the learner in hands-on activities is sufficient to ensure student learning. However, lessons that are "hands-on," without being "minds-on," only lead to a limited and superficial understanding. Davis, Petish, and Smithey (2006) found that new teachers held weak rationales for implementing hands-on activities, stating that they employed this approach to instruction because it elicited excitement from their students, piqued their interest, and got them engaged. Keeping one's students happy does not imply meaningful learning is taking place. Teachers at all stages of their careers often feel like novices when it comes to teaching science due to their lack of familiarity and comfort with the subject matter.

Professional Development

It is widely agreed upon that professional development is the key to reform. Research on PD has illuminated various characteristics of effective PD program designs. Teachers require support that addresses their actual needs (Davis et al., 2006), is sustained over time (Garet, Porter, Desimone, Birman, & Yoon, 2001), models the strategies that teachers are expected to implement in their classrooms (Freeman, Marx, & Cimellaro, 2004), and engages the teachers as learners (Loucks-Horsley & Matsumoto, 1999). Programs tend to be more successful when they focus on disciplinary knowledge (Garet et al., 2001) and how students learn, what they learn, and how to access and assess that learning (Little, Gearhart, Curry & Kafka, 2003). Additionally, programs that foster the development of collegiality and peer collaboration (Grossman, Wineburg & Woolworth, 2001), situate the learning in the teacher's own classroom context (Putnam & Borko, 2000), and allow for feedback and subsequent refinement of practice (Prawat, 1992) tend to lead to better results in terms of changing teachers' beliefs and practice, and ultimately student learning outcomes.

Finally, formal PD opportunities, such as institutes and workshops may also serve a key purpose in supporting teacher development. Putnam and Borko (2000) assert that situating PD outside of the classroom can also be important in fostering teacher learning. For example, Schwartz, Lederman, and Crawford (2004) found that engaging teachers in authentic research experiences, where they work at the elbows of scientists, is a component of effective PD.

While there is broad agreement that these are characteristics of effective PD, the science education community continues to struggle with designing programs that directly ameliorate teacher practice (Putnam & Borko, 2000). There is some evidence that multi-component PD models, with multiple stages and types of support, can lead to improvements in teachers' knowledge, beliefs, and instructional practices (Putnam & Borko, 2000; van Driel, Beijaard, & Verloop, 2001). Coaching has recently been touted as an effective component of such support, in order to address the need for PD to be ongoing and situated in teachers' classroom practice (e.g., McCombs & Marsh, 2009). Curriculum materials, on the other hand, have a long-standing history in supporting teachers' classroom practice (DeBoer, 1991). The literature related to multi-component PD efforts, coaching, and curricula are briefly discussed below, and in more detail in Chapters IV and V.

Multi-Component PD

Short-duration PD opportunities situated outside the school, reinforced by school-based support from colleagues and researchers, appear to have a positive impact on teacher learning. Such a multiple-contexts approach was employed by Fishman, Best, Foster, and Marx (2000) in their work related to Project-Based Science (PBS). Teachers who participated in their research were supported by a summer institute, work sessions on the weekend and after school, classroom assistance from support staff, and collaboration with colleagues. Another multi-component PD program is the one that was developed for the Cognitively Guided Instruction (CGI) project

(Carpenter, Fennema, & Franke, 1996). To support teachers in overcoming their incoherent knowledge of students' mathematical thinking, the teacher participants took part in summer workshops. Additionally, during the school year they observed each others' classroom practice, planned lessons together, and discussed student work. Borko (2004) asserts, however, that at this stage in the game, the education community's understanding of what exactly and how exactly teacher learn from PD is only in its infancy.

Coaching

Since teachers require support that considers their school context and related constraints, as well as their students' needs, coaching has been viewed as a promising way to foster such situated learning. McCombs and Marsh (2009) pointed out, "as on-site personnel who interact with teachers in their own workplaces, coaches should theoretically be able to facilitate learning that is context-embedded, site-specific, and sensitive to teachers' actual work experiences" (p. 502). Joyce and Showers (1980) explained that the work of coaches, who support teachers in developing their content knowledge and teaching skills, should be ongoing and involve modeling, allowing opportunities for teachers to practice what they are learning, and feedback. Moreover, coaching should support a self-reflective practice.

While coaches may wear many different hats, Steiner and Kowal (2007) have found that in order to be effective, they must at the very least have a vast and in-depth understanding of the subject matter in which they are supporting teacher growth, knowledge of how students learn, and strong interpersonal skills. Coaches have been found to work with teachers in a supervisory capacity as well as a side-by-side method. In the latter approach, the coach offers immediate support by stepping in during lesson enactment to model particular strategies, while in the former approach support is provided in the form of feedback after the lesson is observed. Research studies have found both approaches improve teacher practice in targeted areas (Kohler, Ezell, & Paluselli, 1999; Kretlow, Cook, & Wood, 2011), although the side-by-side method is more likely to lead to greater sustainment of changes (O'Reilly & Renzaglia, 1992). For this dissertation study, both approaches were employed by the researcher serving as a science coach.

While coaching is being used increasingly in schools across the country to support teachers in the areas of literacy and mathematics, this form of PD is still practically non-existent in the area of science. Moreover, Vanderburg and Stephens (2010) pointed out that there is a dearth of peer-reviewed journal articles on coaching in the literature on education. Furthermore, "we know…virtually nothing about what it is that, from the teacher's perspective, coaches specifically do that is helpful" (p. 143). They go on to explain that we currently do not know "what specifically teachers decide to change because of their coach" (p. 143). The aim of this study was to illuminate elementary teachers' thinking about science instruction and student learning as they were supported by the researcher working in the role of science coach.

Curriculum

Curriculum materials serve as another form of support for teachers, and a very wide-spread and varied one at that. In fact, what teachers do in their classrooms is heavily linked to textbooks and other curricular resources to which they have access (Schwartz, 2009). Over the years researchers have begun to improve on the textbook, which presents a teacher-directed approach to instruction, by designing more educative materials for teachers (Schneider &

Krajcik, 2002), including kits. To support teachers in teaching in more student-directed ways these reform-oriented curricula provide teachers with lesson plans that have been designed to support teachers in enacting more student-centered and hands-on lessons. Kits have become incredibly widespread at the elementary level, where teachers have the least amount of science background. The Full Option Science System (FOSS) was used by the teachers in this study and was adopted across their district. This curriculum is discussed in more detail in Chapters IV and V. At this point, it is important to point out, however, that while these materials are an improvement on traditional textbooks, they are often implemented in ways that are not inquiry-oriented (NRC, 2000). Consequently, Olguin (1995) found that such curricula do not cultivate students' critical-thinking skills, nor do they lead to improved problem-solving skills among students.

Conceptual Framework

Four conceptual frameworks informed this study and are discussed below. These frameworks are: reform-oriented science instruction, teacher learning and change, career stages, and dilemmas.

Reform-Oriented Science Instruction

Over time there have been many cycles of reform. Nonetheless, several ideas have remained constant, although the wording may have changed. Similar to the calls of recent reforms (NRC, 2007, 2011), over a hundred years ago the science education community was advocating hands-on learning, solving real-world problems, engaging students in science as early as possible, and developing students' abilities to reason (DeBoer, 1991). Clearly, classroom practice has been slow to catch up to theory.

Kahle (2007) documented three waves of science education reform in the United States. The impetus for the first wave of systemic reform was the launch of Sputnik in 1957. From 1957 to 1980, the focus of reform was on addressing the issues of textbooks not being up to date with current scientific advances and the inadequate content knowledge of teachers. Curriculum development efforts during this time focused on creating materials that were "teacher proof" (Nelkin, 1977) and "improving and enlarging the scientific, mathematical, and technical workforce for the nation" (Kahle, 2007, p. 916). The second wave took place in the 1980s and was marked by increased regulation at the state level. This occurred in response to the dismal landscape of the American high school portrayed in *A Nation at Risk.* States began developing and instituting high-stakes tests for high school graduation and standards for grade promotion. The goal was to "[increase] scientific literacy and [use] science to improve the quality of life by ensuring all students graduated from high school with adequate *courses* and *competencies*" (p. 912). Unlike the two previous waves of reform, the third was grounded in theory and research. Beginning in the 1990s, the focus shifted to "*excellence* and *equity*" (p. 912). The aim was to improve student learning by supporting teachers to improve their instructional practice with the guidance of standards.

The standards-based reform movement began with the publication of Benchmarks for Scientific Literacy (American Association for the Advancement of science [AAAS], 1993) and a number of other documents have followed since (NRC, 1996, 2000, 2007, 2011). These documents advocate several reform-oriented strategies teachers of science should implement in their classrooms, although it is understood that teaching science in reform-oriented ways is a much more complex and interrelated process than enumerating such strategies implies. Nonetheless, some examples of reform-oriented science instructional approaches include: teaching unifying themes (NRC, 1996) or crosscutting concepts, such as patterns, cause and effect, and systems (NRC, 2011); implementing inquiry-based lessons (AAAS, 1993; NRC, 1996, 2000, 2007); focusing on depth over breadth in terms of science content; alignment of lessons with students' interests and prior experiences (Tal, Krajcik, & Blumenfeld, 2006); teaching about nature of science (NOS) (e.g., McComas, Clough, & Almazroa, 2002); integrating science and the other core disciplines (e.g., Howes, Lim, & Campos, 2009); and engaging students in argument to develop their ability to make evidence-based claims (e.g., Bricker & Bell, 2008).

Supporting teachers to change their practices in the aforementioned ways is a complicated endeavor. Thus far, it has been a challenging process to design and develop effective ways to support teacher change. This literature is discussed in the following section.

Teacher Learning and Change

Reform-based practices require teachers to teach in fundamentally different ways from the ways they were likely taught. Supporting teachers to develop their practice so that it is more in line with reform-based instruction is a slow and complicated process. There is a vast knowledge base for teaching science (Magnusson, Krajcik, & Borko, 1999). More seasoned and effective teachers of science possess content knowledge, pedagogical knowledge, and pedagogical content knowledge (PCK). In addition, they have developed knowledge of the resources needed to teach science in meaningful and productive ways. Since their science teaching knowledge runs deep and is integrated, they have a host of strategies from which to pull depending on what the particular student or situation calls for.

Developing this knowledge base comes from experience in the classroom and professional development. However, teachers' beliefs act as a screen that filters new ideas and experiences (Pajares, 1992). Teachers' beliefs about teaching and learning have become ingrained through years of schooling when they were students. As a result, building up new knowledge, while revising non-normative conceptions, is not an easy feat. Teachers have their own ideas about science—what it is, how it ought to be taught, how students learn, and their capacity to learn.

Further complicating matters is the fact that the relationship between teachers' beliefs and practices is not a direct one (Richardson, 1996). Even if teachers hold reform-oriented beliefs, they may not translate to their practices (King, Shumow, & Lietz, 2001). The relationship between teachers' beliefs and what they do in the classroom, can be viewed as a feedback loop, as suggested by Jones and Eick (2007). These researchers explain that what we think about science teaching impacts how we teach science and our experience teaching, in turn, impacts what we think. The process is a "back and forth…complex interchange" (p. 495). Guskey (1986) pointed out that what teachers believe about science teaching is particularly impacted by how their students respond to their science lessons. When students are engaged and are achieving academically, teachers are more likely to continue to teach that way. When students do not appear to be learning or seem disinterested in a new approach a teacher is trying out, the approach is not likely to become a fixture in the teacher's repertoire.

Supporting teachers to implement new practices so that they are taught in reform-based ways is crucial so that teachers do not give up on potentially valuable lessons or strategies. In addition to teachers' non-normative beliefs, professional developers may have to address time and scheduling constraints related to planning and teaching science. Lack of coordination across the various levels of the school system (district, school, and classroom) also impacts teachers' abilities to progress in reform-oriented ways (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000). Due to the complexity of teacher change and the limited success of professional development efforts to produce widespread and sustained teacher change, there is more to be learned about how teachers' beliefs and practices interact and relate to teachers' likelihood of implementing science lessons in reform-based ways (Keys & Bryan, 2001; Wilkins, 2008). Furthermore, researchers have indicated a need for more research connecting teachers' characteristics to the enactment of kit-based curricula (Young & Lee, 2005).

Career Stages

Due to the vast nature of the knowledge base for science teaching, learning to teach in reform-oriented ways is viewed as a lifelong process. Researchers regularly group teachers based on career stage when discussing their beliefs, needs, and practices (e.g., Davis et al., 2006). Even though teachers experience unique challenges when it comes to teaching science, as a result of their dispositions, prior experiences, and school contexts, there are some common experiences teachers go through as the progress through their careers. Consequently, it can be helpful to consider the particular stage a teacher is in along her career when designing professional development. Nevertheless, it is important to acknowledge that teachers do not always move through the stages in a linear manner. Moreover, they do not necessarily pass through each stage.

A few different, yet overlapping, pathways have been proposed by researchers. As examples, Feiman-Nemser (2001) discusses three stages in which teachers should receive PD focused on different aspects of the craft of teaching: pre-service, induction, and a continuing professional development stage. Ryan (1986), whose work stems from Fuller's (1969), delineated the following four stages: fantasy, survival, mastery, and impact. A third, more detailed, model of teachers' career stages was put forth by Huberman (1989). He proposed the following possible stages: survival and discovery, stabilization, diversification, experimentation, activism, stocktaking, serenity and conservatism, and disengagement. These three aforementioned models will be discussed in Chapter IV in more detail.

Dilemmas

Teachers encounter dilemmas frequently throughout the day and these dilemmas influence how they use their knowledge and skills in practice. Most researchers conceive of dilemmas as unsolvable situations with two or more possible, yet non-ideal, courses of action. Lampert (1985) depicted teachers as active negotiators. In the face of conflicting interests, the teacher goes through an internal struggle (Gort & Glenn, 2010), influenced by her beliefs and prior experiences with teaching and learning (Anderson, 2002). She engages in debate or argument with herself, considers alternative ways of addressing the issue, and instead of ignoring possibilities that contradict each other, the teacher "acknowledges them, embraces the conflict, and finds a way to manage" (Lampert, 1985, p. 190). Managing dilemmas involves compromise

(Cuban, 1992). Dilemmas may be resolved, but not solved. Tillema and Kremer-Hayon (2005) contend that investigating these teaching dilemmas for the purpose of uncovering what governs the relationship between teachers' beliefs about teaching and their actual teaching practice is an area requiring further research.

In the following chapter I present the methods used in this study. This chapter includes a description of the setting, participants, role of the researcher, forms of data collected, and procedure for analyzing the data. This dissertation employs a qualitative approach to conducting research.

CHAPTER III

METHOD

Research Design and Rationale

This study is a case study involving a team of first-grade teachers. The dynamics of teacher learning and change, in the context of an urban elementary school that had newly adopted a kit-based curriculum, were explored through the construction of rich, thick descriptions of the case (Merriam, 1998). A case study approach was employed because "a complex, detailed understanding of the issue" was sought (Creswell, 2007, p. 40). This approach "offers insights … [that] can be construed as tentative hypotheses that help structure future research; hence, case study plays an important role in advancing a field's knowledge base" (Merriam, 1998, p. 41).

As mentioned previously, there is a lack of literature on elementary science education reform in general (Metz, 2009) and there is a need for more nuanced studies of the factors influencing teacher learning and change (Keys & Bryan, 2001), including teachers' perceived dilemmas (Cuban, 1992; Tillema & Kremer-Hayon, 2005), career stages (Bevan, 2004; Kennedy & McKay, 2011), coaching (Vanderburg & Stephens, 2010; Walpole & Blarney, 2008), and multi-component PD models (Putnam & Borko, 2000).

For the first findings chapter, I chose to focus my study on one team of elementary teachers in order to obtain a rich description of how teachers at various stages of their careers reconcile their perceived dilemmas when they have access to a science coach to support them in using their new science curriculum. Cross-case analysis of the three teachers served to ground the findings and augment their stability (Miles & Huberman, 1994). As Merriam (1998) contends:

> The more cases included in a study, and the greater the variation across the cases, the more compelling an interpretation is likely to be…The inclusion of multiple cases is, in fact, a common strategy for enhancing the external validity or generalizability of your findings. (p. 40)

For the second findings chapter, I chose to focus on a single teacher in order to delve deeper into the various forms of support she received and how these supports interacted with and impacted her beliefs and practices. Miles and Huberman (1994) explained that such sub-cases, embedded within the larger case study, can contribute added richness and complexity as data is analyzed. As all the teachers on the team did not receive the same supports, a cross-case analysis was not possible here. Since this paper was focused on a single teacher, it allowed for more in-depth description and discussion related to the impact of multiple forms of PD on teacher practice.

Participants and Setting

The setting for this study was an elementary and middle school, referred to as Morningview Elementary from here on out. The school is located in a large urban district in the northeast. This school enrolled approximately 600 students from pre-kindergarten through eighth grade. African American students represented 75% of the school population and Latino and Latina students accounted for 24%; 10% of students were English Language Learners, 6% were special education students, and 75% of the total student body qualified for the free or reduced lunch program. [1]

In 2009 the lower-elementary teachers at Morningview received a new kit-based curriculum, the Full Option Science System (FOSS). The school district had decided to change the elementary and middle school science program and had schools elect one of three curricular options. Schools could use (1) the kit-based approach (FOSS), (2) the textbook approach (Harcourt's Science), or (3) a blended approach (combination of kits and textbook modules). The administrators at Morningview opted for the kit-based approach. There are 3 FOSS kits for the first-grade curriculum: Air and Weather, Solids and Liquids, and Insects. The Air and Weather kit contains instructions for 18 lessons and the Solids and Liquids kit includes 13 lessons. Each of these lessons is suggested to take 40-75 minutes of class time. The Insects module is set up slightly differently. Teachers are given the option of ordering five different insects, plus extension lessons are proposed for two additional insects. Most of the insect investigations are divided into three parts, but because insects go through their life cycles at different paces, these various parts each have several "breakpoints" where teachers are expected to discuss particular changes in the insects as students notice them. For example, breakpoints occur when the first pupa or cocoon is noticed and when the first adult emerges. Therefore, while there are generally three parts to each insect investigation each part may be spread over several lessons.

The participants for this study were three out of four first-grader teachers at Morningview: Angela, Jenny, and Monita[2]. Like most elementary teachers, no one on the first-

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[1] Data obtained from the school's Quality Review Report for the 2007-2008 academic year.

[2] All proper names in the study are pseudonyms.

grade team had a strong science background. However, the four teachers each completed an elementary science methods course in their graduate programs when they sought their teaching certification. Emily, the fourth teacher on the team, also worked with the researcher over the course of this study; however, she was not included as a participant in this research report, as the aim was to focus on teachers at different stages of their careers. Emily had two years of teaching experience before this study began, while Monita only had one. Monita was selected to represent the novice elementary teacher as she had the fewest years of teaching experience under her belt.

Angela is an African American veteran teacher, in her sixties, who had 25 years of teaching experience at the outset of this study. Jenny is a White woman, who was just moving on from the induction period, with three years of teaching experience when this study began. Jenny was in her mid-twenties. She taught pre-kindergarten for one year, before moving to first grade. Monita is an Indian woman, also in her mid-twenties. She taught sixth grade during her first year of teaching and switched to first grade the year this study took place.

When the FOSS kits arrived mid-way through the 2009-2010 school year (i.e. the year before this study began), the teachers at Morningview were given a half-day with their teams to open them up and explore their contents. Following this, Angela taught two lessons from the Solids and Liquids unit and then decided to go back to teaching the old lessons the team had developed in previous years. Jenny taught nine lessons from this kit during this first year. Neither Angela nor Jenny taught any lessons from the Air and Weather unit or the Insects unit during the 2009-2010 school year. At this point in time, Monita was one of two teachers on the sixth-grade team and she did not teach science. The other sixth-grade teacher taught science to both of their classes simultaneously, an arrangement made because of Monita's lack of confidence in teaching science and teaching in general. Monita did not teach her first science lesson at Morningview Elementary until she began teaching first grade the year this study took place (2010-2011 school year).

Monita had no experience with FOSS prior to this research study. Jenny and Angela had experience from the lessons they had tried out the year before, as described above. In addition, Jenny used the FOSS kits in her student teaching placement. Angela was the only teacher on the team to receive PD related to this curriculum. In July 2010, Angela attended a weeklong Summer Science Institute (SSI) that focused on familiarizing lower-elementary teachers with their newly received FOSS kits. Six teachers from different grades at Morningview attended this institute, including Angela. Angela was the only first-grade teacher from her school to attend. The other SSI participants came from seven different elementary schools in the neighborhood. A total of 36 teachers attended the institute.

The SSI took place on campus at my university and was run by a former principal and a former teacher who worked for the Lawrence Hall of Science. Two university science teacher educators also attended and took part in organizing the institute sessions, although they were mainly run by the Lawrence Hall of Science professional developers. The SSI was one of several PD opportunities offered to teachers in the district through a five-year school-university partnership that began in 2008-2009. The aim of this partnership was to enhance teaching of science, technology, engineering, and mathematics (STEM). In addition to the SSI, these PD opportunities for teachers included the Fall 2009 Workshop Series, Saturday FOSS Training Workshops, Vital video of teacher practice, university faculty or graduate student in-class or afterschool support, and working with preservice teachers in their classroom. My work at

Morningview Elementary was conducted as part of my work as a graduate research assistant with this partnership. Before beginning this study with the first-grade teachers I attended the SSI, participating in the daily activities with the teachers from Morningview, recording field notes, and documenting teachers' participation and responses to the activities.

Role of the Researcher

In this study I served as a participant observer. In this form of inquiry the researcher assumes a dual role. Guba and Lincoln (1981) explained that acting as an observer, the researcher is "responsible to persons outside the milieu being observed" (p. 190). Conversely, acting as a participant, the researcher possesses "a stake in the group's activity and the outcomes of that activity" (p. 190). The combination of these roles enables the researcher to "[understand] the program as an insider while describing the program for outsiders" (Patton, 1990, p. 128). Since this was my aim, I assumed two roles in this study. First, I participated in this study as a coach, supporting the teachers through discussions related to science and science teaching and observing and assisting in their classrooms. Second, I also served as a non-participant observer, video recording teachers' science lessons and attending their regular planning meetings. This approach provided me with a closer look into the realities of teaching science in first-grade at Morningview (Marshall & Rossman, 1999). Further detail about my role as a science coach is described in Chapter IV.

Data Collection

Multiple forms of data were collected over the course of this study to inform data analysis. Data sources included interviews with the teachers and principals, observations of science lessons, meetings with teachers individually and in groups, and a researcher journal.

Interviews

I conducted two semi-structured interviews with each of the first-grade teachers: Angela, Jenny, Monita, and Emily. The first interview took place in December 2010 and the second occurred in June 2011 (Appendix A). The purpose of the teacher interviews was to find out the dilemmas teachers perceived in teaching science, their perceptions of their science teaching practice, and the reasons they provided for any changes in their teaching practices. Length of the interviews varied between 25-60 minutes.

I also conducted an interview with the principal and one with the assistant principal (AP) in the fall of 2011 (Appendix B). The interview with the principal lasted 30 minutes and the interview with the AP lasted 60 minutes. The purpose of these interviews was to clarify information about the school context that came up in the teacher data and to ascertain the principals' visions for science instruction versus instruction in the other core subject areas.

Classroom Observations

Angela's science lessons were observed and video recorded 25 times over the course of this study, Jenny's science lessons were observed and videotaped on five occasions, and Monita's were observed and taped three times. The discrepancy in the number of classroom observations stemmed from the voluntary nature of this study. It was up to the teachers to decide how often they wanted to work with the researcher and how often they wanted her to observe their lessons. Additionally, several observations were cancelled due to field trips, vision screenings, class pictures, assemblies, and other events that came up.

Observations lasted for the duration of the teachers' lesson, ranging from 45-120 minutes. Angela's lessons tended to be in the range of 90-120 minutes, Jenny's tended to last 45-75 minutes, and Monita's were 45-60 minutes. The purpose of the classroom observations was to provide an additional source of data related to teachers' beliefs and practices about science instruction. It is important not to rely solely on teacher perceptions. I heeded Yin's (2003) warning that verbal reports are biased in nature and may be affected by poor recall. Moreover, he cautioned that they may not accurately articulate their feelings or their accounts of situations.

Meetings

Discussions and meetings with teachers took three main forms: teacher meetings, pre-lesson planning sessions, and post-lesson reflection sessions. Each is described below.

Teacher Meetings. The researcher facilitated 12 meetings with the teachers on the first-grade team over the course of this study. Attendance at these sessions varied due to their voluntary nature and the fact that they were not scheduled by the school. Teachers were absent from meetings when they felt they had other work that was more pressing or conflicts with other meetings where attendance was mandatory. The following table, Table 3.1, outlines the schedule of meetings and which teachers were present. Meetings started up in October, occurring once a week for the first three weeks, until teachers requested we meet bi-monthly instead. The lack of meetings between January and March was due to the teachers deciding that all of their prep time needed to be devoted to organizing themselves for the Quality Review in March. It was the team who collectively decided to postpone the meetings until this district evaluation was over. We scheduled the meetings as often or infrequently as the teachers felt was necessary and feasible. Each meeting lasted 30-45 minutes.

The general purpose of these meetings was to foster collaborative relationships and build rapport and trust among the team and between the teachers and me. The meetings served as a space for the teachers to share where they were in the sequence of lessons, how the science lessons were going, and what advice they had for their colleagues who may not have taught the lessons they had yet. Sometimes these meetings were spent organizing and setting up equipment and sometimes we discussed which lessons to teach next in the sequence and which could be skipped (considering time constraints and the state standards). The literacy coach, Melanie, was invited to join one of the spring meetings in order to support the group in discussing ways to maximize their time for science without taking it away from literacy.

Table 3.1. *Schedule of Teacher Meetings Focused on Science*

	Date	Attendance
1	10/06/10	All four teachers
2	10/13/10	All four teachers
3	10/25/10	All four teachers
4	11/08/10	All four teachers
5	11/22/10	Angela and Jenny
6	11/29/10	Angela and Jenny
7	12/06/10	Angela and Emily
8	01/10/11	Angela and Monita
9	03/17/11	Jenny, Emily, and Melanie
10	04/13/11	All four teachers
11	04/27/11	All four teachers
12	05/04/11	All four teachers

In addition to these 12 science-focused meetings facilitated by the researcher, the researcher attended two regular weekly first-grade planning meetings. These meetings occurred in April and May. At the first meeting, science was not discussed due to lack of time, while at the second one science ended up being the topic for the bulk of the discussion. The researcher also attended one regular literacy meeting facilitated by the literacy coach, Melanie, in February and a second meeting toward the end of the school year. During this second meeting, the teachers worked with Melanie to align their literacy units with what their students were learning in science. All of the aforementioned meetings were audio recorded and all were transcribed except the April planning meeting in which science was not discussed.

Pre-Lesson Planning. The purpose of these sessions was to discuss the teacher's plans for her lesson, discuss the relevant content, and/or assist her with setup. Sometimes the teachers preferred to focus on specific aspects of the lessons and other times we worked together to go over the lesson from start to finish. These meetings took place at the teachers' request. Angela and I met 18 times for this purpose (four of which were audio recorded and transcribed), Jenny and I met four times (two of which were audio recorded and transcribed), and Monita and I met twice (both of which were audio recorded and transcribed).

Post-Lesson Reflections. These debriefing sessions occurred following teachers' observed lessons when they were willing to meet. I prompted teachers to share their thoughts and ideas about how the lesson went. I also provided them with feedback on their practice. Moreover, we discussed what teachers would like to do differently next time and why. The formal discussions were guided by semi-structured questions (see Appendix C). In addition, sometimes we watched clips of the lesson video footage and discussed them together. These meetings served as a form of PD and provided insight into their reasons for their actions.

Other times these meetings were less formal. These conversations happened in passing as I checked in with teachers throughout the weeks. I recorded field notes following these discussions since these informal meetings were not audio recorded. The frequency and duration of these reflecting sessions varied based on teachers' schedules and how much time they wanted to set aside to discuss their science practice. Twelve formal meetings occurred with Angela (ten of which were audio recorded and transcribed), three formal meetings took place with Jenny (one of which was recorded and transcribed), and Monita participated in one such meeting (recorded and transcribed).

Researcher Journal

I kept a notebook with logs of her reflections, thoughts, ideas, and field notes. Entries into this journal were made during or following classroom observations, interviews, and meetings. Notes were also recorded in the journal during the SSI. This journal served as an additional source of data that was used for triangulation during data analysis.

Data Analysis

An inductive approach to data analysis was used in this study. Techniques from Charmaz's (2006) constructivist grounded theory approach were employed. Charmaz's multistage approach was used to analyze the data in both findings Chapters (IV and V). First, this involved going through the transcripts of interviews, pre-lesson planning meetings, and post-lesson reflection sessions one line at a time and assigning open codes. Through this initial stage I remained open to the ideas that emerged from the data and continuously compared the newly read data to previously read data and newly read data to previously assigned codes. During a second pass through these data sources, coding became more focused and selective. Codes were revised as I looked at these sources of data with the lenses of my conceptual framework in mind. Next, I compared data from the transcripts of science lessons, teacher meetings, and principal interviews to these codes, seeking relationships between codes as well as confirming and disconfirming instances. Additional passes through the various data sources occurred in order to revise the codes and eventually condense them into themes. Throughout the analysis process I also wrote memos about my thoughts, uncertainties, and ideas to pursue.

Reliability, Validity, and Rigor

Creswell (2007) explained that obtaining biased results is always a concern, regardless of whether a qualitative or quantitative approach is employed. In order to address this potential issue I implemented a number of Creswell's suggestions, as well as those of other researchers (e.g., Guba & Lincoln, 1989). I collected and analyzed multiple sources of data. Triangulating these various sources enabled me to view the participants' beliefs and practices from multiple viewpoints (Yin, 2003) and allowed for finer-grained descriptions of the cases. Rich, thick descriptions were provided to substantiate my findings. From these detailed descriptions the reader can evaluate the findings for themselves and determine transferability. Brickhouse and Bodner (1992) declared, "The degree to which these or any other research findings are generalizable to other situations is dependent on the similarities between the two contexts" (p. 474). I also spent an extensive amount of time in the school and with the teachers, especially Angela. Through this prolonged engagement with the participants in their teaching context, I was able to develop a deep understanding of the case, which assisted the interpretation of the findings. Moreover, I situated myself in the research by explaining, in Chapter I, my background and beliefs coming into this study. I also described the theoretical underpinning that informed my frame of reference in Chapter II. Finally, I engaged in peer review (Creswell, 2007; Guba & Lincoln, 1989) throughout the stages of this research study. Having other science education researchers read through my work was helpful in designing the study (e.g., interview protocols) and pointing out areas that required clarification or further information.

There are both advantages and disadvantages associated with participant observation. A possible limitation of being a participant observer is the potential to become so absorbed in the role of participant that the role of researcher is compromised (Merriam, 1998). On one hand, for my study, this approach enabled me to develop trusting relationship with the teachers. On the other hand, because I provided the teachers with support and was also the one requesting feedback on the support I provided, the teachers may have felt reluctant to disclose their true impressions of the professional development I provided. In order to help address this concern, I spent an extensive amount of time not only talking to teachers in various settings (interviews, teacher meetings, and pre- and post-lesson meetings) in order to build trust and their sense of security in providing candid feedback, but I also observed their classroom lessons in order to go beyond their expressed views of the impact of the PD. I also made it clear to the teachers that I was not evaluating them. Moreover, I met with the principals to discuss any changes they noticed as a result of the teachers working with me. Analyzing data from multiple sources and engaging in peer review assisted me in guarding against possible unwarranted interpretations of evidence due to my role as a participant observer. As Merriam (1998) explained, researchers must be careful to account for any effects they might be having on the research participants. I accomplished this through the triangulation of multiple sources of data and by providing ample supporting examples and segments of data to substantiate my claims in the chapters that follow.

While studies where the science coach is not the same person as the researcher will be valuable to the field, this was not possible for this study since science coaches are currently a rarity across New York City, not to mention nationally. Nevertheless, all the efforts outlined above provide robust evidence of the validity of my research endeavor in this under studied area of science education.

CHAPTER IV

FINDINGS

COACHING AND CAREER STAGES: RECONCILING THE DILEMMAS OF TEACHING SCIENCE IN ELEMENTARY SCHOOLS

Abstract

This study identified and explored the dilemmas experienced by three first-grade teachers at different stages of their careers in teaching elementary school science. The teachers perceived tensions between (1) focusing their efforts on science versus the other school subjects, (2) their responsibility to teach science and their lack of a science background, and (3) using their curriculum as a script, supplement, starting point, or not all. The findings indicated that while the teachers all experienced these same broad dilemmas, they reconciled them in different ways due in part to the sense of accountability they felt to teach science and their career stage. While all three teachers were novices in terms of teaching science, their levels of expertise in other subjects and in teaching more generally were related to how effectively they addressed these dilemmas. Moreover, the evidence suggests that having an advocate for science, such as a science coach, onsite at the school assisted the teachers in addressing their dilemmas in more reform-oriented ways, although teacher readiness was a contributing factor to how the teachers progressed and what types of support they found beneficial.

Introduction

Student learning is directly linked to teacher practice (Darling-Hammond & Youngs, 2002) and increasing emphasis is being placed on standards-based evaluation of students and their teachers. Moreover, given the emphasis on developing scientific literacy, including higher-order knowledge and skills, for example, concepts, principles, theories and relationships among science, technology and society (e.g., Abd-El-Khalick & BouJaoude, 1997; NRC, 1996), the process must begin at an early age, notably at the elementary school level. However, researchers have found that we are still a long way off in terms of moving science teachers toward such reform-oriented classroom practices. Elementary teachers work in an environment where there is an intense focus on literacy and mathematics, which typically leads to the marginalization of science (Appleton, 2007). Further compounding the issue is the fact that elementary teachers are not likely to have much of a science background (Fulp, 2002; Tilgner, 1990) and have little confidence in teaching science (Cochran & Jones, 1998).

It is widely agreed that professional development is the key to reform and that ongoing support situated in teachers' classroom practice is the optimal form of professional development (Davis, 2003; Putnam & Borko, 2000), especially given the complexity of decision-making that most elementary school teachers must confront in their daily practice. Science coaches appear to be a sustainable and effective way to provide elementary teachers with the immediate and individualized professional development they require. However, there remains much to learn about what effective coaches do and how they impact what teachers do (Vanderburg & Stephens, 2010; Walpole & Blarney, 2008), particularly considering the apparent lack of due attention in the published literature. To contribute to the literature on science coaches and how they can best support elementary teachers at various stages of their careers, this study explored the dilemmas perceived by a novice teacher, a teacher just emerging from the induction stage, and a veteran teacher, and how they each reconciled dilemmas related to teaching elementary science.

Literature Review

Elementary Science Education

The elementary school is a unique context for the teaching and learning of science. "Nothing is comparable to this structure in terms of how time is allocated for subject-matter learning, how resources are used and teachers are supported, and how relationships are built"

(Mensah, 2010, p. 979). Unlike high school and middle school teachers, elementary teachers are responsible for teaching all the core subjects, have limited instructional time allotted to science, tend to lack an adequate background in science (Fulp, 2002; Shulman, 1986), and consequently many elementary teachers have low confidence in teaching science (Cochran & Jones, 1998). To cope, elementary teachers avoid teaching science, teach only the topics with which they are most comfortable, or focus on expository teaching rather than discussion and questioning (Harlen, 1997).

Even when elementary teachers do not shy away from teaching science, the quality of the instruction is often problematic, including mobilizing belief systems that bias new pedagogical ideas in complex ways before integrating them (Pajares, 1992; Richardson, 1996; Tilgner, 1990). Prawat (1992) reported that adopting constructivist theory and inquiry-based pedagogical practices requires a drastic change in the teacher's beliefs and their role in the classroom. Teachers must revise their view of themselves mainly as dispensers of facts (Tilgner, 1990) and overcome prior conceptions based on a commitment to use what appears to work (e.g. van Driel et al., 2001), often a more traditional approach to science instruction.

On the other hand, studies have also shown that even if teachers possess reform-oriented beliefs this is not a sufficient condition for ensuring that their beliefs align with their practices (Brickhouse & Bodner, 1992; King et al., 2001). For example, teachers may believe that studying less material in more depth is ideal for fostering learning at the higher levels of Bloom's taxonomy. Conversely, they are held accountable for teaching a broad range of topics by state-mandated tests which appear to value more superficial knowledge that can be memorized, leading in some cases to suppressing their commitment to a constructivist approach (Ramos, 1999). Science instruction is largely influenced by curriculum materials and kit-based materials have become increasingly widespread in the elementary grades as a means of enhancing the inclusion of science in lessons. Full-Option Science System (FOSS) is a curriculum, developed at the Lawrence Hall of Science at the University of California at Berkeley, which has been widely adopted by districts across the United States. The activities in these kits have been designed to align with students' cognitive levels and what we know about how students learn. Although the FOSS kits aim to promote active learning, multisensory methods, peer interaction, discussion, reflective thinking, and interdisciplinary connections (Delta Education, 2011); teachers may enact them in such a manner that they do not promote rich inquiry-based learning for students (NRC, 2000). Therefore, teachers require professional development, such as coaching or other supportive programs, to learn how to implement curricula in reform-oriented ways.

Teacher Professional Development: Coaching

Teachers require support that takes into account the context in which they work and the constraints they believe inhibit them from teaching *their* students, in *their* classrooms, in more reform-oriented ways. Unfortunately, short courses and one-shot workshops, commonly used, have been shown repeatedly not to improve teacher's practices (Yoon et al., 2007). When teachers return to their school, there is rarely a staff member—teacher or administrator—who has a strong science background on site, let alone someone with the skills and knowledge to assist them in making the necessary changes to improve their science teaching practice. Coaching provides the potential for such situated and content-based learning. Although the most effective means of coaching for teachers is not well defined (Walpole and Blarney, 2008), several roles have been delineated. These include “change coaches,” who work primarily with the principal and concentrate their efforts at the school-level; and “content coaches,” who work with and support teachers in a particular subject area (Neufeld and Roper, 2003). Researchers have also differentiated between coaching as a supervisory approach versus a side-by-side method. In the former approach, the coach provides only feedback; in the latter, the coach may step during a lesson in order to show the teacher how a new strategy or change can be enacted (Kertlow and Bartholomew, 2010). There is a lack of studies on coaching in peer-reviewed journals and much of the literature that does exist is focused on literacy coaches. While coaching is increasingly being used by schools for professional development in the area of mathematics (Antsey & Clarke, 2010), science coaches are much less common. This research study aimed to uncover elementary teachers’ thinking about teaching and learning science as they worked with a researcher in the role of a science coach to implement a new curriculum. Since the kit-based curriculum was adopted district wide, it was crucial to uncover teachers’ perceived dilemmas related to implementing the kits and how the teachers each went about reconciling these tensions. The conceptual framework of the study focuses on the professional learning continuum of teaching and the dilemmas of teaching. More specifically, I explored the dilemmas perceived by three teachers at different stages along the professional learning continuum and how these teachers reconciled them.

Conceptual Framework

Teacher Dilemmas and the Professional Learning Continuum

Teachers encounter dilemmas on a daily basis that impact how they translate their knowledge and skills into practice. However, “we seldom examine these below-the-surface conflicts even though [teachers] cope with them continually in [their] work” (Cuban, 1992, p. 6). How teachers address dilemmas is an area of research that requires further investigation, in order to deepen our understanding of the complexities of teaching and learning (Gort & Glenn, 2010).

A dilemma is a situation presenting a minimum of two alternative courses of action, neither of which is optimal. While Berlak and Berlak (1981) viewed dilemmas as solvable, most other researchers believe dilemmas can only be managed or addressed through compromise (Cuban, 1992; Katz & Raths, 1992). Taking the latter stance, Lampert (1985) contended that instead of focusing on solving problems, teachers assume the role of active negotiator. The teacher has a host of interests that must be balanced in the classroom, in doing so, “She debates with herself about what to do, and instead of screening out responsibilities that contradict one another, she acknowledges them, embraces the conflict, and finds a way to manage” (p. 190). Dilemmas characterize the internal struggles teachers go through with regards to the external problems they perceive (Gort & Glenn, 2010). Focusing solely on external barriers or constraints does not provide the whole picture, since “much of the difficulty is internal to the teacher, including beliefs and values related to students, teaching, and the purposes of education” (Anderson, 2002, p. 7).

Researchers commonly categorize and account for differences among teachers based on their years of experience when discussing the challenges and successes of learning to teach (e.g., Davis et al., 2006). Although teachers encounter unique challenges based on their individual dispositions, experiences, and contexts, there are some general stages that teachers appear to go through as they gain experience and knowledge related to teaching. Nevertheless, teachers do not necessarily progress through these stages linearly, nor do they necessarily advance through all stages.

Researchers have proposed different, yet overlapping models for the stages of the teaching career. Feiman-Nemser (2001) has described a professional learning continuum that begins with pre-service education, extends through the induction period (the first three years in the classroom), and continues right up until retirement. Ryan (1986) delineated four stages: (1) pre-service teachers envision themselves being like their most effective teachers (*fantasy* stage), (2) upon assuming the role of classroom teacher they realize the challenges of fulfilling their responsibilities and working within the confines of their school context (*survival* mode), (3) with experience teachers develop a repertoire of knowledge and strategies (*mastery* stage), and (4) some eventually reach a level of proficiency where they can share their wisdom with their colleagues (*impact* phase). It is important to keep in mind that teachers may be in the mastery stage in some aspects of their practice, but they may not have attained mastery in other respects.

Huberman's (1989) model is more detailed and consists of several stages. He described new teachers as in a stage of *survival and discovery*, characterized on the one hand by "continuous trial and error…wide discrepancies between instructional goals and what one is actually able to do in the classroom…[and] concerns with discipline and management that eat away at instructional time" (p. 349). On the other hand, the challenge of learning to teach can be perceived as exciting due to "the sharp learning curve [and] the headiness of having at last one's own pupils" (p. 349). Teachers may enter the *stabilization* phase as successes with their instructional practices begin to accrue and their concerns shift from issues of survival to the quality of their instruction, after which some teachers enter an *experimentation and diversification* phase where they seek out new knowledge and ideas to try out in their classroom. Beyond this point teachers may enter a phase where they question themselves as teachers if they have tried to diversify their practice unsuccessfully (*stock-taking*), some pass through a "self-accepting" period where they exert less effort on improving their practice and take on a mechanical approach perceived as successful (*serenity*), and others may go through a time where they become more prudent in their practice and more dubious of reforms (*conservativism*). The final stage in Huberman's model is *disengagement*, which involves a gradual process of withdrawal and a refocusing of one's efforts outside of the classroom and school.

Research Questions

This research study aimed to uncover elementary teachers' thinking about teaching and learning science as they worked with a researcher in the role of a science coach to implement a new kit-based curriculum. The research questions were:

1. What dilemmas did three teachers at various stages of the professional learning continuum perceive related to teaching and learning science?
2. How did the teachers reconcile the dilemmas they perceived related to science teaching?

a) What were the differences and similarities in how the teachers at different stages of their careers reconciled the dilemmas they perceived related to teaching science?

b) What impact, if any, did the researcher—in the role of a science coach—have on the teachers' reconciliation of their dilemmas?

Method

This research study is a case study in which rich, thick descriptions (Merriam, 1998) were composed regarding how the three teachers addressed the dilemmas they perceived related to teaching science. A case study approach was appropriate in order to provide "a complex, detailed understanding of the issue" (Creswell, 2007, p. 40). This depth of detail is not possible with large-scale quantitative studies, which "provide a general picture of trends, associations, and relationships, but they do not tell us why people responded as they did, the context in which they responded, and their deeper thoughts and behaviors that governed their responses" (p. 40).

Setting and Participants

This study took place over the course of a school year (October 2010-June 2011) at "Morningview Elementary." This school is located in a large urban district in the northeast and served approximately 600, primarily African American (75%) and Latino and Latina (24%), students. 75% of whom qualified for free or reduced lunch.[3] The school district recently changed

[3] Data obtained from the school's Quality Review Report for the 2007-2008 academic year.

their science program and the teachers at Morningview received their new FOSS kits midway through the 2009-2010 school year.

The participants in this study were Angela[4], Jenny, and Monita; who had 25, 3, and 1 years of teaching experience, respectively, at the outset of this endeavor. Emily, the other first-grade teacher, was not included as a participant in this study in order to focus on three teachers at different stages of their careers. None of the teachers on the first-grade team had a science degree; however, they had all completed a graduate-level elementary science methods course at the time of their certification. Angela is an African American woman in her sixties, Jenny is a White woman in her mid-twenties, and Monita is an Indian woman, also in her mid-twenties. Monita had no prior experience with the FOSS curriculum before this school year. Jenny had used the FOSS kits when she student taught in college and had tried out nine lessons from the Solids and Liquids kit the year before this study. Angela taught two lessons from the Solids and Liquids kit that year and had also gained some experience with the FOSS lessons before this study began by attending a five-day Summer Science Institute (SSI) (July 2010) that focused on familiarizing teachers with their FOSS kits. Angela was one of six teachers from her school, and 36 teachers total, to attend the SSI.

Role of the Researcher as Participant Observer

Guba and Lincoln (1981) explained that acting as an observer one is “responsible to persons outside the milieu being observed,” while acting as a participant one “has a stake in the group’s activity and the outcomes of that activity” (p. 190). By integrating these roles, a

[4] All proper names in the study are pseudonyms.

participant observer “become[s] capable of understanding the program as an insider while describing the program for outsiders” (Patton, 1990, p. 128). On one hand, I worked in the capacity of a science coach, facilitating meetings with the first-grade teachers, helping out in their classrooms as a co-teacher, and offering constructive feedback and support with respect to lesson planning and instruction. On the other hand, I was a non-participant observer. In this capacity, I observed and video recorded the teachers’ science lessons and I was present at regular planning meetings. This approach permitted me to live through the reality of teaching first grade science at Morningview (Marshall & Rossman, 1999).

I worked with all teachers in a supervisory role to gain some ideas of their practices and what their needs were, as well as a side-by-side role in order to model how new strategies could be implemented. Modeling took many forms, including stepping in during lessons to demonstrate certain strategies or addressing students’ questions when the teachers requested assistance with the content. I also provided the teachers with handouts that could be used as models to assist them in carrying out new strategies in context (Appendix D), such as prompts to assist them in probing student thinking and handouts to assist them in carrying out student-driven investigations. Various modes of feedback were also employed, including providing immediate suggestions during enactment of a lesson, as well as providing support prior to and after teaching lessons.

I was not hired by the school as a science coach and due to the fact that this study was voluntary and the teachers had the option to participate in coaching sessions and meetings as often or infrequently as they liked, the results achieved in this study are likely to be less powerful than if the teachers had been required by their administrators to work with a science coach with a similar approach to mine. According to Steiner and Kowal (2007), at a minimum, effective coaches must embody the following qualities: pedagogical knowledge (including how children learn), content expertise, and interpersonal skills.

Data Collection

Multiple forms of data were collected and used to construct the cases of Angela, Jenny, and Monita.

Interviews. The three teachers participated in interviews (2 each) which served to elucidate their dilemmas in teaching science and the reasons they ascribed to instructional changes (Appendix A). Interviews conducted with the principal and assistant principal (AP) (Appendix B) provided information about the school context and assisted in triangulating data. These interviews also provided insight into how the administrators viewed science in relation to the other core subjects.

Classroom Observations. Angela, Jenny, and Monita's science lessons were observed and videotaped 25, 5, and 3 times, respectively. Observations were not consistent due to the fact that participation in this study was voluntary and teachers individually decided how often they wanted to work with the researcher. Angela's lessons usually lasted an hour and a half to two hours, Jenny's were between 45-75 minutes, and Monita's were in the range of 45-60 minutes.

Pre-Lesson Planning. I met with the teachers when they wanted assistance planning their science lessons. Such sessions occurred 18 times with Angela (four of which were audio recorded and transcribed), four times with Jenny (two of which were audio recorded and transcribed), and twice with Monita (both of which were audio recorded and transcribed). The purpose of these sessions was to discuss the teacher's plans for the lesson and/or to help her setup.

Post-Lesson Reflections. Debriefing sessions with the teachers took place after observed science lessons, if the teachers wanted to meet. During these sessions I prompted the teachers to discuss their thoughts on how they believed the lessons went and provided them with feedback, using a semi-structured approach (Appendix C). Sometimes we also reviewed segments of video footage from lessons and commented on them together. These reflections served as a form of PD and were used as a way for me to find out their perceived reasons for their actions. I met with Angela a total of 12 times to reflect on her lessons (ten were audio recorded and transcribed), with Jenny three (one was recorded and transcribed), and Monita once (recorded and transcribed).

Teacher Meetings. Twelve science-focused teacher meetings were held over the course of the school year. Attendance at these meetings varied due to teachers' other commitments and the format of the teacher meetings varied based on teacher needs. Meetings took place during a prep period, afterschool, or during lunch. These 30-45 minute meetings served as opportunities to cultivate collaborative, trusting relationships among all of the teachers and me. Teachers shared how their lessons were going, their suggestions for their colleagues, and what they planned to teach next. At times we setup equipment or discussed the sequencing of lessons. The researcher asked the literacy coach, Melanie, to join one of the meetings in the spring to discuss ways in which time for subjects could be maximized through integrating them as appropriate. An additional meeting with Melanie took place at the end of the year in order to discuss how to sequence the literacy units for the following year, so that they aligned with what students were learning in science. The 12 science-focused teacher meetings were audio recorded and then transcribed and so was the additional meeting with the literacy coach. The researcher was also present for a regular planning meeting in March and one in April. Science was discussed at the latter, but not the former meeting because the teachers ran out of time (an apparently common occurrence during these meetings).

Researcher Journal. For the purpose of triangulation, I kept a running log of field notes regarding classroom observations, interviews, teacher meetings, and the SSI.

Data Analysis

In order to analyze the data I used an inductive multistage approach, employing some of the techniques of constructivist grounded theory (Charmaz, 2006). Transcripts of lessons, teacher meetings, and one-on-one discussions and interviews with teachers were entered into ATLAS.ti. During initial coding, transcripts and field notes were coded line-by-line. I remained open to ideas that surfaced from the data. Through this process I continuously compared data with data and data with codes as they emerged. I read through the data a second time, employing a more selective approach, which Charmaz (2006) refers to as “focused coding.” This time I specifically looked for, coded, and wrote interpretive memos connected to the data using the lens of teacher dilemmas. During this second round, I compared data to codes, sought relationships between codes, and eventually condensed the dilemma-related codes into themes. From this process, three overarching teaching dilemmas emerged: whether to spend time and effort on science or the other core subjects, how to go about teaching science with the lack of a science background, and whether to use the curriculum materials as a script, starting point, supplement, or not at all.

Figure 4.1 outlines how I arrived at these three themes from my initial dilemma-related codes. Through a third examination of the data, I focused on how the teachers each reconciled these tensions, paying specific attention to the impact of coaching as a form of professional development and the impact of the teachers' levels of teaching experience. This enabled me to "synthesize and explain larger segments of data" (Charmaz, 2006, p. 57), which I did through memo writing. Memo writing occurred throughout the entire analysis process to document my developing interpretations.

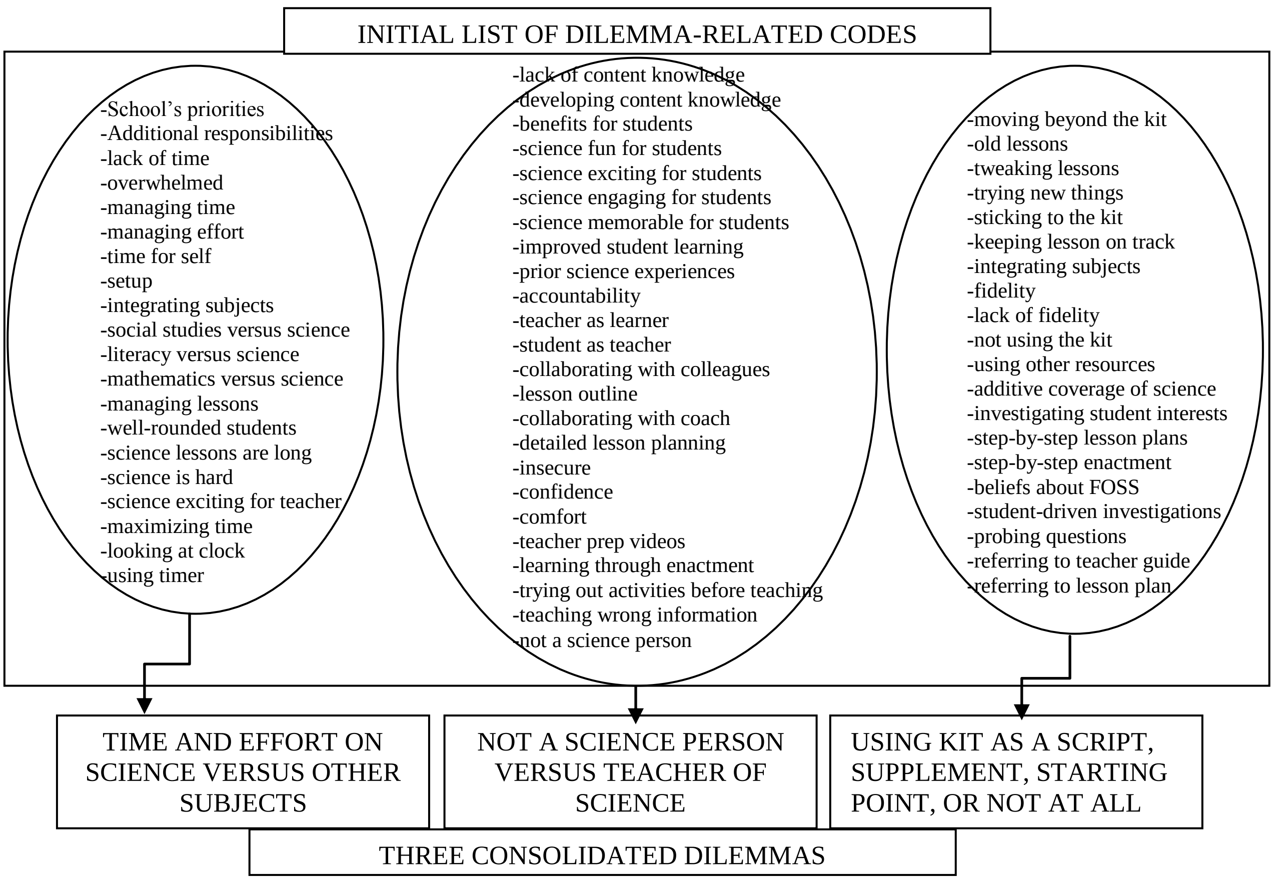

Figure 4.1. Emergence of three dilemmas related to science teaching.

Findings

Three dilemmas emerged through the data analysis process: (a) the teachers struggled to reconcile whether to spend their time and efforts on science versus the other subjects they taught; (b) the teachers felt a tension related to teaching science given the fact that they all possessed a limited background in this discipline, and (c) the teachers had to figure out the best use for their FOSS curriculum: as a script, a supplement to their old lessons, as a starting point, or not at all. How the teachers conceptualized and reconciled each dilemma is described below.

Dilemma #1: Spending Time and Effort on Science or Other Subjects

All three teachers found time to be their biggest constraint in terms of teaching science. Instructional time was curtailed due to Talent Tuesday[5] and Studio in the School[6] which occurred one afternoon a week, and the need to test students' reading levels each month. Planning time for science was in short supply as well because the first-grade team met with their literacy coach once a week, received literacy PD eight times over the course of the year, and attended meetings with their mathematics coach once a month. The teachers were also responsible for serving on different subject-matter committees that met during half days and took their classes on numerous field trips each year. The teachers all articulated that when time was lacking, science was the first subject to go.

The year this study took place was Monita's first year teaching first grade, and also her first year teaching science. She had previously worked at Morningview for one year as a sixth-

[5] Talent Tuesday is a (one afternoon a week) project-based enrichment program where each teacher teaches a cluster of mixed-grade students who elect to join a particular group based on their interests. For example, one group collected food and books for a local food bank.

[6] Art program where an artist comes into the classroom to work with the students.

grade teacher, but the other sixth-grade teacher taught her students science. Midway through this study, Monita described herself as “still trying to figure out everything” and she described her science teaching practice as essentially “nonexistent.” Throughout the entire year she conveyed feeling “overwhelmed,” making statements such as: “I don’t know how they expect us to do everything.”

All three teachers felt overwhelmed by various school initiaves related to literacy and mathematics. Angela asserted, “There are so many things…that are demanded of us like reading number one, math number two…we’re observed in those areas.” On the other hand, none of the teachers were required to be observed teaching science. While student promotion was tied to students’ reading levels, and progress in mathematics and literacy was carefully monitored; there was no such accountability for science. Jenny explained, since “this is the big year for reading…a lot of time is spent...planning my reading lessons, my small groups, making intervention groups…I won’t have a job if they don’t advance in their reading levels.” The teachers believed that, provided their students were progressing in reading, their administrators would not have a problem with them going for several weeks without teaching science.

In an interview, the AP admitted that she did not focus her efforts on observing and developing teachers’ science teaching practices as she did not feel she had the knowledge and skills to “speak to it in depth.” Science made her feel “uncomfortable” and, consequently, it “has gone pretty much unrecognized” at Morningview. The AP’s background was in literacy and that’s where she felt she could best support her teachers.

Since Monita was new to first grade, the principal and AP told her to focus her efforts on developing her knowledge and skills related to teaching literacy:

> Everyone says that if I were to focus on one thing and get really good at one thing this year it's reading…So, even if we don't teach anything else, it doesn't matter. And it stinks that it's like that. We're not building a whole child like that."

Monita felt conflicted about not teaching science because of her desire to develop "well-rounded" students who would "grow up and want to pursue science." She felt that all subjects should receive the same level of emphasis in elementary school, as they do in high school. In an effort to partially reconcile this tension, Monita relied on the science cluster teacher, Ms. Warren, as her students' main source of science instruction: "I have no time. That's why I'm using Ms. Warren as my savior for science." Neither Jenny nor Angela viewed the cluster teacher in this way, since Ms. Warren only saw their students for 40 minutes per week.

Monita, Jenny, and Angela also found science to require more effort and time to teach than any of the other subjects. If Jenny felt like she was running behind schedule, she would say to herself:

> I know the science lesson is long…once in a while, I'm like, oh my god, maybe we shouldn't do this, I don't want to do it [split over] two days and then we're going to have to skip a read aloud…So, it's about managing everything.

Jenny and Monita constantly monitored how much time they spent on activities during the day, while Angela took a more laid back approach. For example, Angela did not have any issue dedicating her entire afternoon to science, "You have to spend that time" for "quality." While Angela spent more time than the other teachers teaching science each week, she did not spend as much time as they did planning and preparing for each lesson. As a veteran teacher, Angela felt comfortable teaching off the cuff in subjects in which she felt skilled and knowledgeable. Angela claimed, "Reading, writing—I can just do it with my eyes closed." However, "Science I don't know well enough to do that." Angela did not like winging science lessons, but she often resorted to this because of a perceived lack of time to plan. Since she was accustomed to doing this in literacy, she carried this approach over into science, even though she felt it was not effective. "I feel like…they're missing out…when I don't know what I should know before going into it." To reconcile this tension, Angela was willing to meet with the researcher to plan her lessons during lunch. She also began referring to the FOSS teacher's guide during her lessons to ensure she did not miss key aspects of the lesson. In contrast, when Jenny and Monita planned for science, they carefully read through the teacher's guide and even wrote out an outline in their own words to guide them during enactment.

Over the course of the year, Angela and Jenny each taught 20 FOSS investigations, plus several lessons that extended beyond the kits during the Insects unit, although Angela's lessons were significantly lengthier. Monita taught five FOSS lessons and none that extended beyond the Insects kit. Angela believed her consistency in teaching science was due to working with the researcher each week, which "motivated" her and created a sense of accountability to teach science. Angela also developed a passion for teaching science as she found herself as engaged in the FOSS lessons as her students. She believed that teachers find time to teach the things they care about:

> You know time is so limited around here…but I find if your heart is in something you will find the time….but I do have to push something else to the side to get that science in and I would like not to have to do that…social studies is suffering.

Angela was making time for science, but felt she was pushing other subjects to the side—a tension she struggled to navigate, just as the other two teachers did. Angela stated that she persisted in teaching science because she was impressed with her students' excitement each week and the wealth of knowledge with which they were walking away.

Similar to Angela, Monita felt science required a double period. Unlike Angela, she generally opted to teach social studies over science. Monita found searching through the kit materials, as well as the setup and cleanup to be overwhelming. Monita explained:

> …it's easier to do social studies. The social studies book…it's so teacher friendly that I don't even have to plan for it. I could just pick up the book and I skim it and I'll know exactly what I'm doing, even if I don't know the topic.

This was one way Monita reconciled her beliefs that students should be well-rounded individuals and her perception of the lack of time for anything other than literacy. Jenny also felt that social studies was "easier" to teach than science; however, Jenny did not sacrifice science as often as Monita.

Monita also employed other strategies in attempts to address the tension between the need for students to learn science and the lack of time to setup for it and teach it. She usually employed an additive approach to teaching science, slipping it in when she could. Monita would sometimes make her morning meetings related to science, point out connections to science while on field trips, and bring out science books during reading centers, feeling that "at least they have more exposure to it." Talking about the science content rather than investigating it in action was not Monita's preference, "Science isn't just talking about it, it's doing." Nevertheless, she asserted, "I'd rather have that than not anything."

Monita did make time to teach five FOSS lessons over the course of the year, including two in the fall, when the team was meeting with the researcher more frequently. This approach to coaching served as a form of accountability for Monita to teach science:

> To see how far the other teachers have gotten in their experiments, it makes me feel the pressure of like I have to catch up, I have to do it…'Cause if we didn't have those meetings, we would never talk about science and I would never know and I wouldn't care to try to incorporate it.

She also taught two lessons in January when her principal was planning to visit the first-grade classrooms to check on the consistency between teachers. She used the time normally reserved for Talent Tuesday, since it had not yet started up for the semester. Monita explained her motivation: “I want to be able to show [the principal] that we do science in here. Not just for show, for the fact that these kids still need that.” After these two lessons, Monita did not teach a FOSS lesson again until the insects arrived for her third and final unit of the year in April. Monita asserted:

> I do feel like I taught more towards the end [of the school year], especially with the insects because we had to go with the process of the way things were happening and I feel like that was very good. It made us have to do it.

Mostly, Monita taught about the insects in a more traditional way, mainly touching on students’ observations of the insects in their habitats: “I feel like I took the teaching points from the FOSS and just took out what I thought…I would be more capable of doing within the timeframe.”

Students being “rowdy” during science was another concern that worried Jenny and Monita. Jenny expressed that she sometimes thought to herself, “Oh my god, am I going to get through this lesson? Are they going to pour everything on the table?” To reconcile this issue, Jenny would often schedule science on days where she had assistance from a volunteer college student. She also found co-teaching with the researcher to alleviate this concern: “I also like having you as almost like a co-teacher, helping me facilitate, especially because I love working in small groups…I think there’s a good trust.”

Unlike Monita, Jenny and Angela had more developed general teaching repertoires and greater confidence in teaching mathematics and literacy, which is why they felt they could dedicate more time to science. Jenny stated, “I’m more comfortable in first grade…I’m not as overwhelmed with all the other subjects…I can put more time and effort into science." Jenny also felt that discussions with the researcher contributed to her ability to productively manage this dilemma:

> I feel like meeting with you, we all just started to realize that we need to put more time into it [science]…it's important for them and we're all feeling more comfortable and confident and feeling more secure to just try it out.

After the researcher asked Melanie, the literacy coach, to attend a science meeting and she suggested the teachers allow students to write about what they are learning in science during their literacy writing workshops, all three teachers learned that they could better address the literacy versus science dilemma. Monita stated, "Like how Melanie says we don't always have to do writing workshop [separate from science]." Monita expressed the desire to change her practice; however, she felt that this would only come with experience, "I know that next year I'm not going to do the same thing…I'm not going to be learning everything for the first time. I'll know how to balance things."

On the other hand, Jenny and Angela, began to immediately try out Melanie's suggestions. For example, since Jenny often read a book during her science lesson, she realized that this could be used as her read aloud for the day. Additionally, during a science investigation she was observed bringing students' attention to the mathematics concept of doubles. During Angela's poetry unit, she had her students work as a class to write a song about the life cycle of a beetle using the information they had learned in science. In addition, Angela addressed literacy standards when she read books during science lessons, asking question such as, "What do you think this book is going to be about?" Angela also drew students' attention to features of books like the table of contents, so they could classify the type of book they were about to read.

Dilemma #2: Teaching Science without a Science Background

All three teachers had concerns about teaching science, given their limited knowledge of the discipline. Monita stated, “I do feel like I’m the least confident teaching science because there’s so many…just the concept of am I going to be wrong?” Jenny found that “sometimes science is hard.” Angela expressed, “I’m afraid of giving wrong information…because these kids are like sponges and I don’t want them going home [with the wrong information].” To address this dilemma, Angela took the opportunity to attend the SSI and work with the researcher regularly. Moreover, all three teachers positioned themselves as learners. Angela often stated that she was “learning along with [her] students.” When Monita did commit to teaching science, she took a similar stance: “I like showing the kids that I don’t know everything, that I’m learning with them… it shows them that there’s so many things to dissect in science.”

In addition to learning along with her students, the teachers also had their students assume aspects of the role of teacher. Jenny explained, “I don’t always know all the answers, so I’m having them learn that like we all don’t know everything. Like when we learned about clouds, your parents might not know clouds. You can go home and teach them…” Leveling the roles of teacher and student helped the teachers address their insecurities related to content knowledge.

Another way that Jenny worked around her lack of knowledge about science and science teaching was to carefully read through the FOSS teacher’s guides and write out her own lesson outlines to follow during enactment: “Just making my own routine this year has helped me feel more comfortable…So, now I’m like I know what I’m doing each time, I have this down pat, I can just do it." Monita also met with Jenny to plan a lesson at the beginning of the spring semester, which she felt increased her confidence:

> We're both the same way where we have to write it on paper to say like okay bring the kids to the rug, like a step-by-step thing…so, to have a clear outline…I feel like it calmed my nerves to be like after this they're going to do this.

Because she found the kits overwhelming, Monita expressed to the researcher that it would be helpful to sit down with someone to go over the FOSS teacher guide and write out a step-by-step lesson in her own words. The researcher offered her assistance with lesson planning several times, but Monita only accepted once, because she felt she did not have the time.

Classroom observations of the FOSS lessons Monita taught in the spring semester showed that she remained insecure in her teaching, despite having planned the lessons collaboratively and having her outline in hand. The following dialogue from a lesson on solids, in which she reviewed the three states of matter, portrayed her lack of confidence:

Monita:	Who can tell me what this bag is [Ziploc bag containing a wooden block in the shape of a cube]?
Student 1:	A cube.
Monita:	A cube. [Teacher refers to her outline.] We call this a solid. It doesn't… [Teacher looks toward the researcher:] It doesn't change its shape? I don't want to say the wrong thing.
Researcher:	[Motions to continue.]
Monita:	[Looks back toward the students:] Okay the solid doesn't change the shape.
	(…)
Monita:	Raise your hand if you don't know what one of these words [on your handout] means. Just say the word and I'll explain.
Student 3:	Rigid.
Monita:	Rigid is like … [addresses the researcher:] hard? Is that…how could I describe?

While collaborative planning and having an outline to guide her through the lesson helped ease her anxiety, the impact was only slight because Monita only taught five FOSS lessons over the course of the year.

In contrast to Monita, Jenny's confidence in teaching science grew substantially, attributing her development to the following factors. First, when the researcher originally started meeting with the team, she suggested that the teachers watch the FOSS teacher preparation videos to see what the lessons might look like in practice. Jenny explained:

> Definitely looking at the videos has been so helpful, because I'm a visual person. So, getting to see it, I'm like, oh my gosh, I could definitely do this. It doesn't look that bad. And hearing the teachers talk on the computer, I feel like gives me a good model, even though I have my own style of questioning and everything.

Second, Jenny made sure she had a clear understanding of the content before teaching a lesson. She would do research on the internet to deepen her content knowledge as necessary. The other teachers did not use their time in this way. Third, through consistently teaching the FOSS lessons, Jenny developed her confidence in teaching using a more investigative approach and simultaneously built up her understanding of the subject matter. "Now I feel pretty confident, especially because they're [the lessons] building on each other and we're always reviewing, that I actually learned through this [teaching the consecutive lessons] also." Finally, Jenny felt that discussing the lessons with the researcher and her colleagues during meetings augmented her self-confidence. Because of this, Jenny began to seek out the researcher and her colleagues informally to receive more timely support when she was preparing to teach a particular lesson, "If I know Angela already did the lesson, I'll run into her room…I definitely try to communicate with my colleagues about how their lessons went or how they're planning on implementing it." Knowing what to expect made Jenny feel more prepared to teach the unfamiliar content and scientific processes.

Angela was usually ahead of her colleagues in teaching the lessons, thus she addressed her lack of confidence in teaching science by committing to work with the researcher on a weekly basis—significantly more often than the other teachers on her team. Angela also planned a few times with Jenny which boosted her confidence:

> I felt a little bit more confident doing it with someone or talking to someone about what I was going to do, because you really don't know what you're doing if you don't talk to someone. And that's what was great about having you [the researcher] also is because you are a science person. I am the farthest from being a science person.

While Angela did not feel like she became a science person, trying out the lessons and reflecting with the researcher and her colleagues made her feel much more confident in her science content knowledge and her teaching practice, "I'm happy about science… It's not one of those things I'm dreading like, oh what are we going to do now? And, I don't know that much about that."

Like her colleagues, Angela believed that the teacher's guides made teaching science possible, despite her lack of content knowledge, even though she did not read through them as carefully: "I felt confident [when] I went step-by-step and followed the guide." Angela also felt that the FOSS teacher preparation videos, trying out the lessons, and planning and reflecting on them with the researcher led to increased content knowledge and knowledge about teaching more student-centered investigations.

Angela, through her years of teaching experience, had grown more "laid-back" about her practice, accepting that improving her practice would take time:

> I always like to be laid-back. I don't like to be tense and really nervous about it because it's just the lesson and I could always do it again and that's the benefit of learning from this…And each time that I tweak it I should be able to get a little bit better…If I can learn from whatever mistakes I make, then I think I'll get better and better as the years go on.

Angela wished science was not so "foreign" to her, but felt that she was addressing this issue by trying out the lessons and learning through the process. At the end of the school year, Angela stated, "I have more knowledge about the content area. That's for sure! Ha! You know just from watching the films, and reading a little bit about it, and then listening to the things that you [the researcher] have to say."

Dilemma #3: Using the FOSS Kits as a Script, a Supplement, a Starting Point, or Not at All

The three teachers started off the year teaching the old lessons related to the seasons that the first-grade team had developed in previous years. Jenny stated that she enjoyed these lessons and felt comfortable enacting them and Monita was following her lead. Angela had less of an attachment to the old lessons compared to Jenny. Angela explained that her old way of teaching science "was getting kind of boring." In teaching about the seasons students would fold a sheet of paper in four and draw pictures to illustrate the appropriate clothing for each time of year. When Angela began working with the researcher and teaching the FOSS lessons, this sparked her interest in science teaching and she never returned to the old lessons. Angela found that she had questions of her own about the FOSS lessons, which she spent time discussing with her students. She also delved into her students' questions and ideas. Angela found that her students were more engaged in the FOSS lessons and came away with more knowledge:

> They [the students] really feel like scientists. I know. I've taught science for many years…and I never had children really feel like scientists…It's a good thing when I can ask a child what is a cloud and they can say it's made of drops of water.

Once the researcher began working with Angela and setting up meetings with the team, Jenny and Monita also began teaching from the FOSS curriculum, although they did not make a complete transition. Jenny took breaks from teaching FOSS from time to time to teach old lessons she enjoyed or that she felt addressed standards that the FOSS lessons did not. Flipping between curricula like this was a source of tension for Monita. She was a novice teacher and wanted to stick with the team, but she felt it was confusing to move back and forth between the two sets of lessons. Monita was unfamiliar with both curricula and, therefore, was not aware of how they could be used to connect to and build on each other. Conversely, Jenny, who had two years of experience implementing the old lessons, felt that using these lessons as a supplement was a nice complement to FOSS:

> I think it works out nicely. 'Cause you can relate it, like when we went on our walk today we were talking about what we felt and the kids were like, 'Air,' 'Wind.' And, I was like, 'Oh, what have we been learning?'

As stated previously, Monita and Jenny described their approach to using the kits as following the teacher guide step-by-step. The materials were new to them and they wanted to make sure they were enacting them correctly. Jenny explained, "When I look at this [teacher's guide] I get so overwhelmed. So, I always take a piece of paper and I write out exactly what I should do."

Jenny only modified the lessons minimally by employing strategies for grouping students and facilitating discussions that had been working for her, like the "turn-and-talk" strategy. Other than changes of this sort, Jenny followed the teacher's guide like a script, because she believed it was written by experts in the field and they knew best. However, Jenny began to see room to improve the FOSS curriculum after discussing with her colleagues and the researcher how the lessons were going and the strengths and limitations of the kits:

> I think once we spoke about that, the time when you came in [to observe]…I was like: Why didn't I do this? Why didn't I do that? I need to learn that it's okay to use my own ideas and not just stick with FOSS.

Jenny's comfort level with modifying the lessons was increasing; however, due to perceived time constraints and her lack of comfort with the content knowledge, she resisted veering too far off course from the FOSS teacher guide. Lesson observations indicated that Jenny did not tend to pursue students' questions if they would lead the lesson off on a tangent. The following excerpt was from a lesson she taught in which students were to use their knowledge of the properties of solids to build a tall tower. During this hour and five minute lesson, Jenny monitored the clock, used a timer to stick to her schedule, and passed over students' questions not directly related to the lesson rather than pursuing them:

Jenny:	Does anyone know what an engineer is? [Students make random guesses.]
Jenny:	[Looks at clock.] One more then I'll give you a hint…You're stuck. Okay. So, this is a book called *Across a Bridge* and I want everyone to think about the bridge and look at the bridge. Hmm. What do you think somebody had to know to make a bridge? (…)
Jenny:	Yes, so I hear a lot of you saying that an engineer is someone who's going to build something like a bridge using all of their thoughts and knowledge that they have about solids and they're thinking about all the properties like…shape and the size and if it's bumpy or smooth, the texture.
Student 2:	Also, how do they build a bridge if they can't get over there [across the water]?
Jenny:	So, maybe they'd have to take a boat. [Looks at clock.] Okay, so today you are all going to be engineers and you're going to get to use what you know about solids especially the solids at your seats to build a tower. (…)
Student 2:	Also, how would they get down to the bottom of the ocean [to build the bridge]?
Jenny:	Oh that's definitely for another lesson.
Student 2:	For that, sometimes they might use a submarine.
Jenny:	Exactly. Alright signals up, I'm going to set the timer for about 15 minutes and you're going to get to make your tower.

Angela, similar to Jenny, originally believed that the kits were better than what she could come up with on her own in terms of science lessons, "You know they've tested this stuff. You know it's going to be somewhat better than what you could do." Angela followed the FOSS lessons in order, explaining that "this way I'll know which ones to pick and choose from, because if you don't do them all then you don't know." However, she did not always use the teacher's guide like a script due to perceived time constraints, even though she stated that this was the best way to enact new material.

In contrast to Jenny and Monita, lesson observations revealed Angela taking a more free-spirited approach to teaching the FOSS lessons. Angela took time to dig into students' questions and allowed the lessons to progress naturally from what questions she and her students had, "A lot of my questions come from what they say, so a lot of my questions come from the direction the lesson is going." While her lessons were more student-centered, Angela's lack of preparation led her to sometimes miss opportunities to bring students' attention to key learning goals. For example, when the students made parachutes, she omitted the part of the FOSS lesson where students were supposed to compare releasing parachutes with one versus two "passengers," which were represented by paperclips. After meeting with the researcher to reflect on how the lesson went, Angela realized this issue. After a few such instances, she began referring to the teacher's guide while enacting the lessons.

The following dialogue illustrates Angela's tendency to indulge students' questions and veer off from the directions outlined in the FOSS teacher guide. This discussion took place after the students constructed their own parachutes and investigated how they behaved in the air outside:

Student 1:	Put the marker under the parachute and do it upside down.
Angela:	Put the marker in it then drop it? What do you think is going to happen?
Several students:	It's going to be faster.
Angela:	Why?
Student 2:	Because it's a lot of weight inside.

Student 3: Let's see, let's see!
Angela: Okay. [Parachute drops very fast]
Now let's try it without the marker. What do you think is going to happen?

In order to push student thinking, Angela moved beyond the FOSS teacher guide by also employing questioning strategies during her lessons that had been discussed during the team meetings and reflection sessions with the researcher, such as "Any lingering questions?" "How do you know?" "How could you find out?" Jenny was also observed employing such questioning techniques, although she did not indulge students' questions and explore students' ideas to the extent Angela did. Encouraging Angela to reflect on her practice and try out these questioning strategies, enabled her to begin to see the benefits of using the kits as more of a starting point than a script.

Monita's initial experiences with FOSS were positive in terms of what her students were getting out of the lessons:

> I did my lesson with the parachutes last week as well and …they got it…They're like the air is pushing the parachute up. That was their words. So, I was like gosh that's perfect. So, they were really into it and…they enjoyed it.

Despite her students' engagement in and learning from the investigations in the kit, this was the second, and final, FOSS lesson Monita taught during the fall semester. She felt anxious due to the constant shortage of instructional and planning time she perceived and the unfamiliar content, as well as classroom management issues. Consequently, Monita elected to teach science through the additive approach described previously.

At her end of semester interview in the fall, Monita maintained her favorable perception of the FOSS curriculum. "I love it. I love the concepts of it. It's child-friendly and they seem to enjoy it." She also showed a desire to catch up with her colleagues:

> I especially want [to teach more FOSS lessons], because in the older grades they're so clueless and I saw last year. I want to create memorable lessons, things that they'll remember. 'In first grade we did this,' or 'I remember talking about this'."

In January, Monita attempted to teach two more FOSS lessons, which she planned and taught following FOSS step-by-step. During planning meetings and the debriefing session with the researcher, Monita articulated that she began to realize areas where there was room for improvement with the FOSS lessons. For example, enacting a lesson on the properties of solids, Monita noticed that students were struggling to grasp the meaning of several of the terms they were exploring (i.e., rigid, rough, transparent, and opaque):

> I wish they had sandpaper as one of the [items], something that shows a good example of [the property] *rough*…if there was something that was definitely each of these properties it would be easier for them to understand these properties.

Monita's impressions of the kit-based curriculum continued to transform as she pursued, and eventually secured a teaching position at another school (for the following school year). Monita learned about their vision for science as she prepared a demo lesson for her interview. "Next year, at my new school, I know they use FOSS, but they just use it as a guideline. Not so much like we have to do this lesson [step-by-step]." Monita had a new conception of the FOSS curriculum, describing it as "almost like a one-dimensional way of thinking." She explained that for her science demo lesson:

> I had to do it on the relationships between the insects and plants…but they don't want to look for FOSS. That I knew. So, I did a lesson on perspective…What's a perspective of an insect going to a farm and they see all this food and then what's a perspective of the farmer having the insect eat all the plants. The more realistic view of it…okay we have this knowledge [about insects and plants], but what does it mean? You know, like that extra step, like the gifted and talented approach to it. The follow-up questions…I feel like that's what it [FOSS] does lack.

Monita’s view about using the kits as a starting point in order to promote more in-depth thinking was somewhat in line with what the researcher had been advocating during her interaction with the teachers. However, the researcher focused on moving beyond the kits not only in terms of relating the lessons more to the real world ideas, but also in terms of engaging students in more authentic investigations that stemmed from their own questions about the material. While using FOSS as a starting point rather than as a script appeared to align with Monita’s beliefs about science teaching, she opted not to enact the student-driven investigations the researcher supported her colleagues to carry out during the insects unit. Monita stated that she did not have the time to try out this approach and was not keen on working that closely with the insects due to her fear of them.

With the support of the researcher and the handouts I created to scaffold the lessons, Jenny and Angela engaged their classes in two student-driven lessons. Students designed and conducted their own experiments to answer questions they were interested in, such as: Do beetles climb better on bumpy or smooth paper? Do mealworms like pretzels, Pirate’s Booty, or cereal better? And, which is faster a beetle or a mealworm? As a result of their experiences diverging from the FOSS curriculum in this way, Jenny saw the FOSS lessons in a new light: “Everything is kind of setup for them [the students]…whereas the last [student-driven] investigation they got to choose what they wanted to do.” Following these insect investigations, Jenny setup a permanent interest center for the remainder of the school year where students worked in pairs to plan and conduct investigations related to any other questions they had about the insects. Jenny explained that the purpose was to “leave it open-ended and they could go around the room to get what they need and kind of just letting them figure it out for themselves.”

Jenny and Angela expressed a desire to begin incorporating student-driven investigations into the other two FOSS units the following year. Jenny also stated that she planned on raising snails in order to expand student learning beyond insects to other animals. Over the course of the year, Jenny went from seeing the kits as authority to seeing them better used as a starting point. However, in order to get to this point it was necessary to try out the lessons first and to reflect on their strengths and shortcomings in order to make productive modifications and extensions to the curriculum. She also needed to develop the confidence to take more "risks" with her instructional practice:

> You opened my eyes that I can try new things. It doesn't have to be exactly the way I did it last year, we can use different resources…I definitely think we need to try to make a set time to plan and share more [next year], 'cause I think it's beneficial and it is important.

When Angela was asked what she took away from working with the researcher and her team on science over the year, she asserted,

> I think I took away a little creativity…the fact that I don't think I'm going to be as hesitant to be creative in extending the FOSS kits or adding a little bit of something more to it to give it a little pizzazz. I think that fear is gone. It gave me that.

Discussion

Three common dilemmas emerged from the data analysis. First, elementary teachers feel a tension between spending their time and energy on science or on the other core subjects. Second, they struggle to manage their lack of science knowledge and skills with their responsibility to teach the subject. In addition, elementary teachers grapple with whether to use their kit-based curriculum as a script, a starting point, a supplement to their old science lessons, or not at all. The results of this study support the viewpoint that dilemmas are unsolvable and can only be managed through compromise; therefore Lampert's (1985) vision of teachers as dilemma managers seems apt. Teaching is an inherently uncertain task (Lortie, 1975). Teachers encounter a plethora of uncertainties throughout their daily practice "due to the complex nature of their work, which is centered on human relationships and involves predicting, interpreting and assessing others' thought, emotions, and behavior" (Helsing, 2007, p. 1317). Adding to the uncertainty is elementary teachers' unique teaching situation. Primary teachers must make time to teach all of the core subjects, teach science without much knowledge of the discipline, and figure out how to effectively enact curriculum materials in the absence of significant science content and pedagogical content knowledge.

Results also suggest that how teachers reconcile the dilemmas they perceive partially depends on their career stage (Feiman-Nemser, 2001; Huberman, 1989; Ryan, 1986). Although, the teachers in this study could all be considered novices when it comes to teaching science in reform-oriented ways. This is not surprising considering all three teachers were learning to implement a new curriculum in a subject area that was relatively unfamiliar to them. Ryan (1986) pointed out that teachers progress through a non-linear pathway as they move through their careers. Teachers may be in the mastery stage in some aspects of their practice (literacy and mathematics teaching); meanwhile, they may not have attained mastery in other respects (science teaching).

All three teachers showed signs of being in Huberman's (1989) initial *survival and discovery stage*, as they were acclimating themselves to their new science curriculum. None of the teachers had a catalog of strategies built up for teaching the science subject matter. However, Jenny and Angela had a repertoire of general pedagogical knowledge and skills that helped them with their classroom management and enabled them to focus on the *discovery* aspect of this phase. Monita appeared to be more in *survival* mode. She spent much less time and energy exploring and discovering the FOSS curriculum and developing her science teaching practices, compared to the other two teachers. Unlike the other two teachers, in addition to learning to teach science, Monita had the task of familiarizing herself with teaching first grade more broadly. Mastery in the areas of literacy and mathematics teaching appears to open the door for teachers to take on new endeavors, such as improving one's science teaching practice. It appears that in the current elementary school culture, issues that teachers perceive as priorities must be addressed before they are ready to work on their science practice.

Teaching the FOSS investigations requires a commitment in time and effort that Monita was not ready to make. This is understandable in light of the fact that Jenny admitted she had not been ready to make this commitment until the year this study took place. Thus, teachers appear to prioritize their efforts. With Jenny being in her fourth year of teaching and moving out of the induction phase, she felt more comfortable and confident in the aspects of her instructional practice she deemed a priority and her concerns shifted from issues of day-to-day survival to the quality of her instruction. Jenny was ready to tackle her science teaching practice as she saw it as impacting the quality of her instructional practice as a whole. Angela appears to have been ready for a while, but did not have the capacity or support needed to move her science teaching practice forward. She appears to have been in the *serenity* phase, where her practice was routine and mechanical. The assistant principal described Angela as having reached a "plateau" in her teaching. The AP had not noticed much change in Angela's practice for several years despite making recommendations that she make her lessons more student-centered. At the end of the year, however, the AP reported a drastic improvement in this area of Angela's teaching practice, elaborating that the change was noticeable across the subject areas.

It was evident that Angela felt re-invigorated to improve her practice through a combination of supports including the SSI which sparked her interest in science, the curriculum which gave her a usable model to guide her in making the change, and the researcher who coached her and created a sense of accountability for her to change. Instead of refocusing her efforts outside of school which is typical of teachers nearing the end of their career (the *disengagement* phase), Angela refocused her efforts on science. In terms of teaching science, she moved back to the more productive stage of *experimentation*. While Jenny was also moving into the *experimentation* stage, she had never been through the self-accepting *serenity phase* and was more preoccupied with keeping to a schedule than Angela. Jenny was more *conservative* in trying out new things, feeling a need to stick closely to the teacher's guide. Angela was more inclined to allow the lesson to follow the students' lead. The findings of this study support Ryan's (1986) claim that teacher development is a complicated and nonlinear journey.

In order to contribute to the literature on what it is that coaches do that teachers find helpful and how the work that coaches do impacts teachers (Vanderburg & Stephens, 2010), this study explores three teachers' perceptions of the impact of their relationship with the researcher—working in the capacity of a science coach—on their ability to address their dilemmas and improve their science teaching practices. Findings suggest that having a coach regularly on site can create a sense of accountability for teachers to work on improving their science teaching practice. Science cannot as easily be swept under the rug when teachers are required to talk about and consider ways to address their issues with teaching science during regular meetings. As Angela stated, the researcher served as a “constant reminder” for her to keep science in the forefront of her mind. When literacy and mathematics are made a priority by administrators, science will suffer unless other sources of accountability for this subject are put in place or fostered. Being coached in the area of science led the teachers to feel a stronger sense of responsibility to their students and to each other to make science a more substantial part of their efforts.

Through the team meeting with the researcher, teachers’ dilemmas were identified and laid out on the table, so that they could collectively work to address them. This occurred by bringing in the literacy coach to assist in helping the teachers find ways to integrate science and literacy to maximize their teaching time for both subjects (dilemma #1) and providing more individualize support for the teachers in one-on-one formal and informal meetings. During both group and individual meetings, discussions focused on building teachers’ content knowledge and knowledge about science as a process (dilemma #2), as well as their curricular knowledge (dilemma #3). The teachers felt that the team meetings were the impetus for them to begin talking about their science teaching practice more often and more in-depth. They began engaging in discussions, outside of the formal team meetings, about how their lessons went and how to best enact them. Furthermore, reflecting with the teachers on their practice during meetings and one-on-one helped ensure fidelity of implementation by bringing teachers’ attention to reasons why they should or should not skip FOSS lessons, modify them, or read them more closely. Without reflecting on their practice with a more knowledgeable other:

> teachers may not be aware they are implementing a strategy incorrectly and may continue doing it because they or their students like it, or teachers may not have success with a strategy and discontinue it because they do not feel it works or do not have access to help. (Kretlow & Bartholomew, 2010, p. 281)

In addition, various forms of modeling reform-oriented practices can be helpful for elementary teachers. For example, viewing the FOSS teacher preparation videos, observing demonstrations of unfamiliar strategies, and receiving handouts outlining prompts for class discussions and student-driven investigations, can assist teachers in developing a more detailed picture of how to improve their science teaching practice.

Working with a science coach can stimulate a number of changes, although it is crucial to note that the level of impact varies from teacher to teacher. Monita exhibited more trivial and sporadic changes and did not make use of the researcher much outside of the team meetings. In addition to the team meetings, Jenny made use of the researcher mostly through informal discussions about whatever the upcoming lesson was that she was getting ready to teach. Angela felt that she got the most out of the regularly scheduled one-on-one meetings with the researcher, without which she admitted she would not have taught science consistently. Flexibility of the coach and accountability from the school appear to be key ingredients in making the approach to PD productive for teachers who are at various stages of their careers.

Working with a coach is crucial to illuminate shortcomings in the teachers' practices that they are not aware of due to their lack of knowledge about science as a discipline. In this study, Jenny and Angela developed knowledge about student-driven investigations, including the importance of such activities for creating a more authentic science learning experience and how to facilitate them. This new knowledge and their experiences trying out the student-driven investigations problematized these teachers' practices and created an additional dilemma for them to address. This aided Jenny and Angela in moving their practice forward in more reform-oriented directions; however, Monita appeared to not be ready to undertake this task at this stage of her career. Helsing (2007) distinguished between “disabling uncertainties” and “uncertainties which lead to more complex theories and better practice” (p. 1318). I argue that science coaches can serve to not only create new dilemmas or uncertainties, but can also assist teachers in moving from viewing dilemmas as immobilizing their science teaching practice to addressing dilemmas in ways that are more aligned with best practices. As Helsing asserts, identifying and describing the conditions that move teachers from the former to the latter form of uncertainty has crucial implications for those who educate and provide PD for teachers, as well as administrators.

Coaching Teachers at Various Stages of Their Careers

Approaches to coaching teachers who are in different stages of their careers should look different. Veterans, similar to Angela, who are nearing the ends of their careers, may be more comfortable with their practice and less inclined to want to put in the effort to change than teachers earlier on in their careers. Angela did not try out as many of the FOSS lessons as Jenny when the kits initially arrived. In order to move from the *serenity* or *disengagement* stages back to the more active stages of *diversification* and *experimentation*, veteran teachers may need to have their interest and motivation sparked. Coaches should show teachers how teaching in more-reform oriented ways can bring life back into their practice and give them a renewed sense of excitement for teaching. Veterans may be more comfortable and confident in their general teaching practice and teaching off the cuff. These teachers may be open to veering off course from the curriculum and more confident trying new things with less scaffolding than those with less teaching experience. Coaches could focus their efforts with these teachers on how to veer off track from the curriculum in ways that are aligned with learning goals for students and reform-based practices.

Teachers who are just exiting the induction phase may be more intrinsically motivated to try new things than either veterans or novices. At this stage, teachers may be more comfortable with their daily practices and thus feel ready to begin expanding their repertoire and refining it. These teachers, however, may need to learn how to let go of the reins they held on to so tightly in their novice years. Coaches should focus their efforts on supporting these teachers to take risks and learn strategies that will help them relinquish some of their control, allowing students to guide the direction of the lesson more.

Novice teachers are often in survival mode, so it is especially crucial for coaches to be cognizant of their time constraints. These teachers have everything to learn about teaching in a classroom of their own. The more coordinated the coach's efforts are with the vision of the school and supports in other subjects areas, the more helpful the coach will be. Scaffolding from the coach is likely to be greater at this stage since the novice not only has to build up their knowledge and skills in teaching science, but in the other subjects as well. This may entail spending more time on building teachers' confidence to teach science, for example through direct modeling in the classroom followed by allowing the teacher to try out the skill. Coaches should work closely with administrators to ensure a clear and unified vision for the novice's development, focused primarily on the most crucial aspects of their practice. The particular area of support will depend on the particular teacher. While a coherent plan for PD is helpful for all teachers, regardless of their stage, it is most crucial for those just embarking on their careers.

Angela and Jenny were better able to find time for science with just the assistance of the coach, not the administrators.

Conclusion

A key finding of this study is that the dilemmas and constraints that teachers view as priorities, such as those related to literacy and mathematics, may need to be addressed before teachers are ready to focus on other aspects of their practice, such as science. However, with effective support and accountability, it may be possible to speed up the readiness process by instilling in teachers the need and motivation to expand their efforts. Creating a culture in schools where avoidance is not possible through open and candid talk about the various aspects of teachers' practices seems like a viable means of demarginalizing science in early elementary classrooms.

Having access to and support from a "science person," as Angela put it, who is regularly onsite at the school, has an education background, as well as knowledge of reform-oriented science teaching, has the potential to impact teachers' abilities to reconcile the dilemmas they perceive in ways that are more consistent with reform-oriented teaching. Working with the researcher appeared to have an impact on teachers' confidence in their content knowledge and pedagogical knowledge for science teaching, their sense of accountability to teach science, their ability to better manage their time and efforts, and their ability to use the curricula in productive ways. At the same time, we must keep in mind that the teachers each experienced these benefits to greater or lesser extents depending on their prior knowledge and experiences, and their comfort levels in other areas of teaching. Future research needs to investigate the applicability of these findings to larger pools of teachers to determine their generalizability.

The purpose of this research is not to place the blame on teachers for the lack of science instruction in elementary classrooms when left to their own devices, but to inform teacher educators, administrators, and education researchers of the encumbering tensions teachers perceive related to teaching reform-oriented science and how teachers at different stages in their careers reconcile these tensions with support from a science coach.

If we are serious about our nation's vision of moving to the top of the heap in science, then schools need to be equipped in science with the same resources available in literacy and mathematics. The fact that so many elementary schools do not employ a single person with a science background is inexcusable. Providing schools with a science coach, who possesses both a science background and expertise in science education, has the potential to be a scalable form of this much needed support. Since literacy coaches have become ubiquitous, hiring science coaches could be a feasible approach to ensuring ongoing classroom-based support for teachers in this subject area.

CHAPTER V

FINDINGS

THE IMPACT OF MULTIPLE FORMS OF PD ON A FIRST-GRADE TEACHER'S PRACTICES AND THE MEDIATING FACTORS INFLUENCING TEACHER CHANGE

Abstract

This study examined the impact of multiple forms of support—including a summer institute, a kit-based curriculum, and collaboration with grade-level colleagues, a science education researcher, and a literacy coach—on a first-grade teacher's beliefs and practices related to reform-oriented science instruction. Findings suggest that, in addition to one's belief system mediating the teacher change process, other factors contributed to this teacher's development of reform-oriented practices in elementary science teaching. Changes in teacher practice came about as the participant (1) recognized a need for change, (2) developed the capacity to change, (3) felt accountable for change, and (4) possessed the motivation to actually change.

Introduction

In order to prepare the next generation of citizens to navigate an increasingly-complex and technologically advanced world, the main goal of science education, as espoused in current reform documents (AAAS, 1993; NRC, 2007), is to produce a scientifically literate populace. It is crucial that we begin building the foundational skills and motivation for success in science from an early age. Science education reform documents are asking kindergarten through fourth-grade students to be able to "ask a question about objects, organisms, and events in the environment, plan and conduct a simple investigation, employ simple equipment and tools to gather data and extend the senses, use data to construct a reasonable explanation, and communicate investigations and explanations" (NRC, 1996, p. 122). Fifteen years have elapsed since the publication of this document and it is apparent that we are a long way off in terms of moving science teachers toward such reform-oriented classroom practices.

Reaching reform goals requires teachers to make fundamental changes to their beliefs and employ instructional practices that diverge significantly from the traditional teacher-directed lessons to which they grew accustomed over the years they were students. Even the most experienced secondary science teachers find teaching in reform-oriented ways to be difficult (Wallace & Kang, 2004). Hence, elementary teachers who are much less likely to have a science background face a host of additional challenges.

Elementary science education reform is a relatively under-researched area (Metz, 2009). While professional development (PD) has been described as the key to reform, learning opportunities for teachers thus far have been largely ineffective as they tend to be fragmented and lack coherence (Wilson & Berne, 1999). Although researchers have a clear understanding of the characteristics of effective PD (Loucks-Horsely et al., 2010), designing learning opportunities that effectively transform teacher practice remains a challenge (Putnam & Borko, 2000), particularly for elementary school settings.

Literature Review

Professional Development

Reform-based instruction requires teachers of science to learn to teach in new and fundamentally different ways. However, there are a number of challenges specific to elementary teachers due to the unique context in which they work (Mensah, 2010). Science instructional time in elementary schools is often limited as it takes a backseat to mathematics and literacy which are priorities as a result of the No Child Left Behind legislation (Appleton, 2007). Furthermore, elementary teachers are not likely to have a science background (Fulp, 2002), which adversely impacts their confidence in teaching this subject (Cochran & Jones, 1998). Consequently, elementary teachers often avoid teaching science (Harlen, 1997).

PD is widely accepted as the key to reform and we have an understanding of the characteristics of effective programs. Loucks-Horsley and colleagues (2010) have found:

> widespread consensus regarding what constitutes effective professional learning: It is directly aligned with student learning needs; is intensive, ongoing, and connected to practice; focuses on the teaching and learning of specific academic content; is connected to other school initiatives; provides time and opportunities for teachers to collaborate and build strong working relationships; and is continuously monitored and evaluated. (p. 5)

However, despite consensus regarding these characteristics, teacher educators continue to grapple with how to design PD experiences that move teachers toward more reform-based science instruction (Putnam & Borko, 2000).

The most prevalent form of PD for teachers continues to be the one-shot workshop; notwithstanding the fact that it has proven time and again that it fails to improve teachers' practice on its own (Yoon et al., 2007). While this form of support is the most feasible way to bring information to a large number of teachers and can sometimes be the best way to help teachers to learn to think in new ways (Putnam & Borko, 2000), we must keep in mind that such support is short-term and involves participants unfamiliar with each other's contexts. Grossmal et al. (2001) explained:

> The biggest drawback to the summer or weekend approach to teacher learning rests on the assumption that it is possible to take individuals out of their workplaces, transform them in other settings, and then return them to an unchanged workplace to battle the status quo. (p. 948)

van Driel, Beijaard, and Verloop (2001) recognize that "multiple strategies of PD are necessary to promote changes in teacher's knowledge and beliefs" (p. 148). In order to develop and improve teacher practice, supports that are readily available onsite at schools are crucial. Effective curricular resources and the relevant equipment need to be available, and teachers require opportunities to discuss and reflect on their practice with colleagues and more knowledgeable others, such as coaches or mentors. Some evidence exists that models that use a combination of contexts for PD can be effective.

One example of a PD model that utilizes this multi-component approach is that developed by Fishman, Best, Foster, and Marx (2000) to support and scaffold middle school teachers in the successful and sustained implementation of Project-Based Science (PBS) innovations. This program supports teachers through the educative curriculum materials themselves (Schneider & Krajcik, 2002), a summer institute, Saturday work sessions, after-school sessions, in-class visits from support staff, and opportunities for collaboration with colleagues. The Cognitively Guided Instruction (CGI) project (Carpenter, Fennema, & Franke, 1996) serves as a second example of such multifaceted PD. This project aimed to address evidence that elementary teachers' knowledge of their students' thinking tended to lack coherence and be informal or spontaneous. Their PD model included summer workshops and ongoing support during the school year from CGI staff members and mentor teachers. Participant teachers had opportunities to observe other classrooms, plan lessons collaboratively, and collectively analyze student work.

Putnam and Borko (2000) call for additional research that investigates the complex dynamics of such multi-component PD models in order to better understand what combinations of PD design elements enable teachers to shift to more reform-oriented beliefs and practices. While there is evidence that PD can support teachers in improving their instructional practice, "we are only beginning to learn, however, about exactly what and how teachers learn from professional development" (Borko, 2004, p. 3).

Kit-Based Curricula. Professional development can take many forms, including provision of curriculum materials. Kit-based curricula, complete with teacher's guides and materials, have become especially prevalent at the elementary level where teachers tend to lack a strong science background. Full-Option Science System (FOSS) is one curriculum program that has been adopted by a number of districts across the country. While the kits have been designed to promote active learning, multisensory methods, student-to-student interaction, discourse and reflective thinking, and interdisciplinary connections (Delta Education, 2011); they may be implemented in ways that do not engage students in rich inquiry (NRC, 2000) and do not foster critical-thinking and problem-solving skills (Olguin, 1995). In addition, the kits do not support teachers in guiding students through the process of investigating their own questions based on their interests (Reardon, 1996).

Conceptual Framework

Reform-Oriented Science Instruction and Teacher Change

Current standards-based reform documents (e.g., NRC, 2011) advocate science instructional practices that diverge significantly from the traditional lecture-based instruction to which most individuals have grown accustomed. Reform-oriented science instruction cannot be reduced to a list of discrete practices as it is a complex endeavor, with many interrelated aspects. Nonetheless, it is helpful to discuss various aspects of the current reform vision in order to clarify the types of practices promoted in this study.

The National Science Education Standards (NRC, 1996) suggest that students learn about unifying themes or big ideas in science, such as measurement, evidence, models, and equilibrium that should be explored and built upon through studying various aspects of the content. To support students in learning the big ideas of science, inquiry-based instruction is viewed as an ideal instructional approach (AAAS, 1993; NRC, 1996, 2000). Inquiry teaching involves engaging students in "posing questions…planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results" (NRC, 1996, p. 23).

Reformers also advocate for depth over breadth in content coverage, suggesting that teachers promote more detailed learning of key concepts through a smaller number of units that that designed around students' interests and experiences (Haberman, 1991; Tal et al., 2006). Other reform-oriented practices include explicitly teaching nature of science (NOS) (e.g., Schwartz, Lederman, & Crawford, 2004), integrating science and the other subjects (e.g., Howes et al., 2009), engaging students in argumentation and debate (e.g., Bricker & Bell, 2008; NRC, 2007), teaching for social justice (e.g., Barton, 2003), and employing learning progressions (NRC, 2007). Preparing teachers to take on these new roles is not a straightforward process. The challenge has been figuring out effective ways to support teachers to change their practice (Forbes & Davis, 2008).

Teacher change is a complex and slow process for several reasons. For starters, the knowledge base for teaching is vast. To be successful, teachers must build their knowledge of science, curricular resources, pedagogy, and how students learn; and then develop an understanding of how to translate this knowledge into practice, adapting their approach based on students' diverse needs and interests (Magnusson et al., 1999).

Teachers' beliefs and experiences also play a crucial role in determining what they do in their classrooms (Roehrig & Luft, 2004). However, the relationship between teachers' beliefs and practices is not a direct one (Richardson, 1996). Jones and Eick (2007) conceptualized the interaction between a teacher's beliefs and practices as a feedback loop where each interacts with and informs the other. Furthermore, studies have shown that even if teachers possess reform-oriented beliefs this is not a sufficient condition for ensuring that their beliefs align with their practices (King et al., 2001). Davis, Petish, and Smithey (2006) have accounted for such inconsistencies by explaining that either teachers do not know how to translate their beliefs into action, or their beliefs about effective science instruction may be superseded by other beliefs about teaching and learning or the school context.

In response, professional developers ought to focus their efforts on changing teachers' practices, not just their beliefs. It is crucial that teachers gain experience implementing innovations in practice. Having support in order to implement new practices in reform-oriented ways that lead to improved student learning is crucial so that teachers do not abandon potentially effective lessons from their curriculum. Moreover, teacher educators should keep in mind that teachers perceive a number of constraints at the classroom, school, district, state, and national levels that inhibit their ability to enact lessons that align with their views on teaching and learning (Penuel et al., 2007). For example, teachers may believe that studying less material in more depth is ideal for fostering learning at the higher levels of Bloom's taxonomy. Conversely, they are held accountable for teaching a broad range of topics by state-mandated tests which appear to value more superficial knowledge that can be memorized. Due to the complex nature of teacher change, there is more to be learned about how teachers' beliefs and practices interact and are associated with the implementation of reform-oriented instructional practices (Keys & Bryan, 2001; Wilkins, 2008) and kit-based curricula (Young & Lee, 2005).

Research Questions

Considering the challenges of teaching science and fostering teacher change, the purpose of this study is to develop a nuanced and detailed understanding of the relationships between PD experiences, teacher learning, and teacher practice. Specifically the research questions guiding this study were:

1. What was the impact of receiving various forms of support on a first-grade teacher's beliefs and practices related to reform-oriented science instruction?
2. What mediating factors enabled or hindered the teacher's enactment of reform-oriented science teaching practices?

Method

This research study is a case study of a first-grade teacher that took place between October 2010 and June 2011. Multiple forms of data were collected in order to develop rich, thick descriptions (Merriam, 1998) regarding the relationships between various forms of professional development and teacher change. A case study approach is relevant here to satisfy the need for "a complex, detailed understanding of the issue," (i.e., the link between PD and teacher change) which is not possible with large-scale quantitative studies (Creswell, 2007, p. 40).

Setting and Participant

The site for this study was “Morningview Elementary,” a school located in a large urban district in the northeastern United States, serving approximately 600 students from kindergarten through eighth grade. The student body was primarily comprised of African American (75%) and Latino and Latina (24%) students, and 75% of the students qualified for free or reduced lunch.[7] The science program at Morningview recently changed due to a district-wide initiative and the teachers received their new FOSS curricula midway through the 2009-2010 school year (the year before this study began).

The participant in this study was Angela[8], a 25-year veteran elementary school teacher. Angela taught at a private school prior to obtaining a job at Morningview, where she had been working for 9 years when this study began. Angela was a member of the first-grade team, comprised of four teachers who had one to three years of teaching experience prior to this study. Angela, similar to the other teachers on the first-grade team, did not have a strong science background; however, all four teachers had completed a graduate-level elementary science methods course at the time of their certification. Angela’s experience with FOSS prior to this study came from looking through her new kits with her team during a half day the school set aside for this purpose. Angela also taught two lessons from the Solids and Liquids unit the year the kits arrived, and attended a Science Summer Institute (SSI) in July 2010. This five-day institute, run through a school-university STEM partnership, focused on familiarizing teachers

[7] Data obtained from the school’s Quality Review Report for the 2007-2008 academic year.

[8] All proper names in the study are pseudonyms.

with their newly adopted FOSS curriculum. Angela was one of six teachers from her school to attend the PD and the only first-grade teacher. 36 teachers from kindergarten through fifth grade attended in all.

Angela became a participant for this study after indicating on the exit survey from the SSI that she was interested in receiving classroom-based support for science. The researcher then extended invitations to the rest of Angela's grade-level team to become participants in this research; however, they were not subjects in this particular paper.

Role of the Researcher as Participant Observer

I had a dual role in this study as participant observer. As a graduate research assistant, my role was similar to that of a science coach or mentor. I engaged in direct classroom assistance, provided content support, collaborated with Angela during lesson planning, modeled particular strategies, offered feedback, and facilitated science meetings with Angela and her grade-level team. As a non-participant observer I videotaped science lessons and attended regular first-grade team planning meetings. Additionally, I attended the SSI where I recorded field notes and collected PD materials (i.e., handouts and activities that the teachers engaged in during the SSI). I also kept a journal to document my reflections, reactions, ideas, and field notes throughout the study. This journal was used as an additional source of data for the purpose of triangulation.

Through the combination of my roles as participant and observer I was "capable of understanding the program as an insider while describing the program for outsiders" (Patton, 1990, p. 128). Employing this approach enabled me to experience the teachers' realities

(Marshall & Rossman, 1999) as they worked to teach science and teach it in more reform-oriented ways in the context of their school and classrooms.

Data Collection

Over the course of this study, multiple forms of data, including the researcher journal mentioned above, were collected. These sources of data were used to construct the case of Angela and her change over time.

Interviews. Semi-structured interviews (Appendix A), lasting an hour each, were conducted with Angela twice (December and June) in order to illuminate her beliefs, including the reasons she attributed to any changes in her practice. Interviews were audio recorded and transcribed. In addition, the principal and assistant principal (AP) were each interviewed (Appendix B). These interviews took place after the data had been collected with Angela and lasted 30 and 60 minutes, respectively. The aim of these interviews was to garner information related to the context of the school where Angela worked and any changes the administrators noticed in Angela's practice during the study.

Classroom Observations. 25 out of the 26 science lessons Angela taught between the beginning of October and the end of June were observed and videotaped. Angela's science lessons are listed in Table 5.1. Lessons lasted 90 to 120 minutes each. Science lessons were observed so that I did not rely solely on Angela's perceptions expressed in interviews and so that I had a thorough understanding of her practice. I did not use a protocol to record observations during lessons. Instead, I ran the video camera and following the lessons I recorded field notes, guided primarily by the theories and ideas outlined in the literature review.

Table 5.1. *Science Lessons Angela Taught Between October 2010-June 2011.*

	Lesson	Source	Date
Unit 1 – AIR AND WEATHER			
1	Air is There	FOSS	10/06/10
2	Air Under Water	FOSS	10/14/10
3	Parachutes	FOSS	10/21/10
4	Pushing on Air	FOSS	10/28/10
5	Air and Water Fountain	FOSS	11/04/10
6	Weather Calendars	FOSS	11/18/10
7	Measuring Temperature (Not observed)	FOSS	12/02/10
8	Watching Clouds	FOSS	12/09/10
9	Wrap-Up Air and Weather Unit	**Not FOSS**	01/13/11
Unit 2 – SOLIDS AND LIQUIDS			
10	Introduce Solids	FOSS	01/20/11
11	Sort Solid Objects	FOSS	02/03/11
12	Construct With Solids	FOSS	02/10/11
13	Liquids in Bottles	FOSS	02/17/11
14	Properties of Liquids	FOSS	03/02/11
15	Skype With Meteorologist	**Not FOSS**	03/10/11
16	Liquid Level	FOSS	03/31/11
17	Liquid Level (revisited)	FOSS	04/01/11
Unit 3 – INSECTS Butterflies & Mealworms			
18	Butterflies: Part 1: Caterpillars (handling and caring for insects, observation)	FOSS	04/14/11
19	Butterflies	FOSS	04/28/11
	• Part 1: Caterpillars (silk formation, pupation)		
	• Part 2: Chrysalises		
	• Part 3: Butterflies (discuss death and disfigurement)		
20	Butterflies	FOSS	05/04/11
	• Part 1: Caterpillars (observation, structures, molting, survival needs)		
	• Part 3: Butterflies (life cycle)		
21	Mealworms		05/12/11
	• Part 1: Mealworms (survival needs, observation)	FOSS	
	• Part 2: Larva, Pupa, Adult (structures of mealworm and beetle, molting, pupa, adults	FOSS	
	• Student-driven investigation (Which is faster a mealworm or a beetle?)	**Not FOSS**	
22	Mealworms: Student-driven investigations:	**Not FOSS**	05/13/11
	- Climbing ability (bumpy versus smooth paper)		
	- Food preferences (carrot, asparagus, and green pepper)		
	- Smell preferences (vanilla versus vinegar)		
23	Butterflies		05/19/11
	• Part 3: Butterflies (mating & eggs, hatching eggs)	FOSS	
	Mealworms		
	• Continued s-driven investigations	**Not FOSS**	
24	Mealworms: Beetle Olympics	**Not FOSS**	5/26/11
25	Mealworms: Life Cycle of a Beetle Song	**Not FOSS**	6/7/11
26	Mealworms: Life Cycle of a Beetle Song continued	**Not FOSS**	6/27/11

Pre-Lesson Planning. Prior to observed lessons, I usually met with Angela to discuss her plans for the lesson and/or to help her setup. The purpose of these meetings was to provide support for Angela. We discussed content, tried out aspects of the lessons, talked about the sequencing of activities during the lessons and potential modifications, and setup for the lessons. Which of these actually occurred during an individual session depended on Angela's expressed needs, how prepared she was for the lessons, and how much time she had available to meet with me. Pre-lesson planning meetings lasted 5-30 minutes and occurred 18 times over the course of the school year, four of which were audio recorded and transcribed.

Post-Lesson Reflections. Following the observed science lessons, I prompted Angela to reflect on how she felt the lesson went using a semi-structured approach. Reflections served as a form of PD and were used as a way for me to find out Angela's perceived reasons for her actions. When we met formally, a protocol was used and the discussions were audio recorded and transcribed. The protocol (Appendix C) used included the following questions: How did you feel the lesson went? What do you think the students got out of the lesson? What don't you think the students got out of the lesson? What was your purpose or goal for the lesson (what did you especially want the students to come away with)? What, if anything, would you do differently next time? These formal debriefing sessions occurred ten times. I also informally discussed how Angela thought her lessons had gone twice. Field notes were written following the informal discussions.

Teacher Meetings. There were 12 teacher meetings (30-45 minutes) scheduled with the first-grade team to discuss science. The meetings were held periodically over the course of the school year, when it was convenient for the team to meet. Attendance at these meetings varied due to the fact that participation was voluntary. Angela attended ten of the 12 meetings. Teachers missed meetings when they had other work to focus on, such as getting field trip permission forms ready or writing pre-assessments for their subject area committee. There were three meetings in October, three in November, one in December, one in January, one in March, two in April, and one in May.

Meetings served as a form of PD and an opportunity to foster collaboration, build rapport, and cultivate trust among all of us. During these meetings the teachers usually shared what lesson they were on, how their lessons were going, and made suggestions for those who had not yet taught the particular lessons they had. Sometimes meetings were focused on setting up materials or determining which lessons to cover next and which ones to skip based on state standards and time constraints. In the spring semester, the researcher asked the literacy coach, Melanie, to join the March meeting in order to help the teachers figure out ways to maximize their time on both science and literacy by integrating the subjects when possible.

All 12 science-focused teacher meetings were audio recorded and transcribed. I also attended one regular planning meeting in March where science was not discussed (time ran out which was apparently a common occurrence) and one regular planning meeting in April, where the teachers spent the majority of the 45 minute block discussing science rather than the other core subjects. This second observed planning meeting took place when the teachers were preparing to teach lessons about the insects that had recently arrived. While both of these meetings were audio recorded, only the April meeting was transcribed. An additional meeting with the literacy coach took place in June, where the teachers and Melanie discussed how to align the reading, writing, and science units. This meeting was audio recorded and transcribed. Angela participated in all three of these additional meetings attended by the researcher.

Data Analysis

An inductive approach to analyzing data was used. While I did not necessarily generate new theory, I employed some of the techniques of constructivist grounded theory (Charmaz, 2006). First, the video footage and audio recording from interviews, teacher meetings, pre-lesson planning, and post-lesson reflection sessions were transcribed and entered into Atlas.ti. Next, I went through the interview, pre-lesson planning, and post-lesson reflection data line-by-line and assigned initial codes using this program. At this stage, I remained open to ideas that emerged from the data and continuously compared data with data. While I tried to remain open to whatever emerged from the data, the ideas described in the literature review were in the back of my mind.

During the second level of coding, referred to as focused coding (Charmaz, 2006), data analysis was more selective and direct. I went through the data again, specifically looking for segments of data related to Angela's perceptions of her beliefs and practices. During this level of coding, I compared data to codes from the initial round of open coding, revising them along the way. Once these revised codes, related to Angela's beliefs and practices emerged, I used this list to code the data from her science lessons, looking for confirming and disconfirming instances. I sought relationships between codes and grouped codes into larger categories. Once I had an idea of her beliefs and practices, I went back through the interviews and pre- and post-lesson sessions, with my first research question in mind, to look for how she accounted for her beliefs and practices and what role was played by the various forms of support she received. Then I went through the data from the classroom observations, teacher meetings, and field notes (including those from the SSI) in order to confirm and disconfirm her perceptions.

In reading over my memos at this stage in the data analysis process, factors surfaced that seemed to mediate Angela's enactment of reform-oriented practices. In a final pass through the data, keeping in mind my second research question, I searched for instances where these factors came up, compared the data to these codes, and grouped these codes into themes. Through the data analysis process, four themes emerged as mediating factors influencing how the professional development Angela received impacted to her practices. Figure 5.1, below, outlines how I arrived at these four themes from my list of codes related to Angela's beliefs and practices.

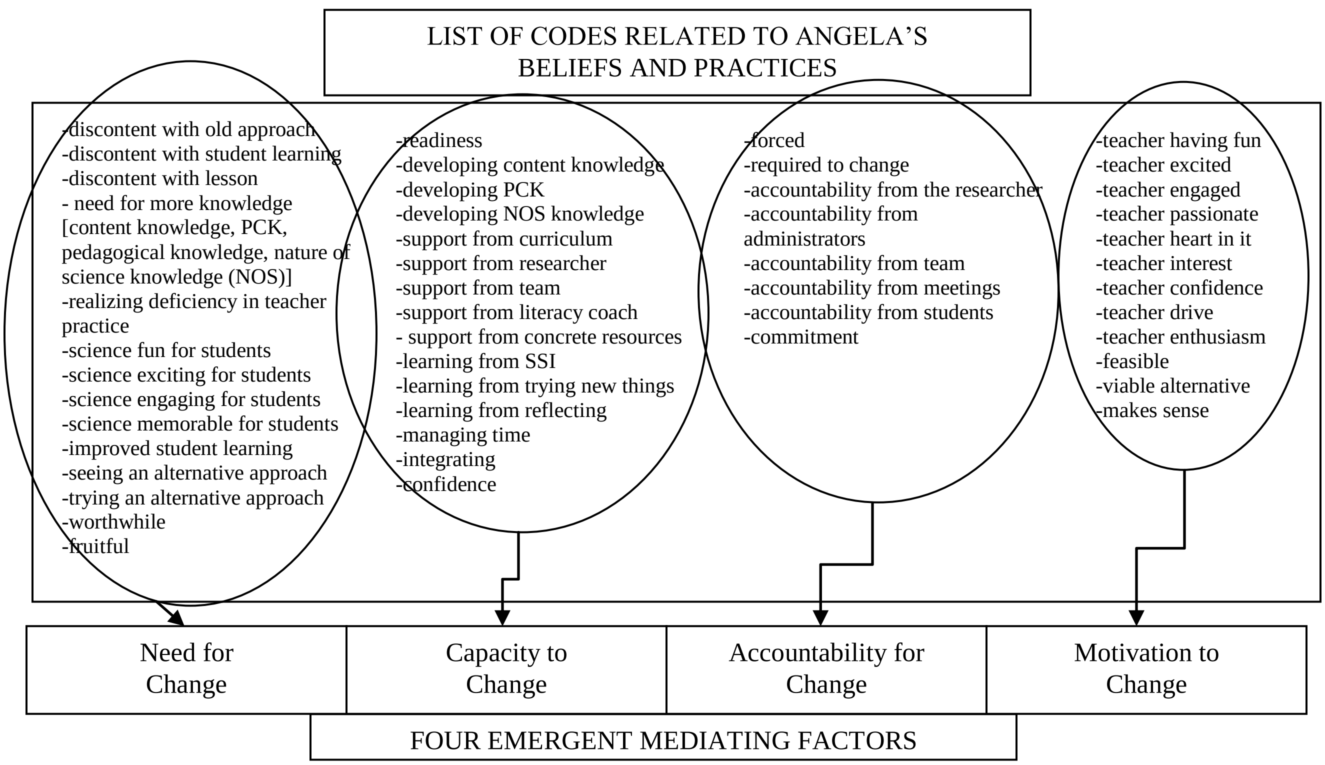

Figure 5.1. Emergence of the four factors mediating Angela's development of reform-oriented science teaching practices.

Findings

The aim of this study was two-fold: (1) to examine the impact of the various forms of support (curriculum materials, formal summer institute, researcher serving as coach, and meetings with colleagues) received by Angela on her beliefs and practices; and (2) to explore the mediating factors that impacted whether the various forms of support facilitated teacher change or not. From the data analysis, four interrelated themes emerged: recognizing a need for change, developing the capacity for change, being held accountable for change, and possessing the motivation to change. First, I discuss key information related to the context. After that section, I delve into the findings related to each of the mediating factors.

The Context for Change

Due to the school's hyper-focus on mathematics and literacy, Angela described science as "the first to go." In an interview she elaborated that before this study began, "there were a lot of weeks that [science] got swept under the carpet." She believed that time for science was restricted due to the literacy-related tasks for which her administrators held her accountable. For example, she had to test her students' performance with sight words, made-up words, and writing. Angela was also held accountable for assessing each student's reading level every month. She felt extensive pressure from her administrators to focus on literacy and mathematics which came up every time we discussed making time for science.

The first-grade teachers had coaches in mathematics and literacy, as well as ongoing PD in these subjects. In stark contrast, Angela was never required to be observed teaching science and she did not have such guidelines for teaching her students science or deadlines for assessing her students in science. She believed, “If I didn’t teach science for a month I don’t think people would mind, if my children were moving along in their reading levels.” Angela perceived the school’s disproportionate emphasis on literacy and mathematics as having contributed to the lack of science she taught prior to this study. In an interview, the assistant principal explained:

> To be completely honest, I haven’t gotten into that [science] yet because of literacy, math, and social studies. I think we all feel a little uncomfortable with science. I know what to look for in literacy because that was my area, but science—that’s an area that has gone pretty much unrecognized…Truthfully, rarely do I say I want to observe a lesson in science because what’s the conversation with the teachers going to be? I can’t speak to it in-depth.

The lack of accountability and support for science in the face of the overt accountability and support for literacy and mathematics inhibited the amount of time Angela taught science and limited her capacity to improve her science teaching practice. On the other hand, when Angela was provided with a combination of supports for science—namely the kit-based curriculum, the SSI, coaching from the researcher, and collaboration with colleagues—changes in her practice began to transpire. The interrelated mediating factors, that impacted the extent to which Angela used what she learned from these various approaches to PD, are each discussed in detail in the following sections.

Recognizing Need for Change

At Morningview Elementary, each grade-level team from kindergarten through fourth grade was asked to select a representative to attend the SSI in July 2010. Angela explained that she volunteered “because I know that [science is] one of the things that I don’t approach well. So, I said well let me know it.” Moreover, she was dissatisfied with her original approach to teaching science, which she described as “kind of boring…You fold your little paper in four.

You write winter, fall, spring, summer." Angela saw a deficiency in her practice, a need for change, and took the opportunity to attend the SSI in order to learn about her new FOSS kits and experience an alternate way to teach science:

> The SSI really gave me a boost…It was fun the hands-on. I mean we were making things and I was working with my hands… they had us spin that rubber band and see how that propeller goes around and what makes it do this and what makes it do…I've never had that curiosity about science before.

From the institute, Angela learned that science could be fun and engaging if she used the kits. Angela was already discontent with her old approach to science teaching, but became more so after her experiences during the SSI. The PD experience made Angela realize that her former approach "[didn't] have any meat in it" and that she "didn't really dig into it." Angela realized that her first-graders would walk away with a more "memorable" science learning experience if she facilitated more investigative science lessons, like the FOSS lessons, rather than ones that were simply hands-on. Unfortunately, this was not enough to change her practice. When Angela returned to school in September, she reverted back to her old lessons.

Once Angela began working with the researcher, she made the transition to FOSS. However, initially, Angela was more concerned with students enjoying science, than learning the content. In reflecting on the lesson "Air Under Water," Angela stated:

> As long as they're enjoying it. They're learning that science is fun—that's one thing. They're learning about those bubbles coming out—that's another thing. I think that's enough, because by the time we come to the end of this FOSS kit, if you take one or two things you're learning each investigation, that's enough for me…There's no right and wrong in discovering something because we're not patenting it.

As we continued to discuss and reflect on her lesson that day, she began to see the need to change her belief about her goals for student learning, realizing that she did not want her students to walk away with misconceptions. In order for her science lessons to be memorable, then she had to better facilitate student learning. At the end of our discussion I asked her if there was anything she would change next year related to this lesson and she responded, "I think I would investigate it a little more myself so that I should be prompting them for certain answers…I would like to be a little more solid as far as the things [content] they are learning."

While Angela was able to find two-hour blocks of time for science instruction in her school day, setting aside time to plan her lessons proved to be a challenge. Angela only skimmed the teacher's guides and watched the FOSS teacher preparation videos[9] online. Consequently, sometimes Angela only covered part of the learning goals and sometimes she guided the students toward non-normative conclusions since she did not read the content section of the teacher's guide. For example, during the "Pushing on Air" lesson, where students experimented with a system of two syringes attached together with rubber tubing, Angela neglected to delve into the concept that air is compressible. The FOSS learning objective was: "Plunging one syringe compresses the air, creating pressure and pushing the other one out." The students grasped the concept that air can move things, but not the more in-depth idea the air can be compressed and it is the pressure from compressed air that causes things to move. Angela and I discussed her omission during the debriefing session following the lesson. The next day in class she made sure to connect the lesson to the concept of compression. In an effort to be better prepared for her science lessons, Angela asked the researcher to plan with her prior to enacting them. Furthermore, Angela began referring to the FOSS teacher's guide during enactment in order to ensure she remained more on track in pursuing the learning goals for the lesson.

[9] FOSS teacher preparation videos are approximately three to six minutes in length and provide an overview of each lesson and glimpses into how a teacher guides discussions with a classroom of students.

Becoming familiar with the FOSS materials, teaching the FOSS lessons regularly, and working with the researcher, led Angela to realize that she was not only dissatisfied with her old science teaching practice because it was not engaging enough, but also because it was not authentic. She saw her old approach as more like art and less like the work of real scientists. Her understanding of what science entails and how to teach science in more meaningful ways was beginning to develop. Regarding her old lessons, Angela stated:

> It was more art…but you don't get a chance to really see it, you know what I'm saying, whereas the investigations they're right there in front of your face with FOSS. I know what it looks like…I don't know if you call it—real science versus fake science. I don't know what you call it, but yeah, I like the FOSS kits.

Working with the researcher as coach helped her recognize that there was a need to change several other specific aspects of her practice. For example, Angela saw the need to use more in-depth questioning strategies, as suggested by the coach, in order to more fully understand her students' thinking. Consequently she began using prompts such as: How do you know? How can you find out? Who agrees/disagrees and why? Additionally, Angela recognized the need to provide her students with opportunities to move beyond the FOSS lessons by allowing them to investigate questions based on their own curiosities and interests instead of the ones predetermined by the curriculum. Guided by suggestions and a student handout developed by the researcher (Appendix D), Angela supported her class in designing and conducting experiments to find out the answers to their own questions, such as: Which is faster a mealworm or a beetle?

Angela also saw the need to change how she described scientists. Originally Angela talked about scientists as being well behaved, "Let's have behavior like an engineer. An engineer would never call out." In response to discussions with the researcher about the nature of science, Angela became aware of the tentative nature of science, which impacted her practice. For example, during the lesson "Air and Water Fountain," Angela said to a pair of students, "So, what you thought was going to happen didn't happen and sometimes that happens to scientists." Two students were demonstrating to the class a discovery they thought they had made, but when it did not work out as they had expected, Angela suggested: "Something's wrong with that theory because you said [that] wouldn't work but [it] did. Try it again." Here the teacher implied the need for repeat trials and the idea that theories change as new information becomes available. Without working with the researcher and learning about science as a process, Angela would not have known to describe science in this way. She first needed to become aware of the need for change, before her practice could improve.

Developing the Capacity to Change

Angela and her team received their FOSS kits during the 2009-2010 school year (the year before this study began). Angela felt that the new curriculum contributed to her capacity to change, "they have all the materials which helps," including the necessary equipment and the teacher's guides explaining how to teach science in more investigative ways. The curriculum provided Angela with an alternative approach—a necessary precursor to change. However, on their own, the kits proved to be insufficient.

Interviews with Angela during this study provided some insight into her science teaching practices prior to beginning my work with her. Of the three first-grade FOSS units (Air and Weather, Solids and Liquids, and Insects), Angela stated that she tried out one the year they arrived—the Solids and Liquids kit. Of the 18 lessons in that kit, Angela taught two of them.

Instead of continuing with FOSS, Angela reverted back to using the old science lessons the first-grade team had developed in previous years. Switching to the new curriculum felt overwhelming and time consuming. Due to perceived pressure from her administrators she felt her time was better spent on reading and writing. Angela felt that she could always "push these children a little harder in literacy." Angela needed to learn why investing her time in improving her science instructional practice was important. She needed to learn more about the kits and science.

The SSI familiarized Angela with the FOSS curriculum, including the objectives behind the kits and the structure of the lessons. Over the course of the five-day institute, she learned how to setup a student science journal—keeping one of her own during the five days—and was guided by the professional developers to write entries in her journal for each of the several lessons the teachers carried out. She also learned about the types of materials and resources available to her to facilitate teaching the lessons, which improved her capacity to change. However, having the kits and attending the summer institute were not enough on their own to change her practice.

Once Angela started working with the researcher she began teaching the FOSS lessons consistently. Trying out the lessons and reflecting on her practice with the researcher supported Angela in recognizing and developing the knowledge necessary to address shortcomings in her practice. As the following dialogue related to the "Air Under Water" lesson illustrates, Angela lacked the capacity to facilitate student learning of the content, as she did not understand it herself. During this lesson, students played around with a vial in a clear bucket of water, submerging it upside down, tipping it, and watching the air bubbles comes out. To effectively teach this lesson, Angela needed to understand that there is air trapped in the vial when it is submerged upside down and that tilting the vial allows the air to escape and water to flow in to take its place. Angela incorrectly believed the bubbles emerging from the tilted vial indicated water was escaping, rather than air. Therefore, even though several students immediately realized that they saw bubbles because tilting the vial "letted out air," she guided students to her non-normative conception that, "the vial…was filled with water."

In reflecting on this lesson with the researcher, Angela realized she had been unprepared and accounted for this saying, "I don't think I had enough time to really investigate what I was doing…I probably would have discouraged saying there was water in there if I had actually known." Angela and the researcher had, in fact, tried out the investigation in advance, but it apparently was not enough to ensure she grasped the content. In order to effectively coach her, I had to first find out her non-normative ideas, before they could be explicitly addressed and transformed. Armed with new content knowledge, Angela revisited this material at the beginning of her next lesson:

Angela:	Now, what was actually happening when we tilted it? What was coming out and what was going in or was there something coming out and going in?
Student 5:	Bubbles.
Angela:	Bubbles were doing what?
Student 5:	Were coming out of the vial.
Angela:	So, the bubbles were coming out of the vial when we tilted it. Do you think something was going in the vial?
Some students:	No.
Student 2:	Water! Water!
Student 6:	Water was going in the vial.

In addition to working on the content necessary for the FOSS lessons, I also focused my discussions with Angela on moving beyond the kits to enact more reform-based practices, such as facilitating student-driven investigations and employing questioning strategies aimed at developing students' higher-order thinking skills. In order to support Angela in enacting these unfamiliar practices, I prepared concrete handouts to guide her. For example, I created a handout for her students to complete to ensure she guided her students to: ask a testable question, come up with a procedure for investigating their question, record their data, draw their conclusion, and back up their conclusion using their data as evidence. I modeled how this could be done through a handout for the teacher (Appendix D) and by co-teaching a lesson in which students decided they wanted to see which was faster a beetle or a mealworm and as a class students completed each section of the handout. The following science lesson, Angela assumed a greater role as we worked together to guide the students to come up with their own testable questions related to mealworms. Each table of students then selected from among the questions they brainstormed and worked as a group to design and carry out their experiments. After they completed their investigations, Angela had one student from each group present their work with the class. The following excerpt illustrates the dialogue that took place between her and one of the presenting students:

Angela:	What did you do with your investigation?
Student:	We had some vegetables on a plate, like the carrots and the asparagus and the green pepper.
Angela:	And you put the mealworm on the plate with those three foods?
Student:	Yes.
Angela:	And what did you want to find out?
Student:	We was trying to find out if it would go to all the food, but it didn't. It just went to the asparagus three times and the carrot twice.
Angela:	So, did he like the green pepper?
Student:	No.
Angela:	Okay…Say that again what you found out.
Student:	I found out that the mealworms like the asparagus.
Angela:	And?
Student:	And mealworms like carrots less.
Angela:	Oh less, because how many times did he go to the carrots?
Student:	Two.

Angela:	And how many times did he go to the asparagus?
Student:	Three.
Angela:	Three. So did you hear what he says? He says I think the mealworms like carrots less and he says that because they only went to the carrots twice and they went to the asparagus?
Student:	The mostest.

Before Angela could adopt a more student-driven practice she needed to build her capacity by learning what a more authentic science investigation looks like. After this experience, she stated to her students, "Wow, we did a whole investigation and we documented the whole thing like real scientists." Her knowledge of what science involves was building from our discussions and from her trying the formerly unfamiliar student-driven investigations in her classroom.

The FOSS teacher's guides provide teachers with prompting questions to guide the children to make observations and comparisons during investigations. They also suggest that teachers ask students what lingering questions they still have at the end of the lesson. However, they do not suggest what teacher should do with these questions. To supplement the curriculum, I provided Angela with a list of prompts that she could directly use to push student thinking beyond the kits, which included: Why do you think that? How do you know? Who agrees or disagrees? How can you find out? The following dialogue, which occurred after the lesson "Liquids in Bottles," illustrates the impact of this support on Angela's practice.

Angela:	Questions about liquids, do we have any questions that you still have about liquids?
Student 1:	What is a liquid?
Student 2:	We know what a liquid is.
Angela:	We do? What is it? [A couple of students' hands go up.] Student 2 was very quick to say we know what a liquid is. So, what's a liquid?
Student 2:	Something that pours.
Angela:	Okay. Anybody else? I'm going to write that down because I don't know, it might be right. So, the first question was: What was a liquid? How could we find out the answer to that?
Student 3:	It is true because you have water in a bucket and when you put it upside

down it pours.

Angela: Okay, so you think this is the right answer? So, how could we find out if this is the right answer?

The assistant principal (AP) noted in her interview that she had tried for several years to encourage Angela to facilitate more student-centered discussions in all subject areas to no avail. However, the AP noticed improvement that cut across subjects after Angela began working with the researcher on science.

An additional form of support received by Angela was meetings with her colleagues. When Angela was asked whether her discussions during her regular planning meetings with her colleagues changed over the course of this study, she explained, “We talk about science, which we’ve never done before.” At the same time, she did not feel that meetings with her colleagues had a significant impact on her science instructional practice. Angela was usually ahead of her colleagues in teaching the FOSS lessons; therefore, she was more of a source of support for them than vice versa. Angela felt that she would have gained more, in the way of capacity, from the meetings if her colleagues collaboratively planned lessons with her or if she could talk to someone who had already tried out the lesson. For example, after working with Jenny during one meeting to plan a lesson on clouds, Angela felt that her capacity to improve her practice increased. Angela explained,

> I actually collaborated…with Jenny on that cloud lesson and that turned out to be great…I like that—working together—because I felt a little bit more confident doing it with someone or talking to someone about what I was going to do, because you really don’t know what you’re doing if you don’t talk to someone. And that’s what was great about having you also, because you are a science person. I am the farthest from science.

Collaborating with a colleague or a more-knowledgeable other developed Angela’s capacity to teach science.

In response to Angela and the other teachers' concerns about a lack of time to teach science, I met with the literacy coach, Melanie, to discuss the idea of integrating science and literacy. Melanie attended our next science meeting and explained to the teachers that to maximize student learning in both subjects, "we could think about taking out or shortening some of the…writing units and using more of those writing workshops to be like writing about science that actually matches what you're teaching." Angela took the idea of integrating non-fiction reading and writing with science to heart and infused literacy into her science lessons when she saw ideas present themselves. Working with the literacy coach and the researcher on integrating the subjects increased Angela's capacity to maximize her time for science.

In sum, capacity in the form of knowledge of the content; science as a process; the curriculum; what student-driven investigations entail, their purpose, and how to enact them; questioning strategies; and strategies for integrating science and the other subjects was necessary for changes in practice to occur. Nonetheless, once again, the capacity to change on its own was not sufficient for change to actually occur.

Being Held Accountable for Change

Despite Angela's invigorating experiences during the SSI and the new knowledge she developed there about the kits and how to implement them, she did not teach a single FOSS lesson once she returned to her classroom until she began working with the researcher in October. From this point on she regularly taught science almost every week for the rest of the school year. She accounted for her consistency, explaining:

> You've given me a certain push in motivation, which I'm happy about because I know I probably would let it slip under the rug if you were not a constant reminder. I would do

> that because it's the first to go…and I probably would sneak away and there are weeks I wouldn't do it. But, you are a constant reminder.

Angela did let science slip under the rug a few times during weeks when I was unable to be at her school. However, if I had previously helped her plan the lesson, she was more likely to teach science in my absence. For example, Angela taught the FOSS lesson on "Temperature" when I had a conflict in my schedule and could not be at her school. We had already watched the FOSS teacher preparation video and discussed the plans for this lesson.

Moreover, when Angela was knowledgeable, confident, and enjoyed teaching a topic, she was also more likely to teach science without my support. This was evident during the butterfly portion of the insects unit. Angela had raised and taught her students about butterflies at her old school and had built up a repertoire of resources related to butterflies, including a National Geographic article, songs, poems, books, cut-and-paste activities, and a poster she had made about the life cycle of the butterfly. Angela would use these resources to teach additional lessons on this topic when the researcher was not present. Angela was so comfortable with butterflies that her colleagues referred to her as the "butterfly whisperer." Despite her love of butterflies, Angela had not raised them in her classroom since she started working at Morningview nine years earlier.

Working with the researcher created a sense of accountability for Angela and motivated her to teach science, although mainly on the days I was in her classroom, when we had planned the lesson in advance, or when she was confident and engaged in the topic. Angela made it clear how much more science she taught since we began working together, despite the school's hyper-focus on literacy and mathematics:

> I think about where we came from, maybe doing science maybe three times a year, I think we're doing a heck of a good job to be as consistent as we are. Because I'll tell you it's the first thing to go…When you ask me, what's the main thing here? It's the reading. Next is math. And it's a lot of work.

In addition to feeling accountable to the researcher, Angela also felt accountable to her students. She believed that for her science lessons to be memorable for the children, she had to take her time during enactment. While FOSS suggests that most lessons should take 45 minutes, Angela set aside the entire afternoon—a two-hour block—to ensure the lessons were of quality for her students. Angela explained:

> My whole idea with anything I teach is to make sure that it is followed through… that's why I like to take my time…they have to get the most out of it…When you leave here I want you to have it and I want you to have it nailed down. That's learning something.

The researcher leveraged Angela's sense of accountability to her students to encourage her to focus more effort and time on planning the science lessons.

As described earlier, in the section on developing the capacity to change, the team meetings did not serve as a form of accountability for Angela in the same way they had for her first-grade colleagues. This was due to the fact that Angela was usually ahead of her colleagues in teaching the lessons. On the other hand, she felt that her colleagues were benefitting from the time together because they learned about what Angela had been able to accomplish in her classroom. In regard to her colleagues, Angela stated, "I know they all have that gumption and motivation in them [to improve their science practice]. They say, 'Yeah, you're doing that? I'm going to try that too'." Interviews with her grade-level team members echoed Angela's perception. Jenny felt that the meetings pushed her to teach more science, "I think definitely meeting with each other…we're all a little more motivated about teaching science…It helps us stay on top of it." Monita also felt that the meetings created a sense of accountability for her to teach more science, “Even to see like how far the other teachers have gotten in their experiments, it makes me feel the pressure of like I have to catch up.”

Since Angela was generally ahead of her colleagues these meetings did not impact her practice in the same way. On the other hand, being a source of accountability for her colleagues made Angela feel the need to continuously attend the team meetings and share her experiences and insights into teaching the lessons. Angela attended all but two of them. Therefore, Angela actually felt accountable to her colleagues because their science teaching practices were somewhat dependent on her.

While Angela felt a sense of accountability to the researcher, her students, and her colleagues; she felt her school conveyed a lack of accountability for teaching science. To persist in her efforts to teach science, Angela stated that she would have to develop a deep passion for the subject. Unfortunately, although Angela had a deep passion for butterflies, she had gone nine years without raising them with her students. Motivation without accountability, or in the face of accountability for other aspects of her practice, proved to be inadequate. Motivation as a mediating factor is discussed next.

Possessing the Motivation to Change

Angela taught a couple of FOSS lessons the year before this study commenced; however, she asserted that her students were not as engaged as they were when she began using FOSS during this study. “I know one thing; the children weren’t as excited [last year] as they are now.” Angela’s perception of her students’ original lack of engagement contributed to her feeling unmotivated to make the switch to the kits. The SSI sparked her interest in the FOSS lessons and she, in turn, sparked an interest in her students. Video footage of her teaching showed that Angela's belief that the lessons were exciting translated into great enthusiasm when she told students it was time for science each week and carried out the lessons. Her students reacted to her tone by getting excited and often saying "Yay," "Science rocks," and clapping their hands. Her students' reactions, like a feedback loop, then refueled Angela's commitment to teaching the FOSS lessons and reinforced her belief that they were worth making the time for.

> You know how you psych yourself [out] and say 'Oh, I don't have time.' Really, it's because you're not really interested in it yourself. But, now there's an interest…you see. Of course I'm going to get them interested.

Angela believed that in the face of conflicting initiatives, teachers must have a deep passion for science in order to ensure the motivation to continue to teach it when such a strong emphasis on literacy and mathematics is pushing against them. Angela stated, "I have to really get it [science] into my system and into my blood and have that passion for it before you go. This way it could be dear to me and I could hold on to it." While the hope is that her passion for science would be sufficient to maintain the changes she made this year, the evidence from this study suggests that some form of accountability is crucial for Angela to teach science consistently once she no longer works with the researcher.

There is hope for continued change in science and more science teaching for Angela and her team as evidenced by a conversation I had with the AP. She commented that there was a noticeable change in Angela's practice not only in science but extending into other subjects she taught as well. The AP described Angela as having reached a "plateau." Despite the AP's comments that Angela's teaching approach was too teacher-directed, Angela had been unable to progress in that area. However, the AP remarked that since Angela began working with me and implementing the FOSS lessons the difference in her practice was “night and day.” The factors that played a role in Angela’s developing practice are discussed in the next section, along with implications for this study.

Discussion

Much remains to be learned about the complex dynamics of the teacher change process (Keys & Bryan, 2001; Wilkins, 2008; Young & Lee, 2005), including how various components of PD individually and collectively impact classroom instruction (Putnam & Borko, 2000). While the work related to Cognitively Guided Instruction and Project-Based Science also incorporate multiple forms of PD, these researchers did not study the impact of those collective supports on teachers’ beliefs and practices. Moreover, there is a dearth of research in the area of elementary science teaching and learning (Metz, 2009). The aim of this study was to contribute to the knowledge base regarding elementary teacher learning and change in the area of science by investigating how the various supports received by a first-grade teacher impacted her beliefs and instructional practice in science. In this discussion focused on teacher change, I delve into the mediating factors that facilitate or hinder the impact of PD on teacher enactment of reform-based practices. As Roehrig, Kruse, and Kern (2007) assert, “It is through exploring teachers’ actual classroom practices and the beliefs and knowledge that support or constrain these practice that more targeted professional development can be implemented” (p. 905). In contrast to most literature on the impact of PD on teacher practice, this study does not rely on teacher self-report data. Instead the researcher spent an extensive amount of time in the teacher’s classroom observing lessons and discussing the teacher’s science teaching practice with her.

As others assert (e.g., Lumpe, 2007), it was found that formal PD situated outside the school context does not have a significant impact on teacher practice on its own. On the other hand, it does have the potential to plant the seed for change to occur down the road, provided teachers receive follow-up support. Teachers need to develop awareness that change is necessary and a sense of the direction in which change ought to occur. Curriculum materials offer an alternative approach to teaching science, complete with materials and teacher's guides to support enactment. For change to occur, teachers need something to change to. A guide is crucial, especially for teachers who do not have an adequate science background, because they are "traveling in an unknown land" (Reardon, 1996, p. 14). Nevertheless, curricula do not lead to teacher change on their own. Teachers require substantial support to implement them effectively. Remillard (2005) explains that teachers "need to learn about the content, goals, approaches, and underlying assumptions of the curriculum they are being asked to use" (p. 239).

Moreover, curriculum materials do not always support reform-oriented teaching practices. Reardon (1996) asserts that kits do not support students in developing their own investigations into questions of their own choosing. While kit-based curricula may be a helpful starting point for supporting teachers to try new practices in their classrooms, in order to ensure the implementation of reform-based practices, curricula must be modified, supplemented, and revised to remain current with reform-oriented approaches. This study confirms the assertions that teachers often do not use curricula in a manner that promotes critical-thinking and inquiry-based learning (NRC, 2000; Olguin, 1995). It follows that in addition to curricula, teachers require guidance from a more-knowledgeable other in order to ensure this type of instruction occurs.

In this dissertation, the researcher provided such guidance, working in the capacity of a science coach. Angela also served as a more-knowledgeable other for her colleagues, as she tried out the lessons first and had insights to share with her team. Coaches, mentors, grade-level colleagues, inquiry teams, and communities of practice, can also provide such guidance. Although, it is crucial to point out that if one teacher is more knowledgeable than the others, she may have less to gain from the group, as was the case in this study. For this reason, and due to the fact that elementary teachers are not likely to have the expertise in science teaching and learning to support each other in enacting reform-based instruction to a great extent, it is crucial for these teachers to have access to support from more-knowledgeable others.

Overtime, collaboration with colleagues can become more beneficial for all members, including those who are more advanced in their knowledge and skills. Grossman et al. (2001) found that although it is challenging to work with teachers' different agendas and expectations for a learning community, over time teachers realize that the group is enriched by various perspectives and reach a point where they are able to capitalize on their colleagues in productive ways. Others argue that the knowledge of the group exceeds the knowledge of any single member of the group. However, to get to a point where the knowledge of the group is usable, teachers must first become familiar with the curriculum they are using. As the first-grade teachers at Morningview become more familiar with the kits and talking about science with each other, there is potential for their team meetings to become more fruitful. Nevertheless, I argue that teachers still need professional development and learning opportunities from more-knowledgeable others to keep their practice progressing in reform-based ways.

A key issue with elementary science education reform is that teachers are being asked to do things that they themselves have never experienced. I argue that providing teachers with a guide or mentor to help them travel through the new lands of standards-based practices is crucial to ensure they do not get lost or decide not venture into this new territory at all. Teachers tend to avoid the unfamiliar (Harlen, 1997). Since there are so many aspects to reform-based science teaching that are foreign to most elementary teachers, this guide must be readily available to support teachers. Furthermore, due to the nature of elementary schools being hyper-focused on literacy and mathematics, this support person must be familiar with teaching science within in the confines of the particular school context.

To address the issue of elementary teachers lacking a science background, this study identified concrete supports, such as prompting questions and model student handouts, as an effective aid in supporting teachers to build their understanding of what about their practice needs to change, as well as their capacity to change in those ways. Schwartz and colleagues (2004) have found it effective to support teacher change by engaging them in an explicit reflective approach to PD focused on the nature of science (NOS). They explain that this involves "intentionally draw[ing] learners' attention to aspects of NOS through discussion, guided reflection, and specific questioning in the context of activities, investigations, and historical examples" (p. 614). I argue that the same is necessary for supporting teachers to take up any of the various aspects of reform-oriented science instruction. In addition, the findings from this dissertation study point to the potential need to expand upon their model. Not only should teachers' attention be explicitly focused on the aspects of desired change, but teachers also require concrete examples and supports of how to enact these reform ideas in their own classrooms. Consequently, I suggest a concrete, explicit, reflective approach to supporting teacher change, in order to highlight that teachers require supports that can help them translate ideas that are talked about into action.

Concrete supports serve as scaffolds that guide the teacher, until she develops the capacity to enact the particular practice on her own. This argument is in line with Vygotsky's (1978) zone of proximal development (ZPD), which is "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (p. 86). The amount of scaffolding depends on the teacher's particular needs. To effectively support teachers it is crucial to work from where they are in terms of their knowledge, skills, and experiences (Koch & Appleton, 2007), because learning to teach in reform-oriented ways is a complex and personal process (Jones & Eick, 2007).

In addition to developing an awareness of the aspects of one's practice that need to change and the capacity to make those changes happen in theory, the findings suggest that teachers must also feel a sense of accountability and develop the motivation to change their practices. Formal PD appears to foster motivation in teachers, as can regularly meeting with a science coach or mentor. In this day in age, where accountability for mathematics and literacy is so prominent in elementary schools, science will continue to be marginalized, unless teachers feel accountable to make room for it in their busy schedules. In this study, it was found that accountability for science teaching can emerge from various sources, such as a science coach or some other advocate for science, colleagues, professional developers, administrators, and the local university (Mensah, 2010). When accountability and support come from several different directions and are aligned with a continuous and coherent school science program, teachers are less likely to feel they can ignore teaching science and sweep it under the rug.

In the context of today's elementary schools, administrators are a key ingredient in developing ongoing accountability for science. They can hold their teachers accountable for this subject in some of the same ways they do for literacy and mathematics (i.e., monitoring student progress and observing lessons). However, since most principals do not possess a science background, they are unable to offer critical feedback related to science teaching (Lanier, 2009). What they can and should do is seek out and inform their teachers of opportunities for professional development in this area.

When teachers are provided with support for science this can spark their interest and sense of responsibility to teach science and improve their instructional practice. Motivation to teach science can come from enjoyable experiences learning about and teaching the subject. It can also come from feeling a sense of accountability. In this study, the teacher felt accountable to spend time and effort on her science instructional practice due to the researcher who was coaching her, to her students who were enjoying the curriculum and learning from it, and to her colleagues whose practices were somewhat dependent on hers. Teachers need to develop a deep commitment to teaching science, especially in the face of an elementary school culture that prioritized the other core subjects.

A final key finding from this study is that addressing teachers' concerns about lack of time in the school day can contribute to improved science teaching. Supporting teachers to integrate science and literacy appears to be one beneficial way to build teachers' capacities and motivation to make room for science in their schedules, without sacrificing time for developing reading and writing skills. This study supports the research of Howes, Lim, and Campos (2008) that when teachers view science as a subject that requires and can benefit from the incorporation of literacy skills, they will be more inclined to spend time teaching science.

Conclusion

To actually achieve changes in the science teaching practices of elementary generalist teachers, they must be supported to recognize the limitations in their science understandings and the opportunities they provide their students to learn science. Furthermore, teachers must develop their capacity to teach in reform-oriented ways, feel motivated to change to a more reform-based approach, and feel a sense of accountability to do so as well. It took several forms of PD to support teacher change in this study, each one resulting in the promotion of particular mediating factors that facilitated teacher change. This study contributes to the field of science education by illuminating these mediating factors that appear to contribute to the complicated process of teacher change, namely developing an awareness of what needs to change about one's practice, building the capacity to change one's practice, feeling a sense of accountability to change, and instilling the motivation to change. Professional developers and teacher educators ought to keep these mediating factors in mind when designing supports for elementary teachers. Can a formal PD address all of these factors? What combinations of supports can work together to foster these factors that are connected to teacher change?

Moreover, this study highlights the potential effectiveness of ongoing school-based support from a reform-minded science coach. Support from the researcher appeared to have the greatest impact on promoting changes in teacher practice, because it was situated, focused on the teacher's needs, aligned with the curriculum, immediately available, and ongoing. At first glance, consistent classroom-based support may not appear to be scalable, due to the necessary time and financial commitments. However, if districts are able to staff literacy and mathematics coaches, there is no reason this same form of support should not be feasible for science. It is unacceptable that, in the technologically advanced era we live in, schools that do not have one staff member with a science background are so prevalent. Generalist teachers cannot be expected to make the changes to teach in more reform-oriented ways if they do not have an accurate vision of what science is and what effective science instruction looks like. Teachers require support from curriculum materials, concrete supplements to guide them in moving beyond the kits, colleagues with whom they can discuss and debate ideas, as well as a more-knowledgeable other that can ensure progress remains aligned with current understandings about effective science teaching.

CHAPTER VI

CONCLUSION AND IMPLICATIONS

As discussed previously, the aim of this study was to explore the impact of teachers' PD experiences, including coaching, on reforming teacher practice. I have argued that the significance of this study stems from the lack of research related to science education reform at the elementary level and the complex nature of teacher change. To engender a more nuanced and detailed account of the challenging process of teacher change, I delved into a study of the dilemmas teachers at various stages of their careers encounter in teaching science at the first-grade level and how they reconcile these dilemmas. I also inquired into the mediating factors that impact the teacher change process. In the following sections I summarize the findings from both Chapters IV and V, and then discuss, more holistically, the findings of this study across these chapters. Furthermore, implications and future directions for research are discussed.

Summary of Major Findings

Chapter IV illuminates three dilemmas that plague elementary teachers who are responsible for teaching science. Teachers struggle to manage their need to (1) focus their efforts on planning and teaching science in a school culture preoccupied with literacy and mathematics achievement, and (2) teach science although they feel insufficiently informed and prepared in this subject area. Additionally, elementary teachers struggle with (3) whether to use their curriculum as a script, supplement, starting point, or not at all. Chapter IV also highlights the positive impact a science coach can have on how teachers manage their dilemmas, although teachers may not make the most of their access to this more-knowledgeable other without a strong sense of accountability to do so. What teachers want from a science coach and how intrinsically motivated they are to accept support from a science coach, depend primarily on teachers' comfort levels in literacy and mathematics, which may be tied to their career stage. Experienced teachers, who have had time to build up their knowledge and skills in the subject areas deemed most crucial by the school culture, are more open to focusing their efforts on science. When science is not a priority in the school context, it is not likely to be a priority for teachers—particularly novice teachers who are under tremendous pressure to maintain and improve students' reading, writing, and mathematics skills. When there are so many aspects of one's practice that require attention, science is likely to be relegated to the margins. However, from this study there is evidence that accountability for science from administrators, fellow grade-level teachers, and a science coach can lead to greater efforts on the part of the teacher to improve her science instructional practice at all stages along the professional learning continuum.

Chapter V identified several mediating factors that influence the impact of PD on the development and enactment of reform-based science teaching practices: the teacher must (1) recognize a need for change, (2) develop the capacity to change, (3) feel a sense of accountability to change, and (4) possess the motivation to change. These interrelated factors appear to be necessary to allow elementary teachers to make reform-based changes in their science instruction. In today's elementary classrooms, science must compete with other subjects deemed more important, as well as subjects that teachers feel more comfortable teaching. To carve out time and space for meaningful science lessons, these conditions must be met. Moreover, it was found that the various modes of PD that make up multi-component PD models each serve a purpose. Such models appear to have the most potential when they work in concert and take these four mediating factors into account.

Jones and Eick's (2007) description of the relationship between teachers' beliefs and practices as a feedback loop appears apt. Teacher change was fostered in this study through PD efforts that focused on supporting teachers in trying new things and discussing their experiences in order to build both their knowledge and science teaching skills in tandem. In addition to reflecting on one's practice and working with a more-knowledgeable other, like a coach, who can explicitly draw one's attention to reform-based practices and areas that require change, teachers need concrete supports that can scaffold the process of change. Teacher change is precarious, especially in the context of science teaching; however, with ongoing and cohesive support and accountability for teaching science coming from several different sources, teachers can effectively move science away from the margins of the elementary school curriculum.

Synthesizing Findings across the Chapters

A key idea related to promoting teacher change emerged from Chapters IV and V: accountability. This idea is discussed in detail below.

Accountability

Current accountability measures, such as standardized testing, work against the promotion of reform-oriented science teaching in elementary schools. At the first-grade level, teachers are generally only held accountable for student performance in the areas of reading, writing, and mathematics. Spillane, Diamond, Walker, Halverson, and Jita (2001) found that the teachers who work in the urban schools are less concerned or not concerned at all with the subjects where there are no extrinsic rewards or sanctions. They explain that, as a result, science instruction is essentially left up to the teacher's discretion.

Moreover, accountability through evaluations conducted by administrators who lack adequate knowledge of science and effective science teaching practices also impedes reform-oriented science instruction. As was evident in this study, administrators who lack knowledge of science and science teaching can offer little constructive feedback to their teachers in this subject area and avoid focusing on it. Consequently, they perpetuate the marginalization of science in elementary schools. Lanier (2009) argues that principals must have at least a basic, if not in-depth, understanding of science education reform goals in order to promote reform-based science teaching and learning. This idea is also echoed by Goldsmith and Pasquale (2002) who contend, "Administrators who are knowledgeable about the issues and challenges involved in developing scientifically literate students will be in a stronger position to promote and facilitate improvements in the science curriculum itself and in its implementation" (p. 25).

Furthermore, my study points to the need for wider conceptions of accountability for science teaching, a call also made by Darling-Hammond (2004). Darling-Hammond asserts that administrators can create more productive accountability through implementing school structures that support teacher learning and investing in the development of teacher knowledge and skill. Furthermore, the findings from my research study show that various sources of accountability hold promise for the promotion of reform-based changes in teachers' science instructional practices. Accountability can be fostered through providing teachers with a well-trained science coach, time to collaborate with colleagues in the area of science, and opportunities to discuss student learning and engagement in science. When accountability for science from coaches, colleagues, and students is combined with accountability from administrators, change in practice is likely. This was evident with all participants in this study, including Monita who was most resistant to focusing her time and effort on science.

Monita felt accountable to the researcher and her team when they shared their experiences teaching from the FOSS curriculum. She also felt accountable to her students after observing their learning outcomes. These experiences motivated her to actually teach from the kits at the outset of this study. However, these forms of accountability were not sufficient to sustain her science teaching practice over time due to the lack of accountability for science instruction from the principals. It was not until Monita felt pressure from the principal to keep up with her colleagues that she became committed, once again, to turning her attention to science. But again, once the principal completed his observations and administrator accountability for science waned, Monita ceased facilitating the in-depth FOSS investigations. While the general lack of administrator accountability for science relative to literacy and mathematics affected the amount and quality of science taught in all the teachers' classrooms, the impact was most severe for the novice teacher. In addition, spending more time with the science coach was linked to the amount of class time spent teaching science. Since there were only three teachers in this study, more research is needed to confirm this result.

In line with Elmore's (2004) idea of "reciprocal accountability," this study highlights the stance that not only should teachers be held accountable for improving their science teaching practices, but administrators and teacher educators should be held accountable for supporting teachers to make the necessary changes. If teachers are underperforming in certain areas, it is more likely a result of being underprepared than a conscious choice made on their part. Teacher evaluations should not end with a meeting informing teachers of their shortcomings. Instead, evaluations should be a starting point for developing a plan for personalized teacher development that will further teachers' personal and professional advancement in science (Moore, 2008). To improve, it is not enough for teachers to be informed of their shortcomings; instead, they must be provided with opportunities for professional development that directly addresses these areas. This study suggests the need for accountability to be coupled with support in order to move teachers to more reform-oriented science instruction.

Implications and Future Directions for Research

This research study has implications for teacher educators, including mentors, coaches, pre-service teacher educators, and other professional development providers who support teacher learning at all stages of the teacher professional continuum. Even before beginning their teaching careers, pre-service teachers require authentic classroom experiences in order to gain an awareness of the dilemmas associated with translating reform ideas into practice and in order to begin working to address them (Gunning & Mensah, 2010). Following this stage, teachers require continued support throughout their careers in order to build their knowledge and skills related to reform-based science teaching. This way teachers will develop the capacity to address the dilemmas they encounter in productive ways, rather than reverting to more didactic forms of science teaching or learning to avoid it. Angela, for example, struggled to find the time to adequately prepare for her lessons and sometimes overlooked key learning goals. In order to address this dilemma which stemmed from the lack of time she perceived to prepare for her science lessons, Angela was resolved to have the learning goals written out in advance for students instead of guiding the students to articulate their learning themselves. Without the opportunity to reflect with the researcher on her approach to reconciling her dilemma, Angela may have implemented this more teacher-directed strategy rather than the one she did enact, which was to keep the teacher's guide by her side during the lesson so that she could remind herself of the direction she wanted to guide student learning.

Coaching appears to hold great potential as a job-embedded component of ongoing PD. This approach provides teachers with a more-knowledgeable other and thus direction for change—instilling an awareness of what needs to change and the capacity to change. Coaches can also create accountability for teacher change and help foster the motivation to change.

While literacy coaches are becoming prevalent in elementary schools, with mathematics coaches following closely behind, science coaches continue to be rare (Cooke-Nieves, 2011). More research is needed on the impact science coaches can have in this marginalized, yet important subject area. Specific directions for future research include: What are the long term effects of multi-component PD models, and coaching in particular, on elementary teachers' beliefs and practices related to science? What is the impact of coaches who are hired by the school, rather than coaches who are university researchers, on elementary teachers' beliefs and practices related to science?

Implications for Teacher Education Programs

Pre-service teacher preparation programs generally require elementary education students to take, at most, one semester-long science methods course. These courses are often not coupled with a mandatory classroom placement and, thus, students do not have a direct opportunity try out what they are learning in practice. It is essential that we begin to prepare pre-service teachers to navigate some of the common dilemmas they are likely to face once they become the teacher of record in the classroom.

This study points to the need for teachers to gain experience trying out the curricula they will likely use in their own classroom; critiquing, modifying and extending these curricular resources to ensure alignment with reform ideas; and integrating science with the other core subjects in ways that do not neglect the key aspects that make science a distinct discipline. Similar to other researchers' findings regarding school placement and science teaching (Gunning & Mensah, 2010), the current study points to the need for science placements and science teaching as part of elementary pre-service teacher training.

Moreover, my research points to the potential benefit of having science educators collaborate with educators in the other subject areas, in order to support pre-service teachers in learning how to maximize student learning in all subject areas during the school day. It is not a common practice in education schools for science and language arts or science and mathematics educators to co-design and co-teach education courses for pre-service teachers. I believe that such courses have potential to bolster student learning in each subject area as long as university educators are careful to convey the need to not lose sight of each discipline's unique features and ways of knowing and doing.

Implications for Preparing Coaches

Lessons Learned from This Study. My year spent working with the first-grade teachers illuminates several key ideas that coaches should keep in mind when working to support classroom teachers. I went into this study expecting to take my time in getting to know the teachers and their particular needs and concerns, so that I could work with them to determine the best approaches to professional development. However, since elementary teachers do not possess a science background and time during the school day is in such short supply, it is important to enter such a professional development endeavor conveying a clear vision for the work from the outset, including what the over-arching goal is for teachers' classroom practice and a concise plan for how much of a time teachers will need to invest in the initiative. The approach to PD can and should be tailored over the course of the work, but transparency and reasons for why teachers should be trying new practices and dedicating their efforts need to be made clear.

Equally important, coaches should find out teachers' perceptions of their needs and their own goals for the coaching support being offered, and then work to address those needs while connecting the support to the over-arching reform-based plan for the PD. Once the coach has built a sense of trust with the teacher, he or she will more likely be granted access into the teacher's classroom to begin identifying other aspects of the teacher's practice that require attention.

My work with the teachers has also taught me the importance of time management when it comes to focusing on science teaching and learning. The teachers at Morningview had so much on their plate due to the several other initiatives going on concurrently at their school. A clear plan or agenda for what each science meeting would entail would have provided the teachers with more of an idea of how much time they would be setting aside and what aspect of their practice they would be focusing on.

Who Should Be Hired as Science Coaches? When schools are mandated to provide their teachers with coaches or mentors, these staff members are often not adequately trained for their position. Science coaches must have a strong background in both science and education in order to have the potential be effective at supporting teacher change in this subject area. Moreover, coaches need to be trained for the position Just because someone is a good student in science, does not mean that they will be a good teacher of science. The same follows for coaching. Just because someone is a good science teacher this does not imply they will necessarily be a good teacher of teachers.

Providing teachers with the opportunity develop their craft and expand their impact by becoming certified coaches can offer job diversity in a typically unstaged career (Lortie, 1975). Schools of education should consider designing such certification programs. Potential candidates ought to be teachers with a science background, which means they will most often be middle school or high school teachers. This is another reason why training to become an elementary science coach is essential. These educators need to familiarize themselves with a completely new teaching context.

Coaches may take on this role full-time, but may also continue to teach in their own classroom part-time. Coaching can serve as a way to promote lifelong learning for teachers, by providing them with new opportunities for learning with each teacher with whom they work.

PD and the Next Generation of Science Standards

The development of the Next Generation of Science Standards is currently underway and are due for public review in spring 2012. These new standards are based on the NRC's (2011) most recent publication: *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* This new vision of science education values the integration of science, engineering, and technology due to their central roles in the development and understanding of the designed world. This framework also highlights several concepts that cut across the fields of science and engineering, as well as the core ideas of the various science disciplines. While the standards based on this document are still in the development phase, a great deal can be done to prepare for their rollout.

To inform the PD teachers will need in transitioning to these new standards, much can be gleaned from the literature that has emerged over the years about the barriers and pathways to successful teacher change and science education reform (Penuel & Fishman, 2012). At a broader level, it is evident that coherence across standards, curriculum, assessment, and professional development are crucial to the success of reform. At the classroom level, there are a host of factors that impact teachers' abilities to effectively implement standards-based reform. Since the process of learning and enacting new standards-based ideas is complex in nature, my study contributes to the literature focused at the level of the teacher working within her classroom context.

The science education community understands that PD should be ongoing, job-embedded, and teacher-centered (Borko, Jacobs, & Koellner, 2010). In order to assist teachers in developing the knowledge base necessary to elicit their students' prior science conceptions and designing lessons that move their students' thinking forward, it is clear that teachers need to have strategies modeled for them, occasions to try out strategies in the context of their classrooms, and opportunities collaborate and reflect with colleagues and science educators (Cooke-Nieves, 2011). Where additional research is needed, however, is in describing the issues involved in designing and carrying out effective PD programs (Borko et al., 2010).

Penuel and Fishman (2012) argue that the focus of research related to new policies, including standards adoption, should be "not just about 'what works,' but also about 'what works when, for whom, and under what conditions'" (p. 294). What teachers learn from PD opportunities and how they work within the confines of their school contexts to decide what and how to teach when it comes to science remains relatively obscure, particularly in the under-studied area of elementary science education (Metz, 2009). In response, my study, highlights some of the dilemmas elementary generalist teachers at various stages of their careers encounter in learning to implement new approaches to science teaching, the potential science coaches hold for just-in-time job-embedded PD in science, and the crucial role of accountability in supporting teachers to enact standards-based instructional practices. With research in this vein available to reformers, the hope is that the uptake of the new standards will be more successful than past efforts to improve science education. However, it is important to point out that this study only contributes to one of several stages of research that need to take place to achieve this end.

Borko (2004) describes three stages of research required to extend the knowledge base in the area of teacher PD. In the first phase, researchers focus on an initial PD program at a single site and study the relationship between the initiative and teacher learning. Phase two of this agenda expands to an investigation of the impact of the PD when facilitated by an increased number of individuals, at an increased number of sites. Borko explains that phase three involves the large-scale study of several PD programs, each of which is carried out at several sites and by several facilitators. Future studies related to elementary science reform will need to move beyond providing preliminary evidence related to the roles and effectiveness of a single science coach or PD program, by increasing the number of coaches, programs, and sites studied. Nonetheless, this study was a vital first step, as phases two and three cannot be carried out until there is sufficient research at the phase one level.

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APPENDICES

APPENDIX A

Teacher Interview Protocol

(I) Teachers' perceptions of their views and practices:

1. How would you describe your approach to teaching science? Examples?

2. How do you think your students learn best? How do you maximize student learning?

3. How often did you teach science at the beginning of the school year? Why?

4. How often have you been teaching science throughout the current unit? Why?

5. How comfortable do you think you are with the science content you are currently teaching?

6. How often do you teach lessons from your FOSS kit? What other science resources do you or have you used?
   -How closely have you been sticking to the FOSS curriculum?
   -How have you been deciding which FOSS lessons to teach and not to teach?
   -What do you find to be the pros and cons of FOSS? What are your impressions of this curriculum?
   -What are your impressions of the student-driven investigations? (Second interview only)
   -What changes would you like to make to your science teaching practice?
   -What is your plan for teaching science next year? (Second interview only)

(II) Professional Development and Support

7. Who do you talk to about science?

   Prompts: Who do you turn to for advice? Who has influenced your thinking about science instruction? Who has influenced your science teaching practice? How often do you interact with these people?

   -Why do you talk to some people and not others about science instruction?

8. Do you find it beneficial to interact/collaborate with your colleagues? Why or why not?
   -What factors facilitate/hinder your ability to interact/collaborate with your colleagues?

9. Do you have any desire to receive science PD or support?
   -What kind of support would you like to receive for science, if any?
   -Have you sought out any support for science?

10. Are you currently registered for any upcoming PD (any of the content areas)?

(III) Challenges & Dilemmas

11. What constraints do you think inhibit your science instructional practice? Examples?
    Prompts: What do you think are your biggest concerns/challenges when it comes to teaching science?

12. How do you think these constraints can be addressed?

(IV) Working with Colleagues and Coach

13. How have your discussions about science during your teacher planning meeting changed over the course of the year, if at all? Changed from last year? In what ways? Whether I am there or not?

14. What do you think you have gained/learned from working with me? With your colleagues this year?

15. What aspects of working together this year have been most beneficial to you, if any?

16. In what ways do you think our time together would be more beneficial?

17. Do you think the teachers on your grade-level team have a shared vision of effective science instruction? Explain.

18. Since you have been participating in this research study, has there been any change in your patterns of interaction with other teachers and colleagues at your school?
    (e.g., Do you interact more/less often? Have the types of things you talk about changed over time? If so, in what ways?)

APPENDIX B

Principal Interview Protocol

BACKGROUND QUESTIONS:

A) How long have you been a principal? How long have you been a principal at this school?

B) What did you do before becoming a principal? How long? [What did you teach? Was that what your degree was in?]

C) What science or science education courses have you taken?

MAIN INTERVIEW QUESTIONS:

1. What are your primary goals for this school?

2. What are you doing/implementing to achieve them? (structures and activities)

3. What is your goal for science at this school?

4. How were the teachers who attended the SSI selected? Did Angela choose to go or was she asked to attend? Why?

5. What theories of school improvement guide your approach or agenda?

6. What was/is your purpose behind implementing the following initiatives?

   a) Common planning time? Expectations for teachers during this time?
   b) Subject committees?
   c) Common pre-assessments for each grade level in each subject? Why is this the current focus?
   d) Why did you have literacy and math coaches last year? What was their role? Why not science? Would you ideally like a science coach and why?
   e) What is the role of Ms. Warren, the science cluster teacher?
   f) What other initiatives are going on at this school?
   (Talent Tuesday, Studio in the School, Literacy…)

7. How do you make sure the teachers are teaching science? Do you expect them to stick to FOSS?

8. Have you observed any of the first-grade teachers teaching science? Have you noticed any changes in their practices?

APPENDIX C

Post-Lesson Reflection Prompts

1. How did you feel the lesson went?

2. What do you think the students got out of the lesson? What don’t you think the students got out of the lesson?

3. What was your purpose or goal for the lesson (what did you really want the students to come away with)?

4. What, if anything, would you do differently next time?

APPENDIX D

Discussion Prompts

Like scientists, students should…	**Possible Guiding Prompts:**
Become aware of their prior conceptions	- What do you already know about ________? (record students' ideas on chart paper)
Propose and design investigations that are meaningful to them	- What do you want to know about ________? - How could you find out?
Carefully collect and organize data	-How will you keep track of your observations/data?
Develop logical explanations (justify their claims with evidence)	- What did you find out about ________? - How do you know?
Welcome constructive feedback from peers and engage in debate based on strength of evidence	- Who agrees/disagrees with that? Why? - Does anyone want to add on to that? - Why do you think that? - How can we find out? - Is that a fair test? (controlling variables)
Reflect on their practice (consider how prior ideas fit with newly generated ideas)	(revise students' original ideas on chart paper) - Any lingering questions? - Can anyone answer that? - What could we do to find out?

Student-Driven Investigations (Teacher Handout)

(1) Before the investigation:

(a) *What do you know about* ______________________?

"I think that…"

(b) *What do you want to know about* ______________________?

"I want to know…"

(c) *How can you find out*?

"I can find out by…"

*some types of questions can be answered with reading materials, some with observations, and some with collecting experimental data
*for the purposes of this activity students should investigate testable questions where they collect experimental data as evidence for findings

(d) *What do you predict will happen during your experiment*?

"I predict that…"

(2) After the investigation:

(a) *Title*:

(b) *What do I want to find out?*

"I want to find out…" or

Question: **"Who/Which/What/When/Where/Why/How…"**

(c) *How did I find out*? [list the steps in the procedure or write a paragraph]

(d) *Data collected*: [table, chart, and/or diagram]

(e) *What did I find out*?

"I found out that…"

"I think this because…"

[use data collected as evidence]

(f) Discussion and debate as a class:

- *Who agrees/disagrees with this student's findings*? *Why*?
  "I agree with _____. I also think that… I think this because…"
  "I respectfully disagree with _____. I think that… I think this because…"
- *Was this a fair test? Why or why not?*
- *What problems did you have during the investigation?*
- *How would you improve this investigation next time?*
- *Any lingering questions*?
- *Can anyone answer that*?

Student-Driven Investigations (Student Handout)

Before the science investigation:

1. What do I want to find out? (Underline your prediction.)

_*I want to find out…*____________________________________

____

2. What steps will I take to find out?

_*First I will…*____

____

____

____

During the investigation:
3. Data: What am I seeing or measuring?
(Example: Draw a diagram and/or make a chart with measurements or tally marks)

After the science investigation:

4. What did I find out?

_*I found out that…*______________________________________

____

____

____

5. How do I know? (Look back at your data to explain your findings.)
_*I think this because…*__________________________________

____

____