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TEACHING SCIENCE AS ARGUMENT:

PROSPECTIVE ELEMENTARY TEACHERS' KNOWLEDGE

A Dissertation in

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by

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ABSTRACT

For the past two decades there has been increasing emphasis on argumentation in school science. In 2007, the National Research Council published a synthesis report that emphasizes the centrality of constructing, evaluating, and using scientific explanations. Participating in argumentation is seen as fundamental to children's science learning experiences. These new expectations increase challenges for elementary teachers since their understanding of and experiences with science are overwhelmingly inconsistent with teaching science as argument. These challenges are further amplified when dealing with prospective elementary teachers.

The current study was guided by the following research questions: (1) What are the ways in which preservice elementary teachers appropriate components of "teaching science as argument" during their student teaching experience? (2) To what extent do components from prospective elementary teachers' reflections influence planning for science teaching? (3) What elements from the context influence preservice elementary teachers' attention to teaching science as argument? This study followed a multi-participant case study approach and analyses were informed by grounded theory. Three participants were selected from a larger cohort of prospective elementary teachers enrolled in an innovative Elementary Professional Development School (PDS) partnership at a large Northeast University. Cross-case analysis allowed for the development of five key assertions: (1) The presence of opportunities for interacting with phenomena and collecting first hand data helped participants increase their emphasis on evidence-based explanations. (2) Participants viewed science talks as an essential mechanism for engaging students in the construction of evidence-based explanations and as being fundamental to meaning-making. (3) Participants demonstrated attention to scientific subject matter during instruction rather than merely focusing on activities and/or inquiry processes. (4) Scaffolded protocols positively influenced participants' attention to having students construct evidence-based

explanations during science planning and teaching. (5) Teachers' beliefs about children's science capabilities influence their attention to and adoption of practices associated with teaching science as argument. Findings are discussed in terms of their implications for teacher education, such as the use of coherent conceptual frameworks to guide coursework and field experiences and the development of video-based cases that represent "images of the possible" associated with challenging reform-oriented teaching practices.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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DEDICATION

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CHAPTER 1: THE PROBLEM

1.1 Overview

The problem affecting teaching science as argument, as described in this chapter, exists within the current perspective of science education reform that places increasing emphasis on students' proficiency in science. This chapter outlines some of the reform challenges for changing science education and the implications from these challenges for elementary science education in particular. Subsequently, the discussion establishes a foundation for the problem by providing an explanation of reconciling theoretical, conceptual, and practical stances while providing an arena for the current dissertation's research questions. Finally, this chapter provides a short description of the context, participants, significance of the study, and the sequence of discussion in the succeeding chapters.

1.2 Teaching Science: Historical Perspective

Educational reforms in general have enjoyed attention since the 1890s. Scholars such as Dewey (1933, 1938) believed that schools in general needed to be interested in problems that engaged children in what was current, and furthermore, in ways that allowed for freedom of thinking. He argued for the need for children to learn things in context and apply that knowledge to concrete, real problems. Vygotskiæi (1962) also influenced general educational reforms when he discussed children's abilities and how the social environment helped with interactions, discourse, and development at different cognitive levels (stages of knowledge acquisition). Undoubtedly, these ideas and others influenced science education, as exemplified by changes in teaching, learning, and policies. However, classroom reforms for

science education have not received the same aggressive attention until the last ten to fifteen years. For example, in science education, during the 1950s, policies pushed the creation of curricula that were more consistent with the nature of science. Since these efforts were more at a policy level, little translated into classroom activities since a disconnect existed between helping teachers make meaning and adapting that meaning to classroom pedagogy. Current reform initiatives such as Project 2061 (AAAS, 1989) and the National Science Education Standards (NSES) (NRC, 1996) have guided science education with notions of what determines scientific proficiency, most recently (NRC, 2007) an initiative for kindergarten through eighth grade (K-8) education. The latter placed strong emphasis on scientific practices such as argumentation.

In an attempt to improve scientific proficiency among US students, teaching science as inquiry has become the focus of science education. Teaching science as inquiry refers to the process of engaging children in investigating testable questions and making connections between prior knowledge and new scientific knowledge. This occurs with meaningful experiments and activities that allow students to collect data and derive explanations based on the data collected (NRC, 1996). The focus on scientific proficiency and the use of inquiry as an instructional tool have a combination of appropriate scaffolds: student's engagement, essential elements of inquiry, and notions of discussing science based on evidence-driven explanations (NRC, 2000).

Many scholars (Abd-El-Khalick, Boujaoude, Duschl, Lederman, Naaman, Hofstein, Niaz, Treagust, & Tuan, 2004; Krajick, Blumenfeld, Marx, & Soloway, 2000; Llewellyn, 2002; Sandoval, Daniszewski, Spillan, & Reiser, 1999; Schwab, 1994; Schwarz & Gwekwerere, 2006; van Zee, 2006) have studied inquiry resulting in new views of the

meaning of proficiency in K-8 science. These new views stretch the envelope of reform initiatives by encouraging thinking that emphasizes giving priority to evidence and explanation and making science discourse practices central to science learning. However, available research is not sufficient for understanding teachers' knowledge about effective science teaching practices as described by current reform. Moreover, only limited research exists to aid understanding prospective elementary teachers' knowledge of the central practices essential for science learning after the conclusion of college level science methods courses.

The current report by the National Academy of Science (NRC, 2007) redefined the notion of proficiency by stating four standards of scientific proficiency:

1. Know, use, and interpret scientific explanations of the natural world;
2. Generate and evaluate scientific evidence and explanations;
3. Understand the nature and development of scientific knowledge, and
4. Participate productively in scientific practices and discourse. (p.37)

According to the report, these standards "represent learning goals for students as well as [providing a broad framework for curriculum design" (p.37). Thus, the standards include the process of acquiring facts, building knowledge, developing skills, and understanding the nature of science. They are part of a curriculum that prioritizes critical scientific discourse, evidence construction, and analysis of scientific phenomena that are appropriate for students' proficiency yet support the development of the four stated standards.

1.3 Challenges of Change

The recommendations embedded in the vision of the standards create ambitious expectations for elementary school science. The movement has renewed expectations for children on what to do, how to think, and how to engage in scientific practices. This

amalgam of expectations brings challenges to contextualizing some of the ways for science learning and teaching within specific contexts, such as teacher education. This is because the recommendations require fundamental shifts in thinking about teaching and learning from what Loughran, Berry, and Mulhall (2006) described as "delivery of content" (p.1) towards viewing teaching and learning as child centered: children taking responsibility and demonstrating interest in learning. These examples of expectations and shifts produced by renewed expectations for scientific proficiency are overwhelming to teachers since the body of literature suggests that teachers themselves struggle with scientific proficiency due to a series of factors from their own experiences as science learners (Crawford, 1999; Darling-Hammond & Bransford, 2005; Gustafson, Guilbert, & MacDonald, 2002).

Science teaching confronts consistent obstacles at the elementary level. Well-documented issues include elementary teachers' generalist nature (Dobey & Schafer, 1984; Jones & Edmunds, 2006), lack of scientific content knowledge (Bloom, 1989; Darling-Hammond, 2000), and struggles with pedagogical content knowledge (PCK) for science teaching (Appleton, 2006; Gess-Newsome, 1999).

The science teaching obstacles are amplified for prospective teachers. Literature suggests that elementary-level, prospective teachers usually accumulate six credits in science courses that are traditionally didactic and inconsistent with the preferred methods of engaging students in science learning. Specifically, in most traditional elementary education programs, required introductory science courses are typically didactic and lecture-based, with emphasis on detailed facts and theory rather than on understanding and application (Kelly, 2000). Furthermore, the commonly used methodology for teaching science (science as a

cluster of facts) is how prospective teachers learn science in science courses prior to college experiences.

1.4 Reconciling the Theoretical and the Practical

Given the challenges arising from the emphasis on scientific proficiency, reconciling the theoretical and practical aspects of science teaching is crucial in order to provide systematic and clear inquiry. Thus, the current study assumes a philosophical position of post-positivism and a theoretical stance of situated learning theories. The conceptual framework of Teaching Science as Argument (Zembal-Saul, 2005, 2009) is the basis for these philosophical and theoretical positions. This conceptual framework aligns with the NRC's (1996, 2000, 2007) current reform initiatives that push for scientific proficiency and brings to the forefront scientific discourses which use evidence when building explanations. The forefront, according to NRC (2007), describes that science should be "a process of logical reasoning about evidence, science as a process of theory change, and science as a process of participation in the culture of scientific practices" (p.28-29). Thus, using the conceptual framework of teaching science as argument is pertinent as a methodological lens for data analysis. The framework provides overarching analytical categories for examining collected data and provides an analytical lens to build explanations about the problem in this study. The framework, discussed in the next chapter, also guides the development of the science methods course and associated field experience in which the current study took place.

The goal of using this conceptual framework is to create a rich description regarding the changes occurring in prospective teachers' knowledge of teaching science as argument and what the factors are which affect that change. Therefore, the critical examination is of how learning theories, educating prospective elementary teachers, and the pedagogical

aspects of teaching science intertwine to provide a base for grounding the relevance of the current study.

1.5 Research Context

The emphasis of science education towards scientific proficiency requires shifts in teachers' cognitive, epistemological, and axiological knowledge, as well as their beliefs and development for teaching science as argument. These shifts challenge teacher education programs and reveal a gap in the literature regarding what is known about prospective teachers' knowledge for teaching science as argument beyond their methods course semester. Scholars (Kelly, 2000; Lavoie & Roth, 2001; Zembal-Saul, Krajcik, Blumenfeld, 2002; Zembal-Saul, Blumenfeld, Krajcik, 2000) investigated ways to assist prospective teachers in adopting inquiry methods. In addition, other scholars (Avraamidou & Zembal-Saul, 2005; Erduran, Simon, & Osborne, 2004; Haefner, Zembal-Saul, & Avraamidou, 2002; Haefner & Zembal-Saul, 2001; Munford & Zembal-Saul, 2002; Sandoval & Reiser, 1997, 2004; Zembal-Saul, 2005) have investigated ways for helping teachers give priority to evidence when building explanations within the broader emphasis of argumentation. However, available information in the literature is unclear regarding understanding prospective teachers' knowledge and beliefs, and the sources of that knowledge in student teaching experiences and beyond. Compounding the difficulty of identifying knowledge and sources of knowledge is that much of the available information on teaching argumentation has a socio-scientific issues context (Erduran, et al., 2004; Newton, Driver, & Osborne, 1999; Zeidler, Osborne, Erduran, Simon, & Monk, 2006).

One apparent problem of engaging in argumentation practices in the context of socio-scientific phenomena is that teaching may be distracted from school science's purpose of understanding foundational scientific concepts (Roberts, 2007). Osborne, Erduran, and Simon (2004) examined pedagogical environments and their effects on teachers' pedagogical practices to support argument construction within socio-scientific contexts. The results demonstrated that teachers could adapt pedagogical practices to help children engage in argumentation. However, teachers were less able to adapt when emphasizing scientific content; thus, argumentation practices were not fruitful in a science oriented context.

The current study stems from TESSA[1]: Teaching Elementary School Science as Argument. The TESSA project, described by the investigator, Zembal-Saul, centered on developing "electronic resources to support preservice elementary teachers in learning to teach science as argument and to [s]tudy the development of preservice elementary teachers' knowledge and practices for teaching school science as argument" (http://tessa.ed.psu.edu/Header_Documents/TESSA_Overview.cfm, NSF Grant No. 0237922). Thus, the current study is a small component of a larger longitudinal study with a particular emphasis on teaching science as argument after teachers complete a science methods course, whose orientation emphasizes explanation driven inquiry and students' construction of scientific claims from evidence. These practices are consistent with the NRC (2007) perspectives for proficiency in K-8 science classes.

This study suggests that science methods courses aligned with current science reforms, can have a positive effect on prospective teachers' knowledge and practices of

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teaching science as inquiry (Olson & Appleton, 2006). Therefore, based on available literature, the quality of experiences of prospective teachers in science methods courses determines, to some extent, their development of knowledge and practices for teaching science within the framework of argument.

1.6 Professional Development School Site and Participants

Many scholars (Etheridge, 1989; Wanzare, 2007) argued that methods instruction "washes out" due to a socialization effect when teachers encounter the pressures of a "new school" assignment (e.g. peers). Given this constraint, as reported in the literature, the Professional Development School (PDS) in which the current study occurred minimized this challenge by assigning prospective teachers, for a full year, to a mentor or cooperative teacher who allows the prospective teacher to teach science as inquiry. The three participants in this study are particularly interesting because they participated in an established PDS program and exhibited knowledge of teaching and learning, beliefs, and enactments consistent with current science education reforms. PDSs appear to provide promising outcomes (Castle, Fox, & O'Hanlan, 2006; Darling-Hammond, 1994) for teacher education because of the potential coherence between post-secondary coursework and school-based experiences. This particular professional development school follows the Holmes Group model (1986) that "assumes three main foci: preservice teacher education, in-service professional development, and inquiry into teaching and learning." According to Fetters and Vellom (2001), by this approach both parties engage in active roles and promote communication of ideas and pedagogical discourse.

A known benefit of established PDSs is the connection and coherence in programs of study for prospective teachers. Darling-Hammond et al. (2005) suggested that program

coherence and cohesion help prospective teachers develop robust understandings of teaching and learning. One aspect, often incorporated in programs that demonstrate extreme coherence, is the development of learning communities. The learning communities according to Cochran and Lytle (1993, 2001) can positively change participants' beliefs and dispositions towards teaching. Therefore, studying prospective teachers in this context should yield useful insights in terms of understanding the ways in which prospective elementary teachers continue to develop knowledge and practices for teaching elementary school science as argument beyond their college-level, methods course experiences.

1.7 Research Questions

The current research, examines what happens to prospective elementary teachers during student teaching, which in this case is in the semester after completing their science methods course. The research questions that guide this work are:

1) What are the ways in which prospective elementary teachers appropriate components of "teaching science as argument" during their student teaching experience?
2) To what extent do components from prospective elementary teachers' reflections influence planning for science teaching?
3) What elements from the teacher education context influence prospective elementary teachers' attention to teaching science as argument?

The first question aims to understand the changes in knowledge that participants undergo after completing the science methods course while participating in the PDS. The expectation is that answering this question reveals that participants will display positive

developmental changes in their knowledge that are consistent with current reforms. Following new information regarding participants' knowledge, the current study aims to uncover the factors and the ways these factors influence those changes, if any, as demonstrated by the answers to Question 2 and Question 3.

1.8 Significance of the Study

The goal of the current research is to produce a substantive description of the changes in prospective teachers' knowledge regarding teaching science as argument. In addition, the study aims to identify the factors influencing those changes and demonstrate the interactions among the factors and changes. Reaching substantive descriptions are particularly important because it is known that by recognizing the unsatisfactory nature of the consequences of behavior, the probability of repeating that behavior decreases (Murray, 2003). Therefore, the current study's hypothesis asserts that specific factors from specialized science methods courses enable and promote participants' continuing to teach science as argument, despite the "wash out" effect heavily emphasized in available literature. Analysis to test the hypothesis will aid and support the notion that well considered teacher education programs such as PDSs integrate theory and practice in scenarios that can enhance prospective teachers' knowledge development (Trachtman, 2007). A second significance of the current study is that findings can inform science methods courses and guide areas that need further development or revision in order to help prospective teachers develop robust understandings of the framework. Since the current study took place in the context of a professional development school, evidence from findings can inform science methods instructors. Therefore, the research can continue to provide evidence to strengthen the school-university partnership, a crucial element in sustaining partnerships (Fetters et al., 2001). Third, the current inquiry can

inform the analytical framework and propose modifications to a coding scheme that subsequently guides future research. Finally, explanations provided in the current study will add to a larger research agenda that ultimately will enhance the available knowledge of what happens, post-methods courses.

1.9 Summary and Preview

Modern perspectives of the meaning of proficiency in K-8 school science are a top priority in today's core science education reform (NRC, 2007). However, these recommendations created ambitious expectations for elementary school science. This study builds on findings from an elementary science methods course that has a particular emphasis on teaching science as argument. This orientation makes explanation driven inquiry and students' construction of scientific claims from evidence the priority which is consistent with the accepted perspectives for K-8 science proficiency.

The subjects of this study are particularly interesting because they participated in an established elementary professional development school (PDS) program. PDSs have been identified as promising for teacher education because of the potential coherence between college coursework and school-based experiences. Therefore, studying these participants yields useful insights in terms of understanding the ways in which prospective teachers continue to develop knowledge and practices for teaching elementary school science as argument beyond their methods course experiences.

The next chapter provides key information that grounds the current study in available literature. In addition, it defines, explains, and links important constructs that provide the conceptual and theoretical foundations for examining proposed research questions. Chapter 3 provides a detailed description of the study's context and design methods, and introduces

each one of the participants. Then, Chapter 4 provides results for each of the participants. These results are later explicated in Chapter 5 by examining results across participants and drawing assertions. Finally, Chapter 6 concludes the study by stating the implications for practice, research, and policy.

CHAPTER 2: LITERATURE REVIEW

2.1 Overview

Historically, teacher education constitutes one of the most complex instructional research areas (Cochran-Smith, 2004; Cochran-Smith & Zeichner, 2005). This has led to inconsistencies that have evolved into multiple debates among advocates of teacher education programs, reformers, and researchers for all subjects, including science. Science education debates involve a variety of topics: the purposes of teaching science in schools, best teaching practices, and currently, the meaning of being scientifically proficient in K-8. For example, some scholars emphasized the aspect of understanding the nature of science (Abd-El-Khalick, 1998), helping children become scientifically literate (Roth & Barton, 2004), as well as the content component in itself (Posner, Strike, Hewson, & Gertzog, 1992). These emphases tend to be cyclical and often respond to the fluidity of educational reform interests. In addition, debates are due to the breadth of topics, as well as the multiplicity and complexity of points of view in teacher education. Thus, the complexity of teacher education has profound implications for teacher preparation programs (e.g. length, types of programs, and courses required).

Elementary science education is not immune to the complexity or impact of teacher education debates. Scholars claimed that science instruction in elementary schools is inadequate and that it neither provides the foundations for preparing children in basic areas of science nor prepares scientifically literate citizens (Raizen & Michelsohn, 1994; Roth et al., 2004). A scientifically literate citizen, according to the National Research Council (1996), means an individual with the ability to articulate the role of science within a community, and the "knowledge and understanding of scientific concepts and processes required for personal

decision making, participation in civic and cultural affairs, and economic productivity" (p. 22).

When reviewing claims purporting to explain why science teaching in elementary schools is inadequate, a critical issue is the definition of what science is. Science, simplistically, is phenomenon investigation with a systematic procedure to drive conclusions in light of evidence acquired (Hempel, 1965). Despite the fact that the process of doing and learning science is by nature inquisitive, science is often taught in schools as a static assembly of facts that require memorization. In fact, high levels of reasoning skills and argumentative discourses about science are not included or are likely to not be included (Duschl, 2000). Since the current, typical methodology of teaching science is inconsistent with the nature of science, many elementary schools are unsuccessful in meeting student outcomes in this area, especially in K-8.

Compounding the dilemma, the common way of teaching (science as a body of facts) is the method by which prospective teachers learn science, because most traditional elementary education programs, which are intensive due to time constraints, require prospective teachers to complete only six to nine credits of introductory level science courses (Kelly, 2000). These credits in science, unfortunately, are typically didactic and lecture-based, with emphasis on detailed facts rather than on understanding and application. Teachers often employ similar and familiar didactic lectures for teaching science when other appropriate alternatives are unknown, unfamiliar, or not provided (Borko, 1991; Bybee, 1991; Kleine, Brown, Harte, Hilson, Malone, & Moller, 2002; Lavoie et al., 2001). Obviously, the expectation must be that in-service teachers will continue to teach science as a body of facts unless effective interventions replace the conventional methods through

specialized content and/or methods courses. Even when appropriate interventions are offered, elementary teachers still struggle to teach science due to the lack of retained science knowledge, another short-fall of the limited time assigned to science-oriented course work in colleges of education (Jones et al., 2006). Since prospective elementary teachers' subject matter knowledge has limitations (McDermott, 1990; Raizen et al., 1994; Zembal-Saul et al., 2002), teachers should receive support from school districts, universities, and communities in order to provide children the foundation for acquiring the level of scientific literacy desired to satisfy the needs of society. Nonetheless, lack of science content is just one of the areas in which elementary teachers struggle in teaching science.

Given these challenges, science education reforms have become the center of attention of the National Academy of Science (NRC, 1996, 2000, 2007). So underwritten, these reforms promote the use of inquiry in classrooms, and most recently, address the issues of scientific discourse and argumentation. However, despite the attention to change and emphasis, many challenges remain from the burden reforms place on teachers. Thus, the purpose of this chapter is to outline some of the issues involving teaching science in elementary schools, the challenges elementary teachers face, the suggestions for addressing the challenges, the nature of the different pedagogical positions for inquiry-based education, and the concerns for supporting prospective teachers in their efforts to teach science as inquiry with an emphasis in argument.

2.2 School Science as Inquiry

Over the years, the uses for the word "inquiry" in educational contexts have proliferated. The National Science Education Standards (NRC, 1996) defines scientific inquiry as:

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

Therefore, "scientific inquiry" is, appropriately, how scientists work; however, "inquiry" in school science is "teaching science as inquiry". The latter term accurately describes a way to teach children so that the learning of science is consistent with its nature. Teaching science as inquiry is certainly not the only way to teach science. According to Treagust (2007), six instructional methods constitute the most widely used methods for teaching science. That is, "demonstrations, classroom explanations, questioning, forms of representations, group and cooperative learning, and deductive-inductive approaches as the learning cycle." (p.373). Treagust (2007) asserted that these methods of instruction rely on notions that students create their own knowledge but that the level of student metacogntion produced by these methods varies. Furthermore, he suggested that the degree to which teaching was student or teacher centered varied across methods of instruction.

The notions of what children are capable of doing when teachers teach science as inquiry has its basis in constructivist philosophy that declares that people construct their own knowledge such that everyday experiences shape beliefs and world views. The notion of using inquiry as a method of instruction in science, is a *modis operendi* in which teachers

guide children to ask questions, investigate, formulate explanations, share those explanations, and question their own and others' evidence.

The actual performance of teaching science as inquiry can vary: Instruction can be teacher directed (guided inquiry) or student directed (open inquiry) (NRC, 2000). Regardless of the variation in the degree of teacher guidance, inquiry has essential features integral to science lessons. For example, five common features are:

(1) Learner engages in scientifically oriented questions;
(2) Learner gives priority to evidence in responding to questions;
(3) Learner formulates explanations from evidence;
(4) Learner connects explanations to scientific knowledge;
(5) Learner communicates and justifies explanations (NRC, 2000, p. 29).

Engaging in scientific questions means that the questions the teacher asks are testable and are not questions for which answers can be retrieved by merely searching a book. On the other hand, students can also pose their own testable questions. Whether teachers engage in scientific practices by leading the inquiry or the students lead the inquiry, teachers must facilitate students by giving priority to evidence when building explanations (NRC 2000). These scientific explanations require connections to existing scientific knowledge. According to the NRC, a component of teaching science as inquiry is communicating results and means that teachers help students engage in peer review and share their conclusions based on evidence.

Variations of inquiry levels are based on the amount of teacher guidance required. These levels varied according to the learners' independence in the inquiry, thus evolving a translation of the teacher's role in teaching science as inquiry. Although these variations can be slightly easier for experienced teachers to adopt, prospective elementary teachers have extreme difficulty adopting these methods. Difficulties in adopting these methods are

extensive; one common problem is that prospective elementary teachers often relinquish classroom control and struggle when students acquire an active role in the decision making process of the curriculum (Hayes, 2002).

Several factors have been shown to inhibit teaching science as inquiry. According to Roehrig and Luft (2004), the "lack of administrative support, lack of pedagogical skills, lack of time, inadequate knowledge of the nature of science, and inappropriate curriculum materials" (p. 4). The most influential of these aspects is limited knowledge of the nature of science, according to Duschl (2000) and Lederman (1992). However, others such as Keys and Kennedy (1999) claimed that one of the main issues inhibiting teaching science as inquiry is the limited "guidance for the actual planning, teaching, and evaluation of inquiry in the science classroom" (p.315). The demands for planning and actual teaching guidance are especially evident in novice teachers and prospective teachers.

Other scholars have also investigated some of the constraints inhibiting the adoption of teaching science as inquiry in schools. In recent ethnographic work, van Zee et al. (2006) found that teachers struggle to help children ask appropriate questions that engender small group conversations and whole-class discussions. Since scientific discourse is critical in inquiry teaching, the van Zee (2006) study suggested that teachers often view these discourse challenges as chaotic classrooms and quickly become discouraged when pursuing the teaching of science as inquiry.

The Roehrig et al. (2004) study developed an inquiry-based environment to help secondary teachers in their first, second, or third years of teaching. In this study, Roehrig et al. (2004) tried to understand the constraints on teachers when teaching science as inquiry and discovered that teaching science as inquiry included emphasis on experimentation, but

ignored interpretation of data. By the latter, these researchers referred to questioning and reasoning required for analyzing data and constructing explanations from evidence. As this last deficiency implies, the Roehrig and Luft study is relevant, since it may provide some understanding of why teachers have difficulty eliciting science discourse.

Skamp and Mueller (2001) studied prospective elementary teachers in an Australian specialized-teacher preparation program for those with Bachelor of Arts degrees. These researchers found that prospective elementary teachers used "hands-on" loosely to describe science activities in which hands-on means "handling materials associated with science concepts…but not necessarily related to science process skills, inquiry, or experimentation" (p. 337). Interestingly, the interview process over the two years of the Skamp and Mueller study showed those prospective elementary teachers' individual conceptions of good science teaching expanded, from fun activities to thinking about content, teaching science as inquiry, integrating science, helping students develop scientific reasoning skills, and using scientific processes. Despite the struggles teachers face when teaching, Colburn and Tillotson (1998), noted that teachers can be encouraged to adopt good practices of science teaching with an emphasis in inquiry. The adoption of these practices, positively influenced by science methods courses, influences prospective elementary teachers' views of science teaching and learning. These researchers reported a teaching case study, in which prospective teachers assisted students' thinking about complex scientific situations and allowed students to reflect upon the views of the nature of science.

Finally, prospective elementary teachers often believe that children do not have the abilities to engage in authentic scientific inquiry (NRC, 2007; Roehrig et al., 2004); however, children can engage in inquiry when provided with the appropriate tools and guidance.

Engagement in inquiry can be reflected in students' construction of ideas, explanations, and development of abilities when doing science. Moreover, children are capable of questioning their surroundings and engaging in practices that lead to evidence-based explanations (NRC, 2000). These claims are further supported in the NRC's current report (2007) that states:

- Children entering school already have substantial knowledge of the natural world, much of which is implicit.
- What children are capable of at a particular age is the result of a complex interplay among maturation, experience, and instruction. What is developmentally appropriate is not a simple function of age or grade, but rather is largely contingent on their prior opportunities to learn (p.2).

Notions of children's capabilities have been contended for years. Scholars such as Bruner (1960) and Werner and Kaplan (1963) claimed that young children are unable to think abstractly and that they are unable to think logically and derive explanatory thinking skills. However, many scholars (Carey, 1985; Gelman & Baillargeon, 1983) have refuted these ideas and insisted that young children, indeed, are capable of engaging in abstract and explanatory thinking. According to Metz (1995) these ideas have been misinterpreted from Piaget's work and claimed that current evidence proves otherwise. Metz (1995) contended previous ideas of children's need to be engaged in hands-on activities because they are concrete thinkers. On the contrary, she argued that children are able to engage in deductive thinking early in their development.

2.3 Science Methods Courses

According to Shulman (1986) the generally accepted, necessary skills needed to become an elementary teacher are often reduced to merely having the aptitude to be around children and the disposition to share knowledge. Learning to teach has also been described as the result of "apprenticeship of observation." Lortie, coined this term in 1975 by stating that

prospective teachers' preconceived views and ideas are much more powerful than teacher education training. These views and ideas are formed by their experiences as learners over the years and are deeply rooted. Since this perception renders teaching to be an art rather than a learned and developed skill, the value of teacher preparation programs, specifically methods courses, have diminished importance even to the degree of trivialization. Unsurprisingly then, prospective teachers often enter science methods courses with biased views, values, beliefs, and representations of good teaching skills (Huinker & Madison, 1997) and how to teach science. Consequently, difficulties arise in helping prospective teachers view and do science in effective ways. The antidote, according to empirical data, is for science methods courses and specialized content courses to provide appropriate scaffolds (multilevel supports), to enable prospective teachers to move beyond cute, *activitymania* (Moscovici & Nelson, 1998) and to initiate thinking about teaching and learning science more meaningfully (Barreto-Espino, 2005; Haefner & Zembal-Saul, 2004; Huinker et al., 1997). Encouraging teachers to move beyond *activitymania* (Moscovivi et al, 1998) is possible, and Hayes (2002) determined that science methods courses in combination with field experiences can help prospective teachers overcome fears of classroom management, begin to interpret the multiple definitions of inquiry, and develop appropriate strategies and knowledge for asking valuable questions when engaging children in scientific investigations.

Unfortunately, some scholars view science methods courses as too little too late. Many scholars, however, have challenged this notion by claiming that methods courses indeed have an influence on prospective teachers' knowledge and beliefs of effective science teaching and that many theoretical and practical aspects should be considered when thinking about science methods courses. For example, Abell, Anderson and Chezem (2000) claimed

that well planned and executed science methods courses can, indeed, confront prospective teachers' prior knowledge and experiences and can help them conceptualize new explanations that are more consistent with the views of the NSES.

Reflection is another construct critical in methods courses and teacher education in general. Accordingly, it helps teachers problematize and improve science teaching practices. Kelly (2000), for example, supported this notion by asserting "prospective teachers can gain important understandings about learning and teaching by being encouraged to be both learner and teacher and to reflect on their experiences in both roles" (p.770). Abell andBryan (1997) claimed that prospective teachers' reflections on peers' teaching and their own teaching and learning causes beliefs towards teaching and learning science to become more consistent with the NSES, if framed that way by the instructor. In addition, Loughran et al. (2006) stated that reflection could help teachers visualize vital elements of science pedagogy and make explicit the nature of science teaching.

Another piece of evidence that demonstrates the effect of science methods courses is in an empirical study (Schwarz et al., 2006) that examined a specialized methods course that used an EIMA (Engage-Investigate-Model-Apply) teaching framework. The EIMA framework, used in the context of lesson planning, had results that demonstrated that most prospective teachers were able to connect planning practices with current science education reforms. In addition, results suggested that the use of the EIMA framework in the science methods course produced changes in prospective elementary teachers teaching orientations: from didactic and activity driven toward inquiry and guided inquiry.

2.4 Elementary Teachers as Generalists

Elementary teachers in the United States generally teach all subjects including reading, writing, math, social studies, and science. This circumstance results in inexpert levels for all of these areas; as generalists, they know a little of everything. Having generalist elementary teachers poses major problems, since, as claimed by Darling-Hammond et al. (2005), "students' achievement is significantly related to whether their teachers are fully prepared or certified in the field they teach" (p.25). Teaching certifications attest to qualifications as generalists and according to Jones et al. (2006), preparing elementary teachers as generalists jeopardizes the quality of science education.

One of the common challenges for prospective teachers when teaching science, as stated earlier, is that their learning from their kindergarten through twelfth grade (K-12) was inconsistent with the nature of science: neither as inquiry nor with an emphasis on argument. That is, the K-12 setting commonly relies on direct instruction methods or hands-on procedures that provide limited opportunities for children to collect evidence, make explanations based on the collected evidence, and question the kind of evidence and explanations they and others make. Since teachers' personal learning experiences do not include inquiry methods, redirection and reeducation is problematic and uncomfortable during college level science methods and/or content courses. During science methods courses discomfort increases when evidence is a requirement for supporting claims and when responses to instructors' questions require reliability and validity. The sense of discomfort is even more pronounced, because prospective teachers, fearing an impending lack of success, are often apathetic toward science. Prospective teachers also have difficulty adopting the inquiry method of instruction since they may erroneously equate hands-on to learning (Koch,

2006) and adopt the misconception that children engaged with manipulatives learn automatically. Thus, novices commonly adopt *activitymania* (Moscovici et al., 1998) as the norm, instead of inquiry.

Requiring teachers to teach with an emphasis on inquiry adds an additional challenge, typically due to limited knowledge of science in their professional careers. Grossman, Schoenfeld, and Lee (2005) asserted that "[e]ffective teachers need subject matter competence; they need to know how to solve the problems they pose to students and to know that there are multiple approaches to solving many problems" (p.205). Thus, if the elementary teacher only completes three science courses, usually lecture-based, their abilities to teach science as inquiry is in doubt due to limited content familiarity. Teaching as inquiry requires a rich and interconnected content knowledge in order to help children make scientific claims based on evidence. Grossman et al. (2005) stated that "[m]aking the right choices as a teacher depends on knowing what kinds of errors or mistakes students are likely to make, being able to identify such mistakes when they occur, and being prepared to address the sources of the students' errors in ways that will result in student learning" (p.205). Logically, then, limited scientific content background operates to the detriment of teaching science as inquiry.

Understanding how being an educational generalist poses problems when teaching science is crucial for understanding the conceptual perspective of the current study. The suggestion is that prospective elementary teachers need to know scientific content, appropriate pedagogy, and have the ability to combine these effectively to help children understand foundational science and how the world works. Unfortunately their generalist training inhibits such abilities. However, evidence from previous TESSA studies (Barreto,

2005; Zembal-Saul, 2005, 2009) demonstrates that generalists are capable of engaging in science oriented reform practices. Nonetheless, the most significant issues concern how to assist prospective teachers to emphasize inquiry and argument when their teacher education programs focus on preparing generalists, and how to resolve the many challenges prospective elementary teachers face in general. This generalist challenge is different from secondary teachers who specialize in a content area, and, as argued by Lotter, Harwood and Bonner (2007), secondary teachers' challenges focus on "teachers' conceptions of science, their students, [and] effective teaching practices" (p.1318).

2.5 Prospective Elementary Teachers Post Methods

Broadly, prospective teachers' inquiry practices decrease after completing methods courses and continue to decline during the first year of teaching (Brown & Melear, 2006). In a study of secondary science teachers, Brown et al. (2006), found that five of eight teachers' actions concentrated on teacher-centered environments. However, when compared to beliefs, only three of the eight matched. Brown et al. (2006) provided an inquiry-based science course (content course) to prospective teachers that allowed them the opportunity to use their own experiences as learners (within the course) and use their experiences in their own teaching. Following the course, participants enrolled in a science methods course that was aligned with the previous science course. Researchers found that as participants' years of experience increased (studied a maximum of three), teachers' behaviors were more teacher-centered and less student-centered. However, most teachers demonstrated behaviors that were inconsistent with their self-reported beliefs and inconsistent with the goals and teachings of the science content course and the science methods course they previously took.

Many studies since the 1990's have focused their attention on examining prospective teachers attrition during field experiences. These studies have attempted to examine the extent to which deliberate efforts by teacher educators emphasizing an aspect of science teaching translated into teaching practices. For example, Anderson, Smith, and Peasley (2000) found that after following three prospective teachers for a year these participants were able to accept notions of constructivism but were unable to enact these ideas in their classrooms. Similarly, Byran and Abell (1999) followed prospective teachers and found that participants, although aware of a self-conflict between their teaching views and practices, were unable to enact their beliefs. These two studies suggested that an incongruence exists between prospective teachers' beliefs and practices during field experiences.

Also reported in the literature (Meyer, Tabcknick, Hewson, Lemberger, & Park, 1999) is that even when prospective teachers retain views of science teaching adopted during the methods courses, they often are resistant to paying attention to students' ideas or using students' ideas in planning and teaching. Another insight gained from the Meyer et al. (1999) study is that even when prospective elementary teachers partially change their views on how to teach science, the enactment of lessons is likely to be consistent with previous views of science teaching. Following this study, Lemberger, Hewson, and Park (1999) examined three secondary prospective teachers. They found that even though participants' views changed positively as informed by a conceptual change framework, none of the prospective teachers were able to conceptualize how to enact their views or actually enact these views in their teaching.

Palmquist and Finley (1997) asserted that some prospective teachers revert to teaching in traditional ways, which may or may not match their own views of teaching

science. One possible connection to this problem might be available from the Anderson et al. (2000) study that noted that prospective teachers in their study struggled to understand how children learn and how to incorporate these ideas into science teaching. However, further conceptions of how children learn and the role children should have in learning also affected how the participants in the study attempted to enact science lessons. Anderson et al. (2000) asserted that even when prospective teachers either accept or start accepting teaching with a student-centered focus, they still have problems rejecting notions of the teacher as the primary source of knowledge. Prospective teachers' understandings of children's knowledge also affected teachers' content representations (Zembal-Saul et al. 2000). Thus, unsurprisingly, in a study by Bryan et al. (1999) participants demonstrated an emerging awareness that connecting thinking and practice is a difficult task.

2.6 Learning Theories

As stated by Bransford, Derry, Berliner and Hammerness (2005b), learning theories help connect science methods courses and science teaching, since teaching prospective teachers how children learn is not enough. Furthermore, basing methods courses and field experiences on a framework of teaching science as argument requires prospective teachers to understand and situate themselves in learning theories that promote communities of practice within elementary school classrooms and that engage children in discourses. Historically, three main directions within learning theories predominate: conceptual change, socio-cultural, and critical tradition as empowerment (Anderson, 2007). The current study adopts a socio-cultural and situated learning theory within the three main directions previously mentioned. According to Anderson (2007), socio-cultural learning theories rely on Vygotskiæi and his notion of learning by engaging with others. Within a socio-cultural

perspective situated learning fits with the current study. According to Lave and Wegner (1991) situated learning is:

> [A] transitory concept, a bridge, between a view according to which cognitive processes (and thus learning) are primary and a view according to which social practice is the primary, generative phenomenon, and learning is one of its characteristics (p.34).

Social interactions promote discourse, as described by Gee and Green (1998), where discourse creates communities of practices. These discourses produce the necessary arenas for critical reasoning to occur in order to promote effective practices in school science instruction. However, discourse can also inevitably produce "competing discourses" (Moje, Collazo, Carrillo & Marx, 2001). Competing discourses fit with teaching science as inquiry since they promote questioning of data's validity and the viability of claims.

According to Morine-Dershimer and Kent (2001), several components that help children develop thinking exist; three of them have critical importance to the current study: learning communities, classroom discourse, and communication patterns. The notion of learning communities, as argued by Morine-Dershimer et al. (2001), is grounded in the idea that learning occurs from the interchange or interaction with others and that it develops with experience. These notions of sociocultural practices guiding learning communities are key aspects of argumentation because they allow public discourse associated with the construction and assessment of arguments (Zembal-Saul, 2009).

An important aspect of situated learning is the notion of the need for an opportunity, for what Brown, Collins, and Duguid (1989) called, "higher order dialogue." Therefore, this process of "higher order dialogue" also promotes in learners a metacognitve process. Morine-Dershimer et al. (2001) developed the ideas of thinking within the context of pedagogical knowledge that teachers and prospective teachers need in order to aid children in science

learning. In fact, Kuhn (2005) demonstrated that prospective teachers have a difficult time mastering *higher order dialogue*. She argued, "We lack sufficient understanding of what it means to be an independent learner and thinker" (p.4). Due to this apparent lack of understanding Kuhn (2005) proposed helping children develop "skills of inquiry" and of "argument" as a way to help children prepare for the future in all aspects of life. Kuhn further asserted:

> To make conceptual progress that stands the best chance of improving education, we need to put aside standardized test scores, and the many studies of the variables that affect them, and look to life outside of and beyond school as a source of wisdom regarding what our children should learn (p.10).

In order to do so, Kuhn (2005) relied on the idea of thinking for improving school education by making a distinction between thinking and inquiry as activities in which people engage. Kuhn strongly believed that argumentation can enhance the act of discourse to improve education. Kuhn's (2005) ideas fit with the Moje et al. (2001) notion of competing discourses, and furthermore her ideas are grounded in situated learning. These components blend well with Gee et al. (1998) whose proposed communities of practice stemmed from discourse, which therefore, provided the perfect frame for the conceptual framework of Teaching Science as Argument (Zembal-Saul, 2005, 2009). However, an imperative highlight is that by using such framework some elements (e.g., constructing arguments in socioscientific contexts) are purposefully de-emphasized.

Furthermore, the current study, although informed by views of science as enculturation that place great emphasis on evaluating and understanding claims, is more focused on bringing together three main areas: participating in scientific practices, structure of

arguments as a discourse tool, public discourse that uses authentic scientific language (Zembal-Saul, 2009).

2.7 Reflection as a Metacognitive Tool

The importance of reflecting "in-action and on-action" (Schön, 1983) has become a critical aspect in teachers' development. Although reflective practices in the field of education have received much attention some disagreement remains about how to focus these reflective practices and the purposes on such activities (Danielowich, 2007). Reflective practices refer to the "thinking/analysis and self awareness" (Thompson & Thompson, 2008, p.19). One aspect that is less conflictive about reflection practices among scholars is the notion of achieving metacognitive levels of thinking as a result of engaging in reflections. Although these metacognitive practices can be directed towards specific constructs such as critical theory, learning, and teaching, an overarching thread suggests that metacognitive processes can indeed positively impact teacher education (Bransford, Darling-Hammond, & LePage, 2005a). According to Bransford et al. (2005b) developing metacognition requires teachers to be able to reflect upon their own learning. Bransford et al. (2005b) argued that teachers' engaging in reflective practices during their early careers helps them "take a first step in making their own assumptions about teaching and learning explicit" (p.85). Another benefit of engaging prospective teachers in reflective practices regarding their own learning is, according to Bransford et al. (2005b), that once prospective teachers "have had an opportunity to identify some of the key characteristics of good learning experiences in their own educational history, they are often more prepared to make sense of what they learn in their teacher preparation program about learning." (p.85) Hammerness, Darling-Hammond,

Bransford, Berliner, Cochran-Smith and McDonald (2005) also stated the need for engaging prospective teachers in reflective practices. Accordingly, they argued that reflective practices allow prospective and practicing teachers to develop a repertoire of classroom images that can potentially be associated with effective classroom practices. These images, can then positively impact the way teachers enact their practices.

The benefits of engaging teachers in reflective practices have been extensively studied (Grimett & Erickson, 1988; LaBoskey, 1993; Richert, 1992; Wildman, Niles, Magliaro, & McLaughlin, 1990). Engaging prospective teachers in reflective practices must be purposefully considered in order to develop competence. Likewise, using reflective practices is important in order to help prospective teachers "become increasingly aware of the complexities involved in teaching and learn how to think systematically about them so that they can better assess their own performances" (Hammerness et al., 2005, p.375).

2.8 Argumentation

Argumentation has a long history. However, it reached its most public moments with the work of Toulmin (1958). He engaged in argumentation studies from the point of view of written rhetoric, and developed a set of parameters for diagnosing an argument as an appropriate way to describe and make claims about a specific event. Figure 2.1 shows Toulmin's structure.

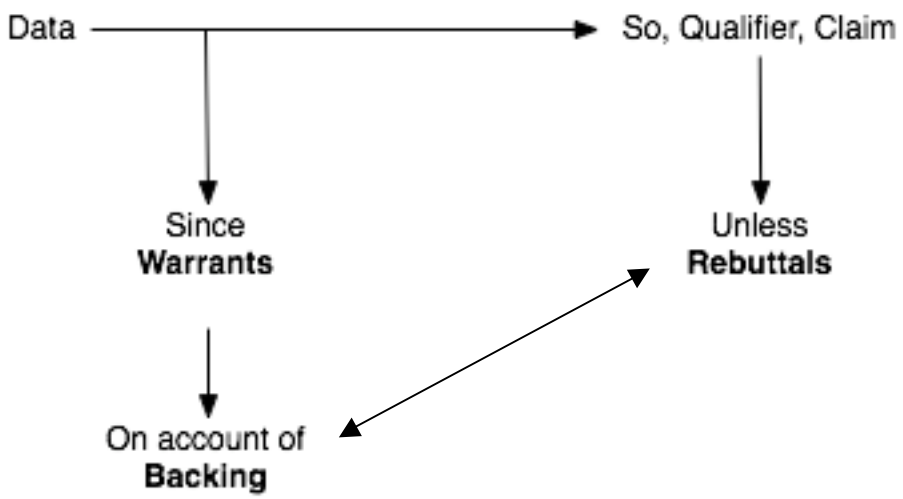

Figure 2.1 Argument structure (merged from Toulmin's diagrams, 1958, p.103-104)

The structure of an argument stems from data that leads to a claim. These data allow for an argument to be warranted with more data that also leads into rebuttals. From an educational point of view, Toulmin's pattern of argumentation provided the necessary tools to help students create better arguments. The original Toulmin concept has been transformed into a more popular and condensed structure that follows the pattern: data-claim-justification-rebuttal. From the literature, two main areas in science education have previously engaged in argumentation practices: (1) structural patterns of arguments in written artifacts, and (2) philosophical studies leading toward argumentation as a way to understand the nature of science.

Currently, the majority of work in science education treats argumentation as a persuasive process, embedded in socio-scientific aspects of important science concepts. For example, cognitive scientists have investigated classroom discourse and norms that help students argue socio-scientific issues (Duschl, 2003; Kuhn & Reiser, 2006; Zimmerman, 2000). However, these studies have their foundation in examining argument patterns rather than the inquisitive process of constructing, analyzing, and reporting scientific data that

emphasizes the quality and accuracy of the evidence. In addition, these works do not emphasize the teacher's role and abilities to do inquiry as fundamental to engaging in elementary school argumentation practices. According to Sampson and Clark (2006), previous studies "have provided little information about how well students engage in argument construction in terms of content quality or normativity" (p.656). Another critique by Sampson et al. (2006) is the notion that previous studies have centered on "field-invariant features of an argument" (p.656) instead of those processes or characteristics that resemble scientific communities. In their article, Sampson et al. (2006) analyzed the current argumentation frameworks: Toulmin's, Zohar and Nemet's, Kelly and Takao's and Sandoval and Lawson's. Sampson et al. (2006) critiqued all of these frameworks for various reasons, but in general, they concluded that an argumentation framework must meet five criteria:

> Criteria 1: Examine the nature and quality of the knowledge claim.
> Criteria 2: Examine how (or if) the claim is justified.
> Criteria 3: Examine if a claim accounts for all available evidence.
> Criteria 4: Examine how (or if) the argument attempts to discount alternatives.
> Criteria 5: Examine how epistemological references are used to coordinate claims and evidence (p.659-660).

Despite assumptions of Sampson et al. (2006) being grounded in epistemological beliefs, the nature and philosophy of science, and knowledge acquisition, they did not consider the teacher's role. Using the aforementioned frameworks, and focusing on Toulmin's argumentation framework, leads science education into considering teaching science as argumentation. That is, placing the emphasis on students' abilities to create well-structured scientific claims. However, as interpreted from current reform in science education, argumentation should also be interpreted within domains of syntactic subject

matter knowledge and pedagogy (Zembal-Saul, 2009); therefore, the current study employs an emphasis on teaching science as argument.

2.9 Teaching Science as Argument

Argumentation provides a robust framework for thinking about science teaching. Currently, many scholars (Haefner et al., 2004; Jimenez-Alexaindre & Pereiro-Muñoz, 2002; NRC, 2007; Sadler & Donnely, 2006; Siegel, 1995; Yerrick, 2000; Zeidler, Osborne et al., 2006; Zembal-Saul, Munford, Crawford, Friedrichsen & Land, 2002) have shifted attention of school science toward an approach that emphasizes argumentation practices within the current reforms of teaching science as inquiry. One of the first scholars to introduce argumentation and discourse practices into school science is Kuhn (1992) with the introduction of the term, *science as argument,* to explain an avenue for helping science educators guide children to achieve "scientific thinking." The shift she proposed was toward dialogic arguments and the kinds of factors that create a dialogic argument: "alternative theories, counterarguments, and rebuttals" (Kuhn, 1992, p.323). Interestingly, Kuhn (1992) linked argumentation with scientific thinking by questioning the kinds of evidence available for dialogic argumentation, during which, she claimed, one must examine the evidence, think about others' rebuttals, and engage in scientific thinking if one is to counter-argue the potential rebuttal. Kuhn's (1992) study is critically significant in the shift of teaching science as argumentation towards teaching science as argument, since the shift is from an emphasis on the analysis of arguments toward emphasis on the process of doing and thinking about science. The assumptions in Kuhn's (1992) work are vital for the current study since they

established the foundations for engaging in dialogic argumentation while actively doing science.

Duschl (2000) also aligned with Kuhn's (1992) work, suggesting the best ways to teach the nature of science is through the use of argumentative practices. In his work, Duschl (2000) stated that when students see data, compare, contrast, and argue about the data, meaningful learning occurs and the nature of science becomes explicit. Duschl (2000) stated, a critical issue, "[v]ery little time, if any, is typically given over to examining and discussing the nature of the problem being investigated, to developing higher level reasoning skills, to engaging in the argumentative discourse of science, or to exploring the assumptions and beliefs held by the investigators" (p.187) in elementary schools.

Despite the limited engagement in argumentation practices in elementary and secondary schools, significant studies have adopted the idea of using argumentation (Driver, Asoko, Leach, Mortimer and Scott, 1994; Erduran et al., 2004). Sandoval et al. (1997) work, for example, focused on helping students build scientific explanations with the help of software (BGuILE) enabling students to develop and evaluate the validity of evidence and explanations that account for patterns in data. They believed that inquiry must be emphasized from the aspect of evidence-based explanations. By engaging in this process, students can develop understandings of scientific concepts, such as evolution, and the nature of science. This is critical; in order to make evidence-based explanations, inquiry has to be viewed "as a cognitive apprenticeship" (Sandoval et al., 2004, p.347). That is, "…focus on engaging students in the reasoning and discursive practices of scientists, and not necessarily the exact activities of professional scientists…viewing such reasoning practices as a form of apprenticeship emphasizes the epistemic aspects of scientific practice" (p.347). This

apprenticeship, however, as stated by Sandoval et al. (2004), requires argumentative and investigative skills as these allow knowledge pursuit.

Scientific practices that promote argumentation in elementary science classrooms challenge classic definitions for classroom norms. Norms are classroom rules that characterize behavior expectations during science investigations. For example, a common norm in elementary classroom is that a child does not argue or contest others' ideas unless the teacher gives permission. However, this classic view of classroom norms has to be replaced with norms of encouragement to rebut others' ideas and the process of questioning evidence (Sandoval's et al., 2004).

The notion of classroom norms in relation to classroom argumentation has been recently studied, as exemplified by Kuhn et al. (2006), who claimed, "[E]ngaging in scientific argumentation requires transforming traditional classroom norms" (p.1). Kuhn et al. (2006) relied on Kuhn's (1992) notions for creating urgency as an avenue for helping children learn how to argue scientific concepts by adjusting classroom norms. This transformation of classroom norms is consistent with other researchers who viewed argumentation practices as social tasks (Sandoval et al., 2004; Duschl, 2003). Although classroom norms and social practices are important and part of the process of developing argumentation practices, they are not a unique aspect for success. Another aspect for developing argumentation practices is emphasis on the scientific content of an argument. Additionally, the process by which an argument is created, that is, the discourse that revolves around creating the scientific argument, is a crucial element in developing an emphasis on teaching science as argument.

Osborne, Erduran and Simon (2004) discussed the difficulty of engaging in dialogic practices. They claimed that dialogic practices, embedded in the classroom norms, aid or hinder the development of argumentation practices in schools. Creating argumentation discourse demands appropriate content knowledge, in order for teachers to engage students in such practices. Simon, Erduran, and Osborne (2002) made the case that, "argument is a form of discourse that needs to be appropriated by children and explicitly taught through suitable instruction, task structuring, and modeling" (p.3).

Studies demonstrated that when teachers adapt classroom norms within their pedagogical strategies, argumentation practices are possible (Driver, Newton, & Osborne, 2000; Simon, Osborne & Erduran, 2003). Simon et al. (2003) reported that teachers, provided with pedagogical strategies to support argumentation practices in schools, can make them somewhat successful in implementing classroom norms conducive to argumentation practices. In their two-year study, Simon et al. followed the activities of twelve teachers who implemented the same activity for the two years, thus providing researchers the opportunity to analyze how teachers' pedagogical abilities developed over a period of time. The researchers, using Toulmin's theoretical framework, analyzed students' arguments for or against government funding for a new zoo. Results demonstrated that argumentation took place over two years without any significant differences in how it was taught. In a later study, Osborne et al. (2004) identified several factors that direct teachers to teach science with an emphasis on argumentation and claimed that providing students with opportunities to work in groups, to scaffold their thoughts while constructing arguments, and to provide examples of what constitutes a good argument are ways to improve science in schools.

These previous notions of engaging in argumentation lead to the question of what counts as an argument, especially in elementary school contexts, since students abilities are not as complex as those of middle school or secondary school students. Newton, Driver, and Osborne (1999) previously defined an argument as "the intentional explication of the reasoning of a solution during its development or after it" (p.554). Accordingly, they believed that an argument is *monological* or *dialogical*. By monological they referred to "a single line of thought," and dialogical means "a number of contrasting lines developed" (p.554). The importance of these definitions lies in the fact that, according to them and other scholars (Duschl, 2000), and in agreement with this current research, science relies on the exercise of constant evaluations of explanations of evidence. In addition, the definition of an argument complements how Osborne et al. (2004) defined argumentation. Thus, an appropriate claim is that what is important in elementary schools is this monological and dialogical argument instead of the accuracy of the argument in comparison to Toulmin's framework.

All these previously mentioned studies have attempted to improve science education in their respective ways; however, the limitation is their emphasis in socio-scientific events rather than on scientific content foundations. For example, Driver, Newton, and Osborne (2000) claimed that engaging students in socio-scientific issues provides science education with the vehicle to portray and teach science as the process of the "*what, how,"* and *"why"* questions for specific phenomenon of surroundings. However, emphasizing socio-scientific issues may more easily allow bypassing the learning of "big ideas" in science. Thus, notions of teaching science as argument attempt to ground argument practices in scientific content instead of socio-scientific issues, which are also relevant.

2.10 Supporting Elementary Teachers in Science Teaching

As mentioned earlier, argumentation practices are rare in schools. Thus, supporting elementary teachers is essential for achieving implementation success for current reforms that push for scientific proficiency. Zembal-Saul et al. (2000) recommended several ways to support prospective teachers in order to address the challenges they face. First, Zembal-Saul et al. (2000) suggested support for prospective teachers by providing science content courses created for them specifically. They argued that prospective teachers with stronger content knowledge "have better understanding of the discipline and how it is organized and are better able to represent it to learners in a meaningful way" (p.230). Second, science methods courses need to include explicit scientific content and the diverse "issues of representing content" (p.230). In addition, Zembal-Saul et al. (2000) asserted that methods courses need to "use planning as a vehicle for supporting prospective teachers' thinking about representing and developing content over time" (p.230). Their rationale is that "[p]lanning can provide opportunities for prospective teachers to attempt to integrate issues of content and learners with issues of managing resources and time" (p.230). Fourth, Zembal-Saul et al. (2000) shifted the attention to field experiences, arguing "[I]t is apparent that practicum experiences alone are insufficient for improving content representation. Experience needs to be coupled with substantive reflection to have an impact on practice" (p.230). These researchers applied these recommendations in the context of reflective practices by emphasizing, "that opportunities to engage in meaningful reflection on practice can play an important role in learning to teach" (p.230), but these reflective practices must be scaffolded in order to make them meaningful and useful in developing knowledge and practical growth.

One way to apply the recommendations of Zembal-Saul et al. (2000) is to engage prospective teachers in science lessons that allow them the opportunity to experience science

in ways consistent with current reforms. Empirical data by Peck and Tucker (1973) demonstrated that certain prospective teachers' behaviors can be modified when they have been exposed to appropriate and effective modeling of teaching behaviors. Van Zee (2006) confirmed Peck and Tucker's claim by arguing that methods courses should model inquiry by teaching science content and pedagogy. Finally, Morine-Dershimer et al. (2001) also supported modeling; they wrote, "[p]rospective teachers must practice…actual lessons that they plan, implement, and evaluate" (p.44). They further noted that planning, implementing, and evaluating would benefit from video taped examples since "it can be particularly helpful for students to be confronted with instructional events that are difficult to observe in normal circumstances" (p.45).

Learning theories also help ground notions of how to support prospective elementary teachers. According to Bransford et al. (2005b) "prospective teachers need to experience what it is like in environments that are consistent with learning principles" (p. 76). They argued that prospective teachers need opportunities to develop fundamental understandings of learning theories and how to use them with students. However, the authors also emphasized the fact that many pedagogies aid in preparing prospective teachers. Among one of the examples they provided is the use of reflection tools. They claimed that when reflection is used to guide prospective teachers to analyze their own teaching and learning in light of specific frameworks, teachers are able to better develop pedagogical understandings.

2.11 Summary and Preview

This chapter presented an overview of the literature in order to describe the main constructs that underline the current study. These constructs: teaching science in elementary schools, the challenges elementary teachers face, the suggestions for addressing the

challenges, the nature of the different pedagogical positions for inquiry-based education, and the concerns for supporting prospective teachers in their efforts to teach science as inquiry with an emphasis in argument provide the link between situated learning theory and the rationale for engaging the current research questions. The following chapter details the methods of inquiry used to investigate these research question. Consequently, Chapter 3 provides a detailed description of the participants, context of the study, data collection methods, and the analysis framework that guided the analysis procedures. The analysis framework builds from the information presented in the current chapter.

CHAPTER 3: METHODS OF INQUIRY

3.1 Overview

Understanding the methodological approach used in a piece of research is critical in assuring transparency for what was done, how it was done, and what remains to be done (Maxwell, 2005). Research transparency is especially important when dealing with qualitative research because critiques arise from perceived subjectivity and the possibility of providing conclusions without appropriate, supporting qualitative evidence (NRC, 2002). This chapter addresses these issues by describing the qualitative methods used to characterize prospective teachers' knowledge of teaching science as argument. Descriptions of the method aim to provide transparency, specifically: Why case study methodologies and grounded-theory tools are most appropriate for the specific research questions, and how the analytical tools apply to the current inquiry. In addition, the chapter describes the conceptual framework guiding analysis, contexts, data sources, and participant selection. Finally, the process for developing rich descriptions is described. The current study addresses the following research questions:

1. What are the ways in which preservice elementary teachers appropriate components of "teaching science as argument" during their student teaching experience?
2. To what extent do components from preservice elementary teachers' reflections on their experience influence planning for science teaching?
3. What elements from the teacher education context influence preservice elementary teachers' attention to teaching science as argument?

3.2 Philosophical and Historical Perspectives of Qualitative Research

Qualitative research has characteristics of being "flexible, evolving, [and] emergent" and creates products of a "…comprehensive, holistic, expansive, [and] richly descriptive" (Merriam, 1998, p.9) nature. Furthermore, qualitative research possesses an open nature that reveals the interpretations people give to their own personal and others' experiences in life (Denzin and Lincoln, 2005). The process of investigating and learning about people's interpretations of events emphasizes an inductive and descriptive product which allows researchers to become the primary instrument of data collection (Merriam, 1998). These characteristics of qualitative research are aligned with the goals of the research questions in this study. Furthermore, the research questions are descriptive rather than a causal agenda. Thus, choosing a qualitative approached was more appropriate than choosing a quantitative approach.

Qualitative research has been part of an emerging historical process of knowledge-searching that resulted from philosophical periods of thinking and representations of science-based research in education (NRC, 2002). Denzin et al. (2005) described the history of qualitative research by separating events into "eight moments." (p.14). These moments are: 1) traditional periods, 2) modernism, 3) moment of blurred genres, 4) crisis of representation, 5) postmodernism, 6) post-experimental inquiry, 7) methodological contested present, and 8) the future (Denzin et al., 2005, p.14). These moments provide a general view that qualitative research has its beginnings in positivist paradigms that aimed to investigate social phenomena objectively and with the same rigor and systematization as applied to "hard sciences." From this notion of objectivity developed a new inclination towards social realism and naturalism that later evolved into a *moment* characterized by a "pluralistic, interpretive, open-ended perspective" (Denzin et al., 2005. p.17). Then, these inclinations led to an era of

questioning methods and truth, and as a result, they evolved into new perspectives, such as critical theory and feminism, during the 1980s. During more recent years, postmodernism and post-experimental perspectives were predominant, and linked social science and humanities.

All eight of these moments possess a rich historical background arising from the philosophical and historical milieu in the nation. However, Denzin's description articulates that qualitative research has developed over a 100 years of conflict, tension, and discussion, and has a legacy that allows researchers in the present to rely on the inductiveness of rigorous investigation in social science research.

Philosophically, qualitative research was originally grounded in positivism as conceptualized by Auguste Comte in 1798-1857. He believed that "knowledge should be based on what is 'positively' and directly observed rather than on unobserved entities, forces, or causes thought to lie behind things" (Bredo, 2006, p.7). Positivist philosophy led some philosophers to apply more metaphysics to aspects of explanations which led to logical positivism. However, the debate continued and in the 1950s Popper and Quine, to mention two, heavily criticized positivism and logical positivism, and presented a list of arguments that provided a new philosophical perspective that is currently called postpositivism.

Postpositivism, as viewed today, focuses on the notion of theory-laden facts. As described by Phillips and Burbulus (2000), postpostivitic views "are united in believing that human knowledge is not based on unchallengeable, rock-solid foundations--it is *conjectural"* (p.26). These descriptions of postpositivism are important because the current study is grounded in a postpositivist philosophical point of view. The current study does, however, rely on the six scientific principles stated by the NRC (2002): 1) Research questions can be

investigated empirically; 2) research is linked to pertinent theory; 3) research method is directly linked to the questions; 4) reasoning leads to a chain of explanations, conclusions, predictions, inferences, and/or theories that are reliable, and 5) research is open to critique and scrutiny (p. 3-5).

3.3 Research Design: An Interpretive Case Study

According to Merriam (1988), case studies have been used in different fields for a significantly period of time. However, not until the 1960s and 1970s did case studies begin to gain some popularity as a method for in-depth investigation of educational problems. The use of case studies in educational research has been controversial. Creswell (1998, 2003) argues that case study is an inquiry component of qualitative research. By inquiry, Creswell means the different strategies by which a person comes to derive meaning from phenomena. Stake (1995), on the other hand, refers to case study as a research method where the qualifier and prefix are either a qualitative or quantitative. Others, like Denzin and Lincoln (2003), have referred to case study as strategies of inquiry, while Merriam has referred to case study as a method that falls under the scope of qualitative research traditions. However, for the purposes of this chapter, the controversy is acknowledged and case study is accepted as a method of research.

The current study was defined within the parameters of a case study as defined by Merriam and is a single case study with multiple participants. The inquiry focuses on student teachers' appropriation of teaching science as argument framework, reflections, and contextual influence as a collective instead of as an individual phenomenon. In other words, the case is *prospective elementary teachers learning to teach science as argument* bounded in the Elementary Professional Development School (PDS) within the limits of a field

experience after completing a college-level science teaching methods course (SCIED 458) and including three participants. Thus, the case study "is both a process of inquiry about the case and the product of that inquiry" (Stake, 2005, p. 444).

Case study was the best methodological approach for the research questions because the end result is a "*thick* description for the phenomena in study" (Merriam, 1998, p.11). Using the thick descriptions that result from the multi-participant case study, generalizations of the phenomena in study were possible. These generalizations, even though specific to the case, also provide an understanding of a more general problem (Merriam, 1988, p.13), which is understanding how prospective elementary teachers learn to teach science in ways consistent with current science education reforms and the nature of the *wash out* effect mentioned in the literature.

According to Olson, as cited in Merriam (1998), the descriptive nature of case studies allows showcasing the complexity of the phenomena. Case studies also provide flexibility in offering the opportunity to gather information from multiple data sources thus, making inferences and conclusions more likely applicable to other cases, while remaining open. From a philosophical point of view, choosing a qualitative research tradition, specifically a case study, is consistent with case study's historical use, which is "to understand how all the parts work together to form a whole" (Merriam, 1988, p. 16).

Another reason for selecting case study was the notion of purposeful sampling. Choosing a small non-random sample leads to a product that is comprehensive and holistic. This aspect of case studies was critical for the current study due to the importance of handpicking the participants for the study since these participants needed to demonstrate attention to the framework.

Another factor that influenced the selection of case study was the fact that case studies allow "spread[ing] the net for evidence widely" (Merriam, 1988, p.29). That is, it allowed for the consideration of more types of evidence within the context of the research questions. Finally, since the study dealt with people, who add an acknowledged complexity, choosing this method was pertinent because the researcher became the primary instrument of data collection, as opposed to standardized tests, which leave the complexity of the case obscured (Keeves, 1997; Merriam, 1988).

Up to this point, the parameters of the research have been qualitative, specifically within a case study approach. However, a formal definition of what a case study is has yet to be provided. Defining a case study requires a description and discussion of its characteristics. Case studies are inductive and operate within the variables of the phenomena without manipulating them to make meaning of the data. Thus, as Merriam (1988) stated, case studies concern themselves with the "how" and "why" questions without controlling or manipulating any desired factor. In order for an inquiry to be categorized as case study research, the inquiry must exhibit some other characteristics. First, a case study is a "bounded system" (Smith, 1978 as cited in Merriam 1988, p.9), "that is, a case study is an examination of a specific phenomenon such as a program, an event, a person, a process, an institution, or a social group. The bounded system, or case, might be selected because it is an instance of some concern, issue, or hypothesis" (Merriam, 1988, p.9-10).

As mentioned earlier, one advantage of a case study approach is to allow the researcher to be the instrument of data collection; however, this can be a disadvantage as well since it allows all the researcher's biases to play roles in the data collection. As a consequence of the researcher being the primary instrument of data collection, issues of

reliability, validity, and generalizability always arise. Therefore, future sections address the handling of these issues.

3.4 Analytic Tools: Grounded Theory

In addition to using case study as the method of inquiry, the current study relies on grounded theory analysis tools to arrive at substantive theory. Grounded-theory, as defined by Charmaz (2005), is "a set of flexible analytic guidelines that enable researchers to focus their data collection and to build inductive middle-range theories through successive levels of data analysis and conceptual development" (p. 507).

Grounded theory was developed by Glaser and Strauss (1967) from the need to interpret data so that relevant theory could emerge from the data collected without loosing the complexity of social phenomena. Through this process Glaser and Strauss were aiming to "build rather than test theory" and to "identify, develop, and relate the concepts that are the building blocks of theory" (Strauss and Corbin, 1990, p.13) without using mathematical methods of interpretation. When referring to theory building in grounded theory, the implication is "work that entails not only conceiving or intuiting ideas (concepts) but also formulating them into a logical, systematic, and explanatory scheme" (Strauss et al., 1990, p.21). Furthermore, building theory refers to "theories about phenomena, rather than just generating a set of findings" (Strauss et al., 1990, p.22). Theories developed through the grounded theory framework can be substantive; the former are those specific to a place or group and the latter are those that apply to a wide problem.

Substantive theory evolving from grounded theory allows an explanation or prediction about a phenomenon (Strauss & Corbin, 1998) and evolves from careful examination of data, including comparison and creation of relationships at the conceptual

framework level. As a result of the theoretical nature of the product, such analysis is an in-depth process of inductively allowing the researcher to organize data into categories, themes, and eventually theory. The inductive process collects insights into emerging inquiry of the phenomenon without compromising the "level of abstraction and conceptualization in interpretive case studies" (Merriam, 1988, p.28). Further, grounded-theory tools rely on the interpretation of the whole stance and aggregations of an excerpt instead of an instance. As a result, in grounded-theory, the goal is to achieve themes by engaging in axial coding and constant comparative analysis (Glaser et al., 1967).

Analysis in grounded theory takes the form of microanalysis which involves using several tools to produce theory. Glaser et al. (1967) used these tools to demonstrate relationships among categories that emerged from "line-to-line" analysis. During this phase, analysis goes beyond the surface, and concepts emerge. These concepts respond to the characteristics inherent in data by explaining what is occurring. Once concepts are found, categories emerge by grouping of those concepts. Subsequently, patterns of categories can be formed "when groups of properties align themselves along various dimensions" (Glaser et al., 1967, p.117). Within all the things previously mentioned, open and axial coding occurs; the former is the first step in uncovering concepts and their properties. The latter, on the other hand, provides the nature of relationships and permits the emergence of categories and subcategories.

The development of categories driven from codes is a complex agenda. Dey (2007) argued, "Categories and categorization depend on our conceptual understandings of the world, rather than on similarity between characteristics" (p.170). This notion of world-view effects is certainly an aspect of engaging in social-science research; however, categories

cannot be completely based on world-view or similarities; a balance must exist in the coding of categories. When categories' development is achieved through balance, they (categories), as stated by Dey (2007), "allow us to conceptualize the key analytic features of phenomena, but also to communicate a meaningful picture of those phenomena in everyday terms" (p.168).

One key aspect for selecting grounded-theory as the analytic tool for this inquiry is that it is not bounded by static preconceptions. As a matter of fact, in the context of grounded-theory analysis, a priori frameworks and hypotheses are constantly modified through analysis of the data itself. Thus, in the current study the preconception of the "wash out" effect is rejected. By turning away from this preconception, making a systematic theory about the factors influencing prospective elementary teachers' knowledge and practices for science teaching becomes possible.

In general, grounded-theory is an "iterative process of moving back and forth between empirical data and emerging analysis [that] makes the collected data progressively more focused and the analysis successively more theoretical" (Bryant & Charmaz, 2007, p.1). In addition, grounded theory generates rather than verifies and "offers a foundation for rendering the processes and procedures of qualitative investigation visible, comprehensible, and replicable" (Bryant et al., 2007, p.33).

3. 5 Conceptual Framework Guiding Analytic Tools

The analytic tools guiding the analysis are utilized within a conceptual framework of Teaching Science as Argument (Figure 3.1). This conceptual framework was developed by Zembal-Saul (2005, 2009) and emphasizes scientific content with practices beyond inquiry while providing clear emphases on discourse, explanation, and reasoning.

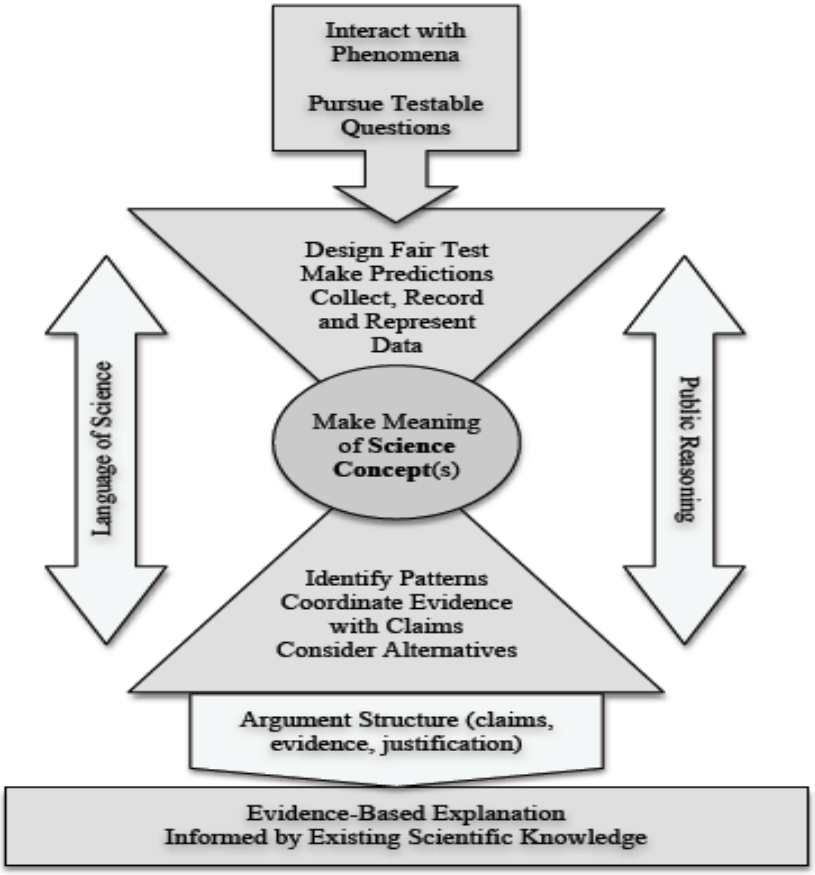

Figure 3.1: Framework diagram (Zembal-Saul, 2009, p. 692)

The framework emphasizes that, by teaching science as argument, children engage in public reasoning about evidence and construct explanations based on available evidence. In fact, the framework for argument, as a complex multi-level process, highlights students' engaging in scientific practices consistent with the nature of science, and yet, learning meaningful scientific concepts. According to Zembal-Saul (2009) the framework informs the users of scientific practices while making explicit other areas. These areas are:

- using an argument structure to guide class discussion, 2) reasoning publicly about the development of claims from evidence and the evaluation of claims on the basis of evidence, and 3) engaging authentically with the language of science. (p.693)

Thus, as stated by Zembal-Saul (2009), the framework "brings together the essential elements of scientific inquiry, in particular giving priority to evidence and explanation and communicating scientifically, with perspectives on argumentation" (p.12).

Since engaging students in such complex scientific practices cannot occur in the exclusive plane of socio-scientific issues, nor with unprepared elementary teachers, the teacher's role becomes critical and more demanding when teaching science as argument. Therefore, within these components the teacher is the vehicle to provide children with meaningful opportunities to engage in authentic discourse, scientific reasoning, and creation of explanations within the context of argumentation.

Based on available literature, the imperative is to explain each one of the components of argumentation and to lay the groundwork for how the framework informs the analytic tools. Varelas, Pappas, Kane, Arsenault, Hankes and Cowan (2007) argued that children in early grades can indeed engage in dialogic reasoning and that current research does not support the notion that children's understanding should be focused exclusively on observing and describing a phenomenon. At the same time, Varelas and her colleagues stated that children can do "explanatory reasoning" when teachers provide nurturing practices that align with development of argumentation. They further argued that language plays a key role in children's argumentation and needs to be seen as a combination of everyday language with scientific language acquired in the classroom that ultimately provides the socio-cultural space for such things to develop. This aspect of reasoning within the conceptual framework guided the analytic process of the development of codes that focus on teachers' self-reported views and practices conducive to teaching science as argument.

To examine argument in science talk it is critical to consider the notion of explanations. The term explanations, studied for years across many fields, including philosophy, arises from philosophers such as Hempel (1965) who defined it as a set of statements asserting the occurrence of certain events and as a set of universal hypotheses that ultimately lead to scientific laws (p.165). However, for the purposes of this study, an explanation was not a description but a series of evidence and justified claims that, when taken together, explain a phenomena and predict future events. Further, an explanation is a monological argument that results from the argumentation practices where scientific reasoning occurs (Kuhn, 1992). The definitions of argument and explanations provided guidance about how to interpret participants' responses when talking about explanations.

Another important aspect of explanations in the current framework is that they must have their bases in evidence. However, not all evidence is valid. In other words, to create accurate explanations, engaging in scientific reasoning of, "*What counts as evidence?"* is necessary. The notion of the "what counts" concerns data validity and accuracy within a scientific context. Consequently, student teacher participants' responses undergo bifurcated analyses: the explanation and the evidence itself and also participants self-report about how they support these practices in their classrooms. These analyses aim to help elucidate how participants appropriated components of the teaching science as argument framework.

In order to combine the components of explanation, reasoning, and scientific talk, a complex set of actions for engaging in discourse is necessary. These activities include presenting data, dialogue that questions data and explanations and creates the knowledge that arises from the discourse process. This scientific talk process is intertwined with what Wickman and Östman (2002) described as "situational and sociocultural circumstances…of

learning and meaning making" (p.602). Ogborne, Kress, Martins, and McGillicuddy (1996) described a component of constructing verbal explanations as engaging in conflictive discourse which is communication patterns at smaller and greater levels where teachers and students argue (without a negative connotation) and "think aloud" (Ogborne et al., 1996) until progress in ideas and explanations become formulated. Finally, these previous components are embedded in teachers' knowledge-based decisions as demonstrated by the kinds of scientific practices provided in classrooms.

3.6 Researcher's Role and World-View

In qualitative research, stating the role of the researcher and delineating qualifications and biases towards the data provides transparency for the process of formulating conclusions and substantive theory. Transparency in the process links to the role of the research since the current study aims to move beyond *speculative theories* (Glaser et al. 1967) and theorize empirically using the conceptual framework. As a result, the researcher's background, sensitivity, ontology, and epistemology become crucial to rendering visibility to the study.

3.6.1 Researcher's Background

The researcher has been collaborating with the TESSA project since 2003. As part of the team, the researcher's responsibilities have ranged from assisting with preparation of research materials to collecting and analyzing data. In addition, the researcher has been involved with the PDS through TESSA, consequently, developing an understanding of the science methods course dynamics and school district's culture. The PDS involvement also included a previous study in 2003-2005 in which the researcher conducted her Master thesis study, which provided an opportunity to gain understanding of the needs, challenges, and

strengths of working with prospective elementary teachers in the PDS context. Finally, the researcher taught a similar science methods course in an on-campus venue using the teaching science as argument conceptual framework.

3.6.2 Researcher's Sensitivity

Strauss et al. (1998) defines sensitivity as "[t]he ability to respond to subtle nuances, and cues to, meanings in data" (p.35). The researcher gained this ability as a result of three years of experience teaching a specialized science methods course similar to one from the research context. These interactions with prospective teachers have provided preparation for appreciating the dynamics and challenges participants face and for developing appropriate social interactions that allow participants to be comfortable in the presence of the researcher. Furthermore, the researcher possesses sensitivity from having taught 4th and 5th grade science and volunteering in a school where two participants were teaching. These experiences allow the researcher to be sensitive to the experiences, and knowledge participants share in the study.

Another noticeable aspect of the researchers' sensitivity is the ability to attune to participants needs. For example, during data collection some participants viewed the researcher as a mentor to propose ideas and to ask for expert opinions regarding content being taught, visible in the following case: Angela (a participant) was conducting a lesson on magnets and during the lesson she asked a few content questions that arose due to results some children obtained. Interactions such as this are critical because a researcher with appropriate sensitivity does not allow such interactions to blur the interpretation of experiences, but rather uses such events to contextualize and provide a dimensional level to

data that otherwise would be impossible. Thus, such sensitivity allows for more meaningful data comparison and substantive theory development.

3.6.3 Researcher's Ontology

Ontology can be viewed in two distinct yet intertwined ways: the most common view concerns the nature of knowledge. Second, ontology can be viewed as what Denzin et al. (2005) described as "what kind of being is the human being?" (p.22). Knowledge is an abstract construct bounded by personal worldviews and is always constructed within the parameters of those worldviews. However, the abstractness becomes concrete when humans interpret world paradigms in ways that allow becoming self-sufficient and "productive" in the surrounding environments.

From a research standpoint, the current study considers ontology to be the process of participant and researcher creating knowledge and decoding realities (Denzin et al., 2005). Therefore, creating the working beliefs that no absolute truth exists and that reality is determined by the surrounding from which people create meaning, grounded in evidence, and deduction.

3.6.4 Researcher's Epistemology

The notion of how knowledge is obtained or perceived is critical in research paradigms. The nature of knowledge is derived from "nonfalsified hypotheses that are probable facts or laws" (Denzin et al., 2005, p.185). The axiomatic ideas of epistemology reside, according to Denzin et al. (2005), in the sense of probability rather than on a certain truth. However, the probable truth is still grounded in cause-effect relationships that lead to the accretion of knowledge, which is, for the purposes of this study, a fluid movement of the

issue of the nature of knowledge since interpretations of experiences can be constructed individually or collectively.

Understanding the researcher's epistemological position is important since it provides the opportunity to see that the "truth" obtained from this research is only true at a particular time within the chosen context, and theory has to be negotiated in order to reach substantivity, validity, and authenticity (Denzin et al., 2005). Furthermore, these epistemological truths have an impact on the analysis since, as stated by Clarke (2005), during open coding "there is no one right reading. All readings are temporary, partial, provisional, and perspectival--themselves situated historically and geographically" (p.8). The researcher's position is that knowledge is acquired through experience that is influenced by personal learning theories. Furthermore, the researcher's views are highly influenced by philosophical perspectives grounded in the post-positivist movement.

3.7 Study's Context

The participants of this study were enrolled in an Elementary Professional Development School (PDS) Partnership at The Pennsylvania State University (PSU, 2006). The PDS is a non-traditional teacher education program for prospective teachers and developed as a partnership between the university and a local school district. This study context is ideal since the goals of the Elementary PDS are to increase the quality of prospective teachers' thinking and practices, while stimulating practicing teachers' professional growth. These goals are met by placing prospective teachers in partner schools, pairing them with an experienced mentor-teacher and professional development associates (PDA). These associations allow prospective teachers to invest in pedagogical ideas learned

throughout the science methods course. Such an opportunity to engage in pedagogical practices, consistent with the specialized method course, is not common in other student teaching programs across Pennsylvania. Through this partnership, mentor-teachers and prospective teachers engage in collaborative efforts to improve elementary students' learning.

These collaborative efforts result in professional development for all involved. The collaboration allows mentor-teachers to refresh subject matter knowledge and pedagogical skills, while it provides prospective teachers a space to engage in intensive field experiences. Field experiences within this PDS context provide nurturing teaching practices, assessments, and reflections for prospective elementary teachers with the aid of mentors and PDAs. The PDS, of which all three participants are a part, has been nationally recognized because it gives everyone involved a better understanding of teaching and learning, and eliminates the disconnect between schools and university teaching programs (http://www.ed.psu.edu/pds, retrieved 10/19/06).

Throughout their participation in the PDS, prospective teachers are enrolled in methods courses that are aligned to the philosophical underpinnings of the PDS. Participants were concurrently enrolled in a science, math, and social studies methods classes in addition to a field experience course and a course on how to create and maintain learning environments.

During formal elementary-level teacher preparation, methods courses are of great importance and can create changes in teachers' conceptions of teaching and learning (Skamp et al., 2001). In these courses, pedagogical knowledge melds with content knowledge to effectively promote planning, teaching, and teacher/student assessment. Many elementary

teacher preparation programs require completion of a methods course for each subject (e.g., language and literacy methods, science methods, math methods, social studies methods) with the intention of providing pedagogical tools to help novice teachers to succeed when teaching a specific subject. Some elementary teacher preparation programs combine science and math. Other universities, community colleges, and alternative certification programs combine all subjects in only one methods course.

The science methods course at PSU takes the perspective that the methods course is an opportunity to enhance prospective elementary teachers' content knowledge for some topics that are characteristic of elementary curricula (e.g., electricity, buoyancy, plants). Thus, the promotion of proper planning, teaching, and teacher/student assessment occurs within the context of these topics. In addition, the course involves the conceptual framework of teaching science as argument, and education students interact in an electronic environment and engage in reflective practices for specific cases. Within the argumentation framework the instructor uses, significant emphasis is placed on evidence-based explanations revolving around scientific discourse and thinking. The larger goal of the course is to assist prospective elementary teachers in developing the understanding and abilities necessary for supporting students' meaningful scientific inquiry and learning. (For a more detailed description of the course, see Appendix A.)

An important aspect of the science methods course is that it is planned collaboratively and taught by a third grade teacher and a science education faculty member. For prospective teachers, the team emphasized the use of evidence when building explanations. This objective and others were achieved using model lessons, assignments, projects, field trips, visiting similar grade classrooms, and participating in planning and teaching science lessons.

3.8 Participants

Sampling, or participant selection, is one of the most crucial aspects in any qualitative research, and therefore, considered carefully for the current study which selected three participants from a larger cohort of sixty-two interns enrolled in the PDS program in 2005-2006. These participants are part of a larger, longitudinal study of beginning teachers' knowledge and practices for teaching science as argument. The three participants were selected because of the quality of their initial science teaching experiences, which exhibited fundamental qualities of argumentation, such as engaging students in data collection and analysis, and attention to using an argument structure for the development of evidence-based explanations. In addition, the three selected participants represented a wide spectrum of experiences and teaching abilities within the analysis framework. Most of the group of prospective teachers in the PDS fit the traditional elementary education major profile. That is, they were typically non-science majors, Caucasian females, approximately 20 years old and not science enthusiasts. Below is an introduction to the individual participants and the details of their unique characteristics.

3.8.1 Angela

Angela[1] is an adult learner with previous teaching experience. She was a paraprofessional teacher in the same school district where she was student teaching. As a paraprofessional, she worked with two first-grade teachers that were part of the PDS and who taught science in ways consistent with the study framework, primarily teaching science as

[1] All names are pseudonyms

inquiry. These two first-grade teachers have a strong sense of community and frequently plan and reflect together. Angela also has children in the school district.

3.8.2 Teri

Although Teri fits the classic profile of a prospective teacher, several of her family members encourage (and practice) science. An example of her family's influence is that one of her sisters works as a scientist in a pharmaceutical company, and she often shares ideas about scientific content and science activities with Teri. In addition, Teri's other sister is an elementary teacher who graduated from the same program. Finally, Teri is a science enthusiast yet describes herself as non-confident about science.

3.8.3 Laura

Laura is a prospective teacher who, like many of her peers, was scared of teaching science. Her first experience with a science topic was magnets and by teaching these lessons she acquired a desire to learn more about inquiry and do other lessons within the same framework. This passion sparked by magnets is apparent when she focuses her PDS Teacher Inquiry project on investigating: *How can inquiry-based science instruction help my students learn about water pollution?*

3.9 Data Collection

Data for this study is derived from three main sources: first, a pre-interview conducted after completion of the science methods course; second, a set of reflections from scaffolded prompts that occurred throughout the student teaching semester, and last, a post-interview conducted at the end of the student teaching experience.

3.9.1 Data Sources

The three main sources of data can be sub-divided into: 1) Pre- student teaching or post-science methods course interview; 2) contextual reflection; 3) unit planning reflection; 4) weekly reflections; 5) follow-up reflection, and 6) post-student teaching (internship) interview. All these data sources were audio-recorded, totaling 633:97 minutes (approximately10 hours) of audio data. Table 3.1 provides an overview of total minutes per data source.

Data Source	Total Time of Audio Data
Pre-student teaching interview	120 minutes
Contextual reflection	24:77 minutes
Unit planning reflection	29:07 minutes
Weekly reflections	289:22 minutes
Follow-up reflection	24:91 minutes
Post-student teaching interview	146 minutes
Total	633:97 minutes

Table 3.1: Total Audio Time for Data Sources

3.9.1.1 Interviews

Interviews, a common data collection tool in qualitative research studies, are conversations, face-to-face or through technological means, that prompt participants to explain and share their thinking about the study topic. These conversations can be tightly or loosely structured depending on the goal of the interview. In loosely structured interviews, participants are only provided with flexible prompts, and participants often guide conversations. In tightly structured interviews, participants' explanations are closely guided

by the researcher's protocol, and responses are followed-up with specific, more in-depth questions to understand participants thinking in relationship to the research questions under study.

In the case of the current study, two structured interviews were conducted: one at the beginning of the student teaching experience (right after completion of the science methods course) and a second at the end of the student teaching experience or internship. The first interview followed a protocol that started the conversation with questions that aimed to learn more about participants' experiences as science learners. Participants' experiences were solicited with questions such as: "Can you share some of your experiences as a science learner back in elementary school? What are the big ideas that you can pinpoint as very important to you about teaching and learning science?" (See Appendix B for complete protocol). The second interview followed the same protocol with some slight modifications to attend to the fact that the semester had ended.

Interviews in general lasted an average of 46.9 minutes per participant for the initial interview and 50.44 minutes per participant for the final interview. Table 3.2 shows the length of minutes per interview per participant.

	Angela	**Laura**	**Teri**
Interview #1 (Pre)	37min.	32min.	51min.
Interview #2 (Post)	57min.	43min.	46min.

Table 3.2: Interview Times for Interviews per Participant

These interviews, in general, provided the opportunity to clarify the context of their teaching. In addition, it created points of reference to determine the ways in which the participants appropriated the framework. Finally, the interviews were a useful tool to capture participants' science teaching beliefs, their self-described perception and practices of science teaching and learning, as well as their sources of teacher knowledge and science content knowledge.

3.9.1.2 Weekly Reflections

In order to attain appropriate data for research questions one and two, a weekly reflection protocol was established. This protocol was key for data saturation to answer the study's research questions. At the end of each week, participants were instructed to audio-record (using GarageBand®) a reflective entry following the protocol. For example, participants answered: *To what extent did the science lessons you taught this week reflect teaching science as inquiry? Use a rating scale from 1-5, with 5 representing the highest level of science as inquiry. Explain your answer.* This question elicited information about their knowledge of science teaching while keeping consistent topics across participants for a more systematic and in-depth comparative data analysis. Other questions, such as: *Provide an overview of your lessons,* allowed analytical contextualization of participants' reflections while providing rich data to contrast and enhance interviews and add better descriptions of the inquiry. Table 3.3 shows all the questions for participants, weekly reflections.

Continuous Scaffold Reflections Protocol
To what extent did the science lessons you taught this week reflect teaching science as inquiry? Use a rating scale from 1-5, with 5 representing the highest level of science as inquiry. Explain your answer.
What science concepts did you intend for students to learn this week? Why is it important for students to know this?
Provide an overview of your lessons.
What knowledge of students' thinking/ideas influenced your teaching?
In what ways did your enacted lessons differ from what you planned? Explain what influenced these changes/differences.
Did other factors influence your teaching?
Identify what you believe were the best examples of the following and explain why: Children collecting data/observations Students looking for patterns in data/observations Students constructing explanations from evidence Students discussing/debating evidence and/or explanations
What kinds of things did you need to do as a teacher to support explanation development and science talk?
How effective were your science lessons at supporting student learning? Provide evidence to support your answer.
How will what you learned from teaching science this week influence what you do in the next few lessons?

Table 3.3: Continuous Scaffold Reflections Protocol

This protocol was focused on providing rich evidence to answer the research questions guiding the current work. Since some participants did not teach science every week, Table 3.4 indicates the weeks they did teach science and if they completed a reflection. Completed reflections are denoted by stating the time duration of the reflection; if no science instruction occurred during that week, the notation is *NO SC*, and if no reflection was completed, the

notation is ------. A total of 24 reflections for the 3 participants were completed throughout the data collection period.

Completed Reflections Per Participant			
Date	**Angela**	**Laura**	**Teri**
2/27-3/3	2:05	18:04	12:07
3/6-3/10		Spring Break	
3/13-3/17	33:11	16:44	14:35
3/20-3/24	25:48	5:54	10:51
3/27-3/31	14:40	NO SC	NO SC
4/3-4/7	12:24	6:08	11:05
4/10-4/14	NO SC	NO SC	7:31
4/17-4/21	NO SC	NO SC	-------
4/24-4/28	NO SC	NO SC	-------
5/1-5/5	---------	2:41	16:37
5/8-5/12	19:34	4:22	6:46
5/15-5/19	15:20	--------	NO SC
5/22-5/26	9:17	2:41	NO SC
5/29-6/2	22:56	2:41	-------

Table 3.4: Weekly Reflections per Participant

3.9.1.3 Unit Planning and Contextual Reflections

Participants responded to two protocols that aimed to create a teaching context: context/initial questions protocol and unit planning protocol. The first protocol (context/initial questions protocol) allows for identification of demographic aspects of a participant's classroom while also providing a context for the individual's science teaching

experiences. In addition, the reflections uncover participants' knowledge regarding science teaching and learning practices. For example, (see Table 3.5) participants were asked whether they considered hands-on and inquiry to be two distinct ideas. This is relevant since it provides access to their thinking in an area of misconceptions among prospective teachers (see Chapter 2) that impedes teachers' appropriate understandings of effective teaching.

Context/Initial Questions Protocol
How many students do you have in your classroom?
How diverse is your class in terms of race and gender?
Do you have learning support students in your class? If so, explain how many and the level of support (e.g., Is there a paraprofessional assigned)?
How often (and for how long) is science taught in your classroom?
Are there designated days and times for science teaching?
How active is your mentor in teaching science?
How supportive is your mentor in your science teaching?
What do you see as the features/characteristics of effective science teaching? What kinds of things should teachers be doing? What kinds or things should students be doing?
Do you consider there to be a difference between hands-on science and teaching science as inquiry? Explain.
What is the role of evidence and explanation in science teaching and learning?
What is the role of "talk"/discussion in science teaching and learning?

Table 3.5: Context/initial Questions Protocol

The context/initial protocol responses lasted an average of 8.25 minutes. Table 3.6 provides a detailed description of the duration of each response by participant.

Context/Initial Protocol Responses Duration	
Angela	10:13 minutes
Laura	8:10 minutes
Teri	6:54 minutes

Table 3.6: Context/Initial Protocol Reponses Duration

The second protocol (unit planning protocol) provides a subject context for the topic participants were teaching and the science concepts participants intended students to comprehend. The unit planning protocol, in addition, provides a context to the continuous-weekly scaffold reflections protocol since science lessons span an extensive period of time. This protocol, as seen in Table 3.7, also examined participants' comfort levels, preparation, and role in the science unit. This information was critical for later understanding weekly reflections and further data saturation.

Unit Planning Protocol
What is the science topic of your current science unit?
What are the big science ideas that students need to understand?
What is your comfort level with the content of the unit? What kinds of things have you done to enhance your own understanding of the science?
What has been your role in planning and teaching lessons from the unit?
What kinds of issues have you faced in terms of planning and teaching lessons from this unit? How have you addressed/resolved these issues?

Table 3.7: Unit Planning Protocol

In general, participants self-reported unit planning responses lasted an average of 4.94 minutes. Table 3.8 provides the specific of each participant's responses.

	Unit 1	Unit 2
Angela	8:47 minutes	8:40 minutes
Laura	5:24 minutes	2:41 minutes
Teri	4:55 minutes	-----

Table 3.8: Unit Planning Time Duration

3.9.1.4 Follow-up Reflection

The follow-up reflection built upon some of the questions answered from the context protocol, unit planning protocol, and entrance interviews. For example, many participants used the terms, "hands-on," as well as "inquiry" during the interviews. Then, in the context/initial questions protocol the explicit question was, *Do you consider there to be a difference between hands-on science and teaching science as inquiry? Explain.* The intent of the follow-up protocol was to obtain more information regarding participants' knowledge and how they were transferring that knowledge to self-reported practices for science teaching that would help understand development. Table 3.9 shows the follow-up protocol. In addition, Table 3. 10 shows the duration of participants' responses.

Follow-Up Protocol
1) Is there a difference between hands-on and inquiry? Explain
2) Have your views of teaching science as inquiry change during this semester?
3) How your views of emphasizing evidence and explanations have change since SCIED 458?
4) When asking students to construct an explanation from evidence describe the kinds of claims you accept from them?
5) In what ways your ability to teach science as inquiry has changed?
6) What people or factors are impacting your science teaching currently?
7) When you rate your lessons using the inquiry criteria of 1-5 what criteria do you use to judge them?

Table 3.9: Follow-up Protocol

Follow-up Protocol Response Duration	
Angela	10:13 minutes
Laura	9:48 minutes
Teri	5:30 minutes

Table 3.10: Follow-up responses time

3.9.2 Data Collection Procedures and Schedule

Data was collected over a period of six months within the context of the TESSA project. Data collection occurred from January 2006 until June 2006. In January, the first data source (interview #1) was collected for all three participants. Subsequent to the first interview, protocols for reflections were provided to participants, and these were collected at the end of each week or early the following week depending on the teaching schedules of the participants. The collection of the weekly reflections was performed until the end of May or

the first week of June. Toward the end of May or early June the second interview was conducted. In order to ensure participants' confidentiality, data was stored in the TESSA project office with access restricted to only two investigators involved in the research. In addition, data was labeled using participants' initials only, which were subsequently modified to pseudonyms for reporting purposes.

3.10 Data Preparation

After all first interview data were collected; the preparation process began immediately, as required by grounded-theory analysis tools. That is, an attempt to analyze data must occur at the same time it was collected. However, data were not analyzed concurrently due to the bulk of data being collected; it was immediately mainstreamed into the process of preparation for transcription for analysis. In order to transcribe data, converting the audio files from an iPod™ (.wav) to a QuickTime® file was necessary. Once interviews were in QuickTime® format, they were imported into StudioCode™ digital video/audio analysis software for transcription. During transcription, participants' interviews or self-reported reflections were transcribed word-by-word, with the exception of some utterances such as "um," "am," and "so." The same process was conducted for the second set of interviews.

StudioCode™ is video analysis software developed for sports uses; however, it has transitioned to use in education, thereby providing opportunities to use data from video (also audio converted into video) sources. The software consists of three main components: 1) a video source, 2) a coding window, and 3) a timeline. Figure 3.2 demonstrates a snapshot of the main components. In addition, supportive applications include a transcription window

(used for transcriptions) and an output window. Figure 3.3 demonstrates a snapshot of a transcription window.

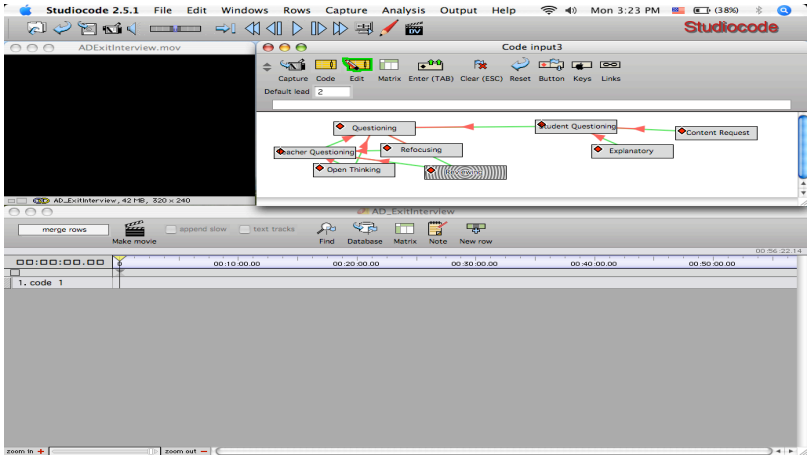

Figure 3.2: StudioCode™ environment

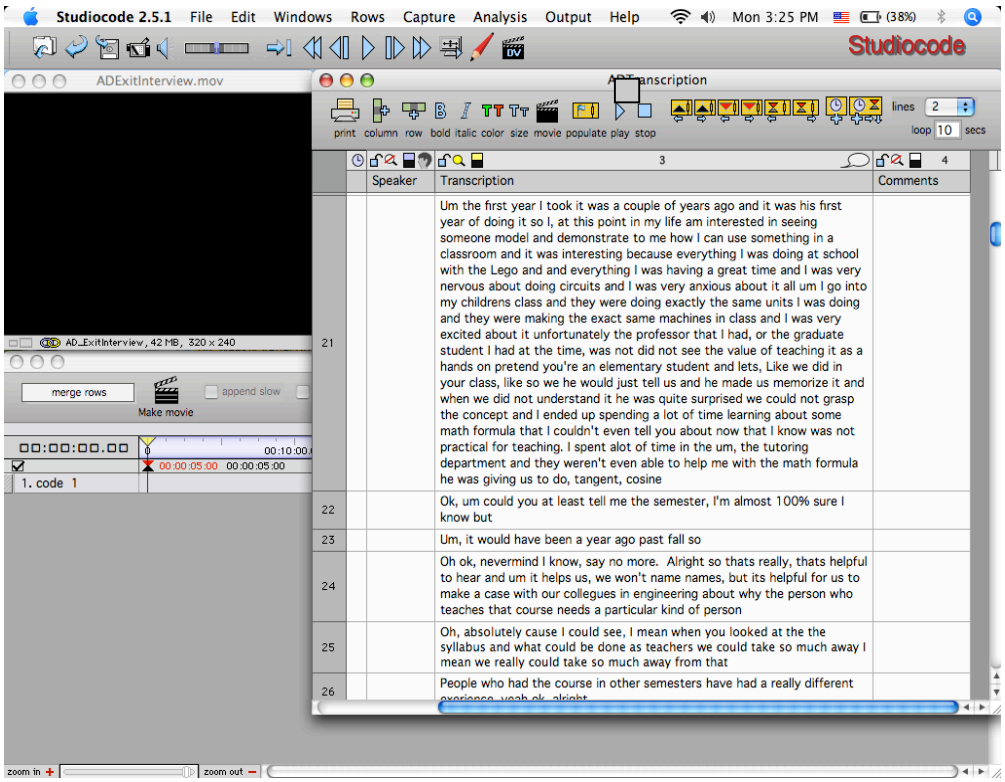

Figure 3.3: StudioCode™ transcription environment

A similar process occurred with each reflection, and all reflections were self-recorded by participants in GarageBand®. In order to transcribe the reflections using StudioCode™

the files were sent to iTunes® and then the previous procedure mentioned was performed for each reflection. Once all files were transcribed, they had to be converted to a text file in order to be analyzed using HyperResearch®. The reason transcribed files had to be converted into text was because HyperResearch can only analyze text files. The process for this conversion was to export a StudioCode™ transcript as a text file (.txt). The latter was also performed for each single data file in the current study.

3.11 Data Analysis

Analysis of data to produce substantive theory through grounded-theory involved a series of steps during and after data collection. Throughout the data collection process and data preparation, the first phase of analysis involved familiarization with data. The second phase was analyzing data according to participants. Finally, the third phase was cross participant analysis.

The first phase of familiarization included listening to interviews and participants' audio recordings to become familiar with what was being mentioned. Concurrent with the familiarization process, preparation of data took place as described previously. As data were being prepared, a process of open coding took place in order to ensure appropriate data saturation. Open coding is the process of "scrutinizing the field notes, interviews, or other documents, line-by-line, or even word-by-word" (Kelle, 2007, p.201). Although open coding was conducted, its use was not for the process of producing results, but instead, exclusively for providing the basis for assuring quality and quantity for the current research questions.

A subsequent phase of analysis (analysis by participant) took place systematically in order to answer the research questions. During this process, open coding was performed for

each data source for each participant. Throughout open coding, close attention was given to evidence leading toward the constructs in each research question (e.g., knowledge, sources, influence). Examination of the codes, creation of a code-chart and establishing the codes' meanings by participant followed. Once all the codes were assigned, they were grouped into categories that broadly fit into the four components of the conceptual framework. In other words, the task was to decide whether or not some subcategories fit or did not fit within these eight categories (as described by the conceptual framework).

During the third phase (cross examination) clustered codes were compared across participants. This constant comparative analysis helped create a set of sub-categories that applied to all participants. Analyzing the categories created for each participant and clustering them into one main list of sub-categories with its particular codes and definitions established the general categories. These coding schemes are presented in Table 3.11. Finally, based on the cross-examination results, assertions were created to for each of the research questions.

Table 3.11 Coding Scheme

Research Question	Category	Subcategory/Definition	Codes
What are the ways in which preservice elementary teachers appropriate components of "teaching science as argument" during their student teaching experiences?	Subject Matter Knowledge for Teaching	Content Knowledge	Accuracy
			Appropriate representation
		Pedagogical Knowledge	Assessment
			Questioning
			Scaffolding
			Adaptability
	Public Reasoning	Dialogic Interactive[2] (Teacher-Student Interaction)	Knowledge Assessment
			Data Assessment
			Evidence Understanding
			Explanation Building
			Explanation assessment
			Rebuttals
		Dialogic Interactive[2] (Student-Student Interaction)	Data Assessment
			Data Collection
			Evidence Understanding
			Explanation Building
			Explanation Assessment
		Non-Interactive (Teacher-Teacher Interaction)	Rebuttals
	Language of Science		Scientifically Consistent
			Scientifically Laden
			Age appropriate
	Science Meaning Making	Problem Construction	Interaction with Phenomena Pursuing Testable Questions
		Data Collection	Designing Fair Tests
			Making Predictions
			Recording and representing data
		Data Analysis	Identifying patterns
			Coordinating Evidence with Claims
			Considering alternative claims
		Explanation Construction	Argument Structure
			Explanation informed by existing scientific knowledge

[2] Mortimer and Scott (2003)

Research Question	Category	Subcategory/Definition	Codes
To what extent do components from preservice elementary teacher's reflections on their experience influence planning for science teaching?	Negotiating	Pedagogical Negotiations	Provides opportunities for data collection
			Provides opportunities for explanation construction
			Provides opportunities for data analysis
			Provides opportunities for discourse
		Content Negotiations	Provides opportunities to evaluate experimental design
			Provides opportunities to evaluate explanations
			Provides opportunities to evaluate data analysis
			Provides opportunities for content discourse

Research Question	Category	Subcategory/Definition	Codes
What elements from the teacher education context influence preservice elementary teachers' attention to teaching science as argument?	Nature of Science		Science as a cluster of facts
			Science as the look for a right or wrong answer
	Influence	Methods Course (Events that occurred during the specialized science methods course)	TESSA
			Class Science Activities
			Class Discussions
			3-day teaching
		Student Teaching (Events that occurred in the context of the student teaching experience and semester)	Mentor Teacher
			Current PDS Intern
			Former PDS intern
			School Teacher
			Mentor Teacher
		Intrinsic (Influences that are inherited within the participant background that are personal. Notions of participant's identity)	Desire to succeed
			Bad experiences in school
			Commitment to scientific literacy
			Enjoyment of science
		Extrinsic (Influences beyond participants' control)	Lack of Time
			Forced to teach science
	Children's Science Learning	Negative Perceptions	Students are unable to construct evidence-based explanations
			Students are unable to interpret data
			Students cannot link claims and evidence
		Positive Perceptions	Students are capable of constructing evidence-based explanations
			Students are capable of interpreting data
			Students are able to link claims and evidence

3.12 Criteria for Evaluating Research Study

3.12.1 Criteria for Evaluating Qualitative Research

The aspect of validity is a crucial element in qualitative research in order to meaningfully impact practice, research, and policy. The notion of validity is a "loaded" term and faces many controversies among philosophical stances since many argue that validity carries a sense of absolute truth attributable to positivists' views. However, the current study is grounded in the perspective that validity is necessary in all forms of research despite philosophical stance, and does not imply absolute truth. Schwandt defines validity, as "to indicate that it is sound, cogent, well grounded, justifiable, or logically correct" (2001, p.267).

In order to assess whether the current study meets Schwandt's standards of validity the following criteria (borrowed from Maxwell, 2005) are provided to judge the inquiry: 1) long-term involvement with data, 2) rich data, 3) respondent validation, and 4) triangulation (p.110-113). Therefore, the current study meets the requirement mentioned above by the following:

1) The research is conducted over more than six months.
2) Multiple sources of data provide "rich" data for conclusions.
3) Participants respond to critical questions several times to avoiding misinterpretations in addition, to identifying changes in participants' thinking.
4) Study sampling involved three participants.

These four aspects of the current study provided validity to the claims and assertions later presented in Chapters 4 and 5. For example, the collection of data over a period of six months ensured that findings regarding participant's appropriation of teaching science as argument did not represent just a one-time instance of their student teaching but rather

multiple instances during their teaching. As a result, data collection for over six months allows explanatory power for answering the research questions. In conjunction with time allocation, multiple sources of data ensured that analysis findings could be corroborated with different sources thus, strengthening the assertions made in Chapter 5. Finally, collecting data from three participants permitted investigating the research questions in the current study with three distinct prospective elementary teachers that exemplify different backgrounds and experiences. These participants' distinctiveness strengthens the study because findings were made across participants.

3.12.2 Criteria for Evaluating Grounded Theory

One of the main aspects for evaluating grounded-theory is reaching saturation, which is addressed in the current study through two distinct means. First, data saturation is present; that is, enough data exists to support the analysis of the research questions. Second, the processes of open coding, axial coding, and constant comparative analysis guarantee saturation of analysis that leads to valid theory building. In addition, the process of creating hypotheses accompanied alternative hypothesis validation of the final substantive theory.

3.13 Limitations of the Study

Qualitative research provides many advantages arising from its interpretive nature and from decisions of what, how and how often to investigate (Merriam, 2002). Such features also may create limitations for the amounts of data possible to collect and analyze simultaneously. The current research retrieved an enormous amount of data, which makes listening to all audio recordings from each participant in a timely fashion extremely difficult.

In addition, and despite the effort to collect data regarding participants' abilities to enact their knowledge of teaching science as argument, traveling to different schools to

collect videos of participants' teaching added to the complexity. Since collected video of all three participants represents such a small component of the science units taught, too much emphasis on them might lead to incorrect inferences and conclusions about participants' teaching practices. Therefore the decision was made to eliminate this data as a source for further data saturation. Unfortunately, the video data would have provided an opportunity to link changes in knowledge and their relationships to pedagogical practices versus self-reports of teaching. Perhaps, analysis of video in the future could expand the implications of this research.

A third limitation of the study is the notion that the principal researcher did not perform the interviews, although present in several of the interviews. It is possible this is an advantage as by not conducting the interviews there may be more objectivity than when trying to create substantive theory.

3.14 Summary and Preview

This chapter presented an overview of methods of inquiry. It provides a contextual philosophical and historical background for qualitative research while utilizing this information to ground the researcher's world-views that impact data analysis. The chapter also provides an extensive description of the participants and the process by which they were selected, leading to the data sources collected to answer the research questions. Similarly, the chapter provides a description of how data was prepared for analysis and how the analysis took place. Finally, criteria for evaluating research quality are described. In the next chapter an extensive description of participants self-reports is provided. In addition, the subsequent chapter illustrates the ways in which participants appropriated the framework, how

reflections influenced their planning, and what contextual elements of the teacher education program influenced their attention to teaching science as argument.

CHAPTER 4: FINDINGS

4.1 Introduction and Overview

The current chapter provides participants' stories regarding their appropriation of framework elements, how reflections influenced their science teaching planning, and last, what elements from teacher education experiences influenced their attention to teaching science as argument. Participant's story begins by a description of their classroom context and teaching. Once the participant is contextualized an overview of the two units they taught is provided. Following representation of the framework elements is discussed. For better comprehension the framework elements was divided into four sections: constructing evidence-based explanations, notions of inquiry, teachers' role, and public reasoning. Finally, influence of reflection protocols and context elements such as science methods course, professional development school peers, and children's ideas is discussed. Finally, a summary is provided for each participant.

Teri's story is first presented because her views as sophisticated and presents an image of a prospective elementary teacher that "gets it". Her views are aligned with the framework and demonstrate the potential prospective elementary teachers have. Viewing Teri's story first is important because it helps us better understand Angela's convoluted story. Finally, Laura's story is presented at the end because she reveals a more typical prospective teacher that focuses her attention in important ideas yet generic to education and not science-specific.

4.2 Teri's Story

4.2.1 Description of Classroom Context and Teaching

Teri's student-teaching assignment was a third grade class comprised of twenty-four students: primarily Caucasian, ten girls and fourteen boys. Three girls received learning support in math and reading; three additional students (two girls and one boy) received speech therapy.

Despite these students' receiving learning support, the class had no supplemental paraprofessional. In addition to student-teaching in a third grade, Teri also taught science to a fourth grade group.

Science was taught on a regular basis throughout the year, at least three times per week, for approximately forty-five minutes to one hour, mostly in the afternoons. Teri's mentor-teacher was actively engaged in science by writing and revising science units for the district, and writing grant proposals for science projects, field trips, and activities. Thus, Teri's mentor-teacher was very supportive of Teri's teaching science, and accordingly was available for discussions that often led to altering lesson plans and questioning whether an activity was inquiry-based instruction. During the course of the current research, Teri taught two units: Simple Machines and Rocks and Minerals. However, for the Simple Machines unit she only taught the ending portion of the unit, a compilation of six lessons. Table 4.1 provides an overview of the goals for the units using Teri's words. According to Teri, since she modified both units, Table 4.2 provides a summary of the curriculum goals and activities as described in the school district's curriculum.

Student-Teaching Field Experience **Student-teaching Spring Semester/Science Teaching**		
Date	**Unit Topic**	**Unit Foci**
2/20-2/24 (Week One) 2/27-3/3 (Week Two)	Unit 1: Levers	To learn what levers are levers: What are the parts of a lever? Can students use levers and other simple machines to solve real world problems?
3/6-3/10		Spring Break
3/13-3/17 (Week One) 3/20-3/24 (Week Two) 3/27-3/31 (Week Three) 4/3-4/7 (Week Four) 4/10-4/14 (Week Five) 4/17-4/21 (Week Six) 4/24-4/28 (Week Seven) 5/1-5/5 (Week Eight) 5/8-5/12 (Week Nine) 5/15-5/19 (Week Ten)	Unit 2: Rocks and Minerals	To describe what rocks and minerals are: Describe the formation process of rocks. Distinguish how rocks and minerals are different and recognize the properties of minerals.

Table 4.1 Teri's Units: Overview and Foci

	Rocks and Minerals	Simple Machines
School District Concepts	• A rock is an earth material composed of different ingredients called minerals that can be observed and described. • The earth has three kinds of rocks: sedimentary, igneous, and metamorphic that are each identified by the way in which they are formed. • Changes occur in rocks because of weathering and erosion. • Rocks and minerals are valuable natural resources. • Coal is fossil fuel that comes from layers in the Earth's crust. • Soil is a natural resource that covers much of the Earth's surface.	• A machine is any object that makes work easier. • A lever is a simple machine that pivots on a fulcrum and is used to lift and move objects. • An inclined plane is a sloping surface that increases the ease with which an object moves, or can be moved, to a higher or lower level. • A pulley is a simple machine with a grooved wheel holding a rope or chain, used to lift or move objects.

Table 4.2 Teri's Units Overview as Described in the School District Curriculum

4.2.2 Overview of the Units

The first unit Teri taught was Simple Machines. In general, the unit aimed to familiarize students with simple machines, recognize these machines, manipulate simple machines, and recognize machine uses. Although the unit encompassed a significant number of concepts, Teri only taught the section on levers that included six lessons over a period of two weeks, and by the time she joined the current research, she was in the second week. The general goals for these lessons were: What are levers? How can students use levers to solve real world problems? What are the parts of a lever, and how does moving the fulcrum affect the lift? However, Teri was very specific in the goals of each lesson in her self-reports. For the first two lessons she said,

> The concept I intended students to learn was that there are different types of levers and that the parts of a lever are not always in the same place. Students were becoming familiar with levers they use in their everyday lives and how they do not all work alike or work like seesaws. During the second lesson students were investigating the influence the location of the fulcrum has on how much force is needed to lift a heavy load. I wanted students to not only realize that the location of the fulcrum influences the force it takes to lift a load but, I also wanted students

> to understand that it takes less force to lift a load when the fulcrum is closer to the load. (Teri, 3/1/06, Continuous-weekly reflection)

The four remaining lessons concentrated on constructing simple machines in order to solve problems. For these lessons Teri described her goals as,

> During these lessons we wanted the students to think critically about how they could build devices using what they had learned throughout the simple machines unit. (3/1/06)

Therefore, students had to use concepts already learned and apply the information while clarifying questions and gathering more evidence to formulate an evidence-based explanation regarding the overarching question posed to each one of the scenarios regarding aspects of simple machines. Table 4.3 provides a summary of the activities in this unit.

Teri's Summary of Activities for Simple Machines Unit	
Lesson	**Summary of Activities**
Lesson 1	Students identified the location of the fulcrum, load, and force in several simple machines.
Lesson 2	Students decided where to place the fulcrum to make lifting easier.
Lesson 3	Students solved problems related to simple machines.
Lesson 4	Students solved problems related to simple machines.
Lesson 5	Students solved problems related to simple machines.
Lesson 6	Students solved problems related to simple machines.

Table 4.3 Teri's Weekly Activities Overview of the Simple Machines Unit

Throughout the first lesson, students investigated the possibility of placing the fulcrum, load, and force in the same location for all simple machines. In order to do so students were provided with a series of materials, and they had to record where they exerted force in order to lift the object. After testing each of the materials, Teri had students, as a whole class, discuss the

results of each testing. In order to record the main results, she used a KLEW chart (Hershberger, Zembal-Saul, Starr, 2006). For the second lesson, Teri helped students investigate where to place the fulcrum in order to make the lifting of a heavy load the easiest. Thus, she gave students the same set of materials and instructed them to change the fulcrum for each object while recording their results. After all the materials were tested, students had a discussion that led to making a claim of where the fulcrum should be to require the least amount of work. In addition, she added a third variable to the testing: the load. Students proceeded to test variations in load placement. Again, Teri had a class discussion that linked the claim (the best location of the load) to the evidence while using the KLEW chart. Following these two lessons that lasted more than two days, Teri provided students with a series of problems that required building simple machines in order to solve problems. In these lessons students used claims they had made earlier about the location of the fulcrum, the force, and the load in simple machines. Solving these problems spanned four lessons.

During the second unit, Rocks and Minerals, Teri described the goals for the unit as each week approached. During the first week she said,

> I wanted the students to understand that rocks are inorganic, or not alive, and naturally occurring, and not man made objects. I also wanted students to learn what geology and geologists are and the properties that geologists use to study and describe rocks. I wanted students to discover a beginning idea of what a rock is, and what a rock isn't. I wanted students to answer the question: What characteristics do we use to describe rocks? (Teri, 3/16/06, Continuous-weekly reflection)

During the second week Teri said that goals of the lessons revolved around the scientific questions of "What do you find when you break a rock, and is it a rock or not?" More specifically she reported,

> I wanted students to understand what rocks are made of and what a mineral is and how a mineral is different from a rock. (Teri, 3/23/06, Continuous-weekly reflection)

Although Teri did not teach during the third week of the unit, the goals for that week that her mentor-teacher covered revolved around the properties of minerals. More specifically, students were to describe the color, luster, hardness, and streaks of a mineral. Following activities that addressed this goal, Teri dealt with the formation of sedimentary rocks. During these lessons she decided to address a scientific question. She said,

> I decided that the lesson was focused on a scientific goal oriented question which was: How are sedimentary rocks formed and how does that process affect the properties or physical characteristics of sedimentary rocks? (Teri, 4/3/06, Continuous-weekly reflection)

For the fifth week Teri intended students to,

> Understand the formation of metamorphic rocks. I also wanted students to understand the rock cycle and the fact that it is an ongoing process and can take many paths. (Teri, 4/12/06, Continuous-weekly reflection)

Following the learning of the rock cycle, Teri's teaching was, as she described, scattered due to school activities (not described). However, she used classroom time to show two videos regarding the material already covered and used the videos to build students knowledge on those topics. As week seven began, Teri focused on weathering and erosion. During this week she posed the scientific question: "What impact will freezing water have on rocks?" With this question she wanted the students to,

> Understand that freezing water expands and breaks up rocks. I then wanted students to recognize that this is a type of weathering and that there are other forces in nature that cause rocks to break up. Our activity acted as a platform upon which I could introduce the scientific term: weathering. (Teri, 5/2/06, Continuous-weekly reflection)

During following the weeks, Teri integrated the science content with language arts and had students apply vocabulary words, definitions, and claims in multiple activities such as word puzzles, writing paragraphs, and creative writing.

Over the span of the second unit, Teri engaged students in multiple activities that built upon each other. During the first week, Teri gave students multiple rock samples and students had to use these samples to create a definition and a description of rocks (as described by Crowther, 2003). In order to aid this development Teri gave students, at the beginning of the lesson, several jellybeans and requested students group the jellybeans into a self-developed classification system. She guided students to progressively increase the complexity of the categories and concluded the activity by linking it to rock samples. Once rock samples were provided, Teri instructed students to sort rocks using the jellybeans activity as a guide and develop a set of categories and their descriptors for a rock classification system. Once each group finished this procedure she had the groups read their categories and descriptors to each other and had the rest of the class "guess" which rock it was while helping each group of students to improve the rock classification system. After this procedure the groups had the opportunity to re-do their classification systems. Once students finished, Teri linked the activity to the following week's lesson and how it was going to provide more information.

The second week followed as a clear continuation from the first week's lessons while adding the concept of minerals. During the first two lessons students broke rocks into pieces and created a web in order to determine the composition of a rock.

The third week included testing minerals for color, luster, hardness, and streak; however, Teri did not teach these lessons. During the following week (fourth week) she dealt with the formation of sedimentary rocks. In this lesson students created a model of how sedimentary rocks form and the effects of pressure on the formation process. After creating the sedimentary rock formation model, using food, students had to compare their models to rocks and report their reasoning to peers.

After dealing with sedimentary rocks and entering the fifth week, Teri engaged students in the formation of metamorphic rocks, through modeling as well. She also did a demonstration of the rock cycle while students collected evidence about the rocks during each phase.

In order to attain the goals of week seven Teri had students create physical models of water balloons covered in clay. These models represented rocks and were placed in the freezer to observe physical changes over time (to represent weathering). After the rocks broke up they were placed on a tilted pan and water was sprinkled over to represent rain. This last simulation led students to observations regarding the effects of erosion. Finally, Teri concluded the lesson by having students construct evidence-based explanations for the overarching question posed. The activities described above are summarized in Table 4.4.

Teri's Summary of Activities for Rocks and Minerals Unit	
Week	Summary of Activities
One	Students defined and described rocks.
Two	Students determined the composition of a rock.
Three	Students tested minerals for color, luster, hardness and streak.
Four	Students defined and modeled the formation of sedimentary rocks.
Five	Students defined and modeled the formation of metamorphic rocks.
Six	Students modeled the effects of erosion.
Seven	Students constructed scientific explanations regarding multiple questions.

Table 4.4. Teri's Weekly Activities Overview of Rocks and Minerals Unit

4.2.3 Representation of Framework Elements

When examining Teri's views of teaching science as argument at three distinct points (prior to, midway, and at the end) of the study she revealed an atypically wide range of ideas,

consistent with some elements of the analysis framework. These atypical views for a prospective elementary teacher were drawn from the fact that a significant aspect of Teri's self-reports on teaching and learning science was, continuously, the construction of evidence-based explanations. At the beginning of the study she viewed evidence as a central element in explanations. Furthermore, she self-reported a relationship between evidence and alternative claims linked to that piece of evidence. For example, during the entrance interview, she described her science teaching as revolving around an overarching question while doing evidence collection and formulating explanations around that question. However, she based her understanding of inquiry, exclusively, on her experiences during the science methods course (SCIED 458) (trying to replicate how she was engaged in class). Conversely, as she completed the first unit and entered the second unit, she described a metacognition of what counted as teaching science as inquiry. By the end of the study, because she focused on the notion that inquiry can be teacher or student led, she demonstrated an awareness of students' misconceptions and how these aided or interfered with meaning-making and scientific explanations. Contrary to the curriculum which supports traditional forms of assessments (recall of static knowledge), Teri decided to add the component of having children articulate an explanation and assess how well students used evidence to support their answers. Interestingly the elements that Teri appropriated at different points of the study appeared to correlate with external factors influencing her (e.g. science methods course, analysis protocols), yet she was consistent with her emphasis towards students constructing evidence-based explanations. In order to provide a depiction of Teri's development, Figure 4.1 demonstrates her emphasis gravitating toward framework elements at three distinct points in the study.

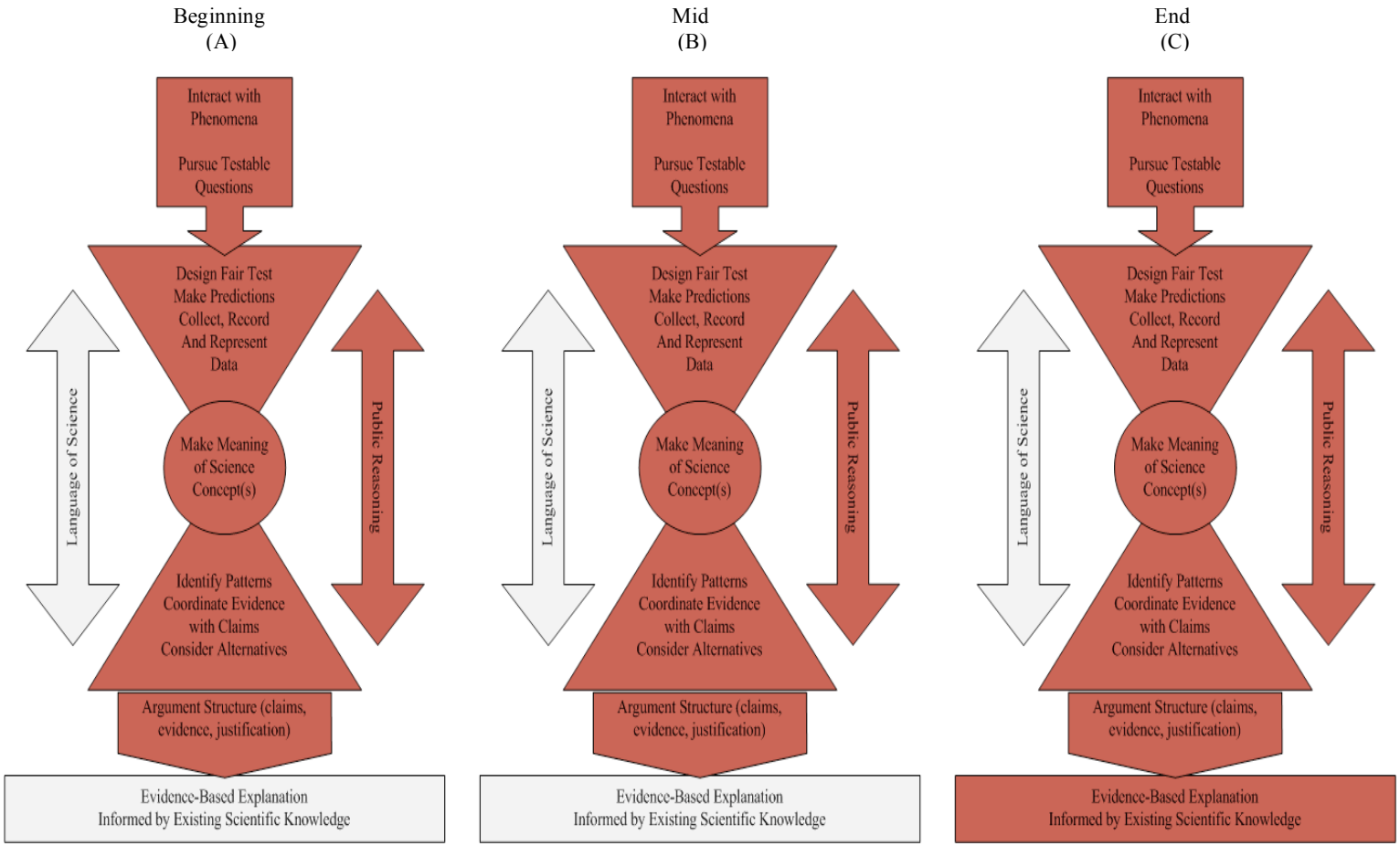

Figure 4.1 Teri's Emphasis of Framework Elements at Three Distinct Points

4.2.3.1 Constructing Evidence-based Explanations

Emphasis on the construction of evidence-based explanation was highly prevalent throughout Teri's self-reports. However, the depth to which these were described or reported as being enacted varied for both units Teri taught. At the beginning of the study Teri viewed evidence as a central element in explanations. Thus, Figure 4.1 section A highlights the areas associated with this view. Furthermore, she self-reported the existence of a relationship between the kinds of evidence students collect and the kinds of explanations they are able to make. In so doing, she was also explicit on how students' evidence collection and patterned observations led to construction of evidence-based explanations. She said,

> During our science talk at the end of the lesson, I encouraged kids to look for patterns in the evidence and then use that evidence to make a claim about where they should put the fulcrum to make it easiest to lift a load. By focusing the students on the scientifically oriented question I posed at the beginning of the lesson, I was able to encourage the students to think about how that evidence helped them make a claim about the influence the location of the fulcrum has on the force it takes to lift a load. (Teri, 3/1/06, Continuous-weekly reflection)

Interestingly Teri was very explicit in her self-reports about aiding the construction of evidence-based explanations. Furthermore, she described not only wanting to support students in this matter but also supporting discussion and analysis of those explanations during small groups and whole class discussions. She said,

> For instance, some groups were discussing and debating where they thought the fulcrum would be on a broom and had to explain to their friends why they felt that way. Most students ended up showing each other the way they were using the broom or lever and pointed to certain parts on the broom or on their bodies to illustrate where they thought the parts of the levers would be. They also had to justify their explanations to their friends. I noticed as I walked around that most groups were in the process of explaining or proving where they thought the fulcrum, force or load was on different levers. Furthermore, because there were varying rates and some level of confusion among students, we discussed and debated the locations of the lever parts we had at the end of the lesson as well. (Teri, 3/1/06, Continuous-weekly reflection)

An aspect that differentiates Teri from participants, Angela and Laura, was the sophistication of ideas in which she grounded evidence-based explanations. For example, the process of reporting her espoused views and self-reported practices were usually grounded in elements of the nature of science, the role of the teacher, and assessment of evidence and explanations. With regard to the role of the teacher, she emphasized that the construction of evidence-based explanations was linked to her role as a teacher when she described the importance for teachers to be aware of students' readiness to formulate evidence-based explanations. That is, the teacher needed to be aware of how much evidence and the quality of the evidence to make such explanations.

An example of Teri's sophisticated views was observable during the second week of the first unit (Simple Machines). Teri self-reports appropriated a sophisticated description of inquiry and supporting evidence-based explanations. She described classroom events and reflected upon these by connecting students thinking, evidence, claims, and explanations to the evidence collected through evidence patterns and observations; thus, once again highlighting the elements shown in Figure 4.1 section A. For example, she claimed that she wanted students to question whether the evidence was or was not supporting the claims. In addition, she wanted students to distinguish between evidence and strong evidence. Teri's ideas are illustrated by the following event,

> I had to remind and encourage students to think back to the terms they had used to label their webs in order for us to have a good science talk. I found that the students wanted to rely on the things they had read in the past or their prior beliefs after completing the activities. For instance, some students made claims that rocks are made from lava because they read it in a book and their evidence was "I read it in a book," or when I asked them about it they said "I heard it," or "Somebody told me." But then after I prompted them to use their evidence to support their answers from these activities I think it helped the students to realize why I was having them do that, or why it was important to only focus on the evidence we were collecting during these activities. However, when I'm thinking about this, I'm thinking I should have had a discussion about why I wanted them to use their evidence from the experiments we completed instead of the things they remembered hearing. (Teri, 3/23/06, Continuous-weekly reflection)

This excerpt provides further evidence that Teri was concerned about students using first-hand observable evidence rather than second-hand non-reliable evidence. And, although she did not explicitly explain the differences in evidence sources to the students, she believed students' understandings of the differences between first-hand and second-hand evidence would help them in the development of evidence-based explanations.

Supporting the construction of evidence-based explanations continued during the second unit. In the fourth week she commented on the importance of the role of the teacher and student in the construction of the explanation. That is, whether or not the teacher or the student was constructing the explanation. Teri said that she changed the district curriculum because she wanted to provide the students the opportunity to construct the explanations instead of the teacher doing the explanations. Changing the curriculum demonstrated a connection between the process of constructing evidence-based explanations and meaning making. In addition, she retained the idea that evidence can be generated from models as well as observable hands-on experiments.

In the course of subsequent weeks, Teri focused her self-reports on emphasizing the aspect of what counts as a reliable source of evidence since she was struggling to provide appropriate opportunities to collect meaningful evidence regarding the multiple concepts within the unit of Rocks and Minerals. Furthermore, Teri was conscious that collecting meaningful evidence could also come from alternative sources of evidence such as using diagrams and constructing models. Teri's views of evidence-based explanation construction are summarized in Table 4.5. The table demonstrates that Teri's views and self-reports were consistent with each other. Hence, her views and practices can be located in section B of Figure 4.1.

Teri's Views on Evidence-based Explanations across Units		
	Unit One: Simple Machines	**Unit Two: Rocks and Minerals**
Views	• In order for students to create an evidence-based explanation they need a scientifically oriented question. • Students need to justify their explanations. • Students construct the best evidence-based explanation when they notice patterns in evidence among groups and in whole class discussions.	• There is a distinction between a claim, evidence, and a justification. • Evidence is a great source for helping students construct definitions of scientific terms. • Justifying explanations is a difficult task and children struggle with this endeavor.
Practice Report	• Provided a scientific overarching question • Prompted students to justify their explanations. • Prompt students to discuss evidence in small groups and conducted whole class discussions about the evidence and potential claims based on the evidence.	• Prompt disagreement in students' discussion as a way to help students rely in observations and patterns to draw evidence-based explanations and to justify these. • Used the KLEW chart to help students connect the evidence with scientific terms. • Persist in helping students justify their answers since time pressure obstructed staying on time with certain concepts of the curriculum.

Table 4.5. Teri's Views on Evidence-based Explanations across Units

Teri's views and self-reported enactment of teaching practices impacted her notions of inquiry. Similarly, her notions of inquiry informed how she approached and viewed the construction of evidence-based explanations. Thus, the next section explores her notions of inquiry.

4.2.3.2 Notions of Inquiry

Teri's notions of inquiry were driven and founded by explanation building from evidence. Thus, this section is a reiteration and further development of her core views on explanation building. Examination of Teri's views on inquiry appeared to be instrumental for her views on supporting the construction of evidence-based explanations. Furthermore, her notions of inquiry influenced what she considered effective science teaching. Nonetheless, across the span of the first unit on simple machines Teri's idea of how to support inquiry was broad. This was evident in her explanation of why she assigned her lessons a three or four in the inquiry scale when asked, during the self-report protocols (see Chapter 3 for protocols). She said,

> I think that both of these lessons focus students on a scientifically oriented question, required students to give priority to evidence when responding to questions, encouraged students to formulate explanations based on those findings and required students to communicate, in both verbal and written form, their explanations. (Teri, 3/1/06, Continuous-weekly reflection)

Nonetheless, Teri attained other elements of inquiry, implicitly. For example, she said that inquiry requires connections to scientific knowledge. Subsequently, that scientific knowledge had to be connected to real life problems in order to promote learning. Interestingly, as observed in the previous quote, despite that Teri was "talking the talk," she did not give herself a higher ranking. Despite not having access to Teri's metacognitive process, a reasonable inference is that she believed that incongruence existed between her espoused views and her teaching practices. An element that allows for this inference is examining how Teri defined inquiry. At the beginning of the unit, Teri measured inquiry by the kind of activities that students performed and the amount of guidance the teacher provided. For example, during the first week she rated her lessons as a three because she had to ask a lot of questions. This was apparent when she said,

> The students were performing activities that guided them to an understanding about what rocks are and how we describe rocks but it required a lot of questioning to get the students to attend to the right properties so they could reach those understandings. I felt that way especially during the first lesson. So, although I was not directly telling them what a rock was, I had to ask a lot of questions and play devil's advocate a lot so the students were observing the right things that would allow them to understand the scientific concept the lesson was trying to get across. However, I did not tell the students what rocks were or how to define the term; they used their evidence and explanations from the activities to create their own definition, which was why I gave it a level of three. (Teri, 3/16/06, Continuous-weekly reflection)

Another aspect that appeared to be important for Teri was students' discovering an idea. This was noticeable when she said, "I wanted students to discover a beginning idea of what a rock is and what a rock isn't." (Teri, 3/16/06, Continuous-weekly reflection)

In addition to the kind of activities and students' own discoveries, Teri intertwined the teacher's role, supporting teaching science as inquiry, and supporting the development of

evidence-based explanations as early as in the first week of the second unit. She communicated in her self-reports that she walked around the classroom checking if students were accomplishing the content goals of the lesson; when not, she scaffolded instruction to meet these goals. Similarly, she continuously prompted students in order to foster disagreement among students, which, as a consequence, would elicit explanation justifications. This was apparent when she narrated the following classroom event,

> So the students relied heavily on their observations of the objects and patterns or similarities they saw in their objects to make the claims about what they thought a rock was or wasn't at the end of that lesson. I would say the sorting lesson provided students with multiple opportunities to discuss and debate their evidence because the students were focusing on different properties of the objects. Some students would give explanations such as "the rocks all have weird shapes and the other objects don't," and I heard one student ask, "Well, I think the sponge has kind of a weird shape; it has some holes." And, students were discussing their reasons or explanations for why they put things in certain columns and agreeing and disagreeing depending on the claims. (Teri, 3/16/06, Continuous-weekly reflection)

Teri also linked these events to the challenges time constraints brought to developing such events. Time constraints are important because, according to Teri, they may decrease the time a teacher pays attention to areas of students' struggles. Furthermore, time constrains may limit teachers' becoming critical about the reasons for students' struggles. Therefore, less time is used to re-focus students' attention through science talks that ultimately lead to providing opportunities for students to justify their answers. These relationships among teachers' roles, elements of inquiry and supporting inquiry, and evidence-based explanations were apparent when Teri described the following classroom event,

> However, as I walked around to the groups as they sorted their objects and discussed their explanations, I realized that they were relying solely on physical properties of the objects and individual objects rather than on the non-objects, and that was actually preventing them from coming to an understanding of what a rock was or wasn't. For instance, when I asked the students why a sponge was in the non-rock side they explained that it was soft and squishy and that rocks are hard. I then asked "ok, well if rocks are hard; then why is this glass marble and wooden block in the non-rock side. Aren't they hard?" To this they,

> students explained well they're perfect, they have edges or the marble is round and rocks aren't. Um, these were all good observations but were not getting to my goal of having the students discover that rocks are natural and not man-made objects. I decided as the students were working to change my approach to my questioning and instruction. I gathered the students on the carpet in a circle and asked one student to bring their plate of objects next to the center. I asked this student to sort the objects in front of us. I then asked the question about all the objects on the non-rock side: What do all of those things have in common? On the non-rock side [category] and how does that differ from the other side, which are the rock items. (Teri, 3/16/06, Continuous-weekly reflection)

During the second week of the unit Teri described inquiry while rating her lessons as engaging students in activities that were focused around scientifically oriented questions. Example of scientific questions in which Teri engaged students during that week were: "What do you find when you break a rock, and is it a rock or not?" In fact, she extended her rationale for what makes a lesson inquiry and elucidated the elements of extending knowledge and evaluating evidence. She said,

> The second lesson was actually an opportunity for the students to elaborate upon their understanding of what rocks are and what they're made of. They extended that knowledge to a new context in this lesson where they were asked to determine if another object was a rock. At the same time they were generating new knowledge about what a mineral was and how it was different than a rock. They then evaluated their evidence at the end and compared their observations to reach a conclusion that would allow them to answer the scientifically oriented question posed at the beginning of the lesson. (Teri, 3/23/06, Continuous-weekly reflection)

As the unit progressed she expanded her views of teaching science as inquiry and how to support it. However, her previous views contrasted with her expanded notion of what counts as evidence since she rated the fifth week lessons much lower than other lessons. She said,

> The lessons I taught at the end of this week and early this week were probably level one in terms of reflecting inquiry. The first lesson I taught involved engaging students in the formation of metamorphic rocks through use of a model from food. The lesson I taught this week involved the rock cycle and a teacher demonstration of one cycle a rock could take. I would say the metamorphic rock lesson was a level two in terms of inquiry because the students were engaged around a scientifically oriented question and were collecting evidence through their observations as they created a model of a metamorphic rock but they were not analyzing or drawing their own conclusions about how metamorphic rocks are made. I felt the same way about the rock cycle lesson this week

> because the students were watching me complete a teacher demonstration of one rock cycle way through various formations through the application of pressure, more intense pressure and intense heat. (Teri, 4/12/06, Continuous-weekly reflection)

4.2.3.3 Teachers' Role

Teri was very specific and explicit in her role as a teacher and described her role as instrumental for supporting student's evidence-based explanations. She characterized her role to include: frequently restating the overarching scientific question, allocating time for science talks, asking focus questions in small and large groups, and coaching students to develop linguistically. All these areas were linked to helping students build evidence-based explanations. These ideas were evident when she said,

> I found myself restating the scientifically oriented question I posed at the beginning of the lesson to encourage students to use their evidence to formulate explanations. Also, to encourage students to support their explanation with evidence, I posed questions such as, "If you wanted to prove to your friend that your claim or explanation is right, how would you do it? Or how did you know that?" This way, the students were thinking about what proof they had to make their claim[s], to prove that their claim[s] was [were] valid. Also, aside from encouraging science talk by allocating time specifically for a science talk, I tried to make my way to various groups throughout the room as they performed their experiments. I asked the group members questions about results they were finding, and what they thought that meant, and what they thought would happened during the next test or trial. I found that these questions usually helped the students discuss their results and findings as they collected their evidence and encouraged them to think critically about their results as they recorded them. This seemed to prepare them to talk during our science discussions as well. Um, I also think that teachers need to coach the students to develop communications skills so that they can lead their own discussion and debates without a lot of teacher's direction, which is what I hope to eventually do. (Teri, 3/1/06, Continuous-weekly reflection)

In addition, to these roles Teri appeared to view her teacher's role as one of providing students with experiences similar to those that scientists have. This was apparent when she implicitly stated, "Students tried out a new location of [for] the fulcrum; they recorded the evidence or results in a systematic and organized way" (Teri, 3/1/06, Continuous-weekly reflection).

An important aspect of Teri's role was her self-awareness of the teacher's role and impact of teachers' actions in inquiry effectiveness. This was observable when she made an explicit connection between students' abilities to think critically and the kind of questions being asked. She said, in her self-report,

> I think the difference in my questions about the rock cycle was that the students had to think about what they had observed and the fact that they observed different rocks being formed based on different processes in the earth to make claims about the rock cycle. (Teri, 4/12/06, Continuous-weekly reflection).

Teri also viewed her role as critical for deciding when to hold class discussions that would lead to evidence-based explanations. Furthermore, she was conscious and intentional in her decisions while teaching in order to ensure that the proper opportunities were available to students to collect evidence, analyze evidence, and make well-supported scientific claims. These views were demonstrated throughout her self-reports in a complex interconnection between multiple constructs of the framework. That is, when analyzing Teri's evidence difficulty arose for coding excerpts independently since each code was linked to another code explicitly and not doing so was excluding rich information and not getting a full picture of her thinking. For example, at the beginning of the study she was vocal about the inquiry process involving multiple points of views; then, she immediately linked the idea to what she needed to do in order to aid such development. Thus, she said, "Students need to work in groups so they can listen and respond to each other's observations" (Teri, 2/20/06, Context/Initial Questions). Then, she proceeded to add scaffolding students' activities and thinking is necessary, and carving out time for such things is essential. This complexity of ideas reveals that Teri viewed the construction of evidence-based explanations as a complex task that required thinking about multiple teaching components at once. It also seems to show that, for her, teaching and learning are closely linked.

4.2.3.4 Public Reasoning

Teri's ideas of science talk at the beginning of the study were grounded in the nature of science. For example, during the entrance interview she said,

> I guess you would just have to address the fact that this is why scientists do multiple tests, and you have to find out if your tests are valid, and it's important to do more than one test to figure out if the result is right. What if you do it again and without the same result? Then you have to figure out what variables are changing and affecting the results. (Teri, 1/25/06, Entrance interview)

This view of the nature of science was then grounded in the concept of public reasoning and helping children discuss evidence, explanations, and experimental procedures. Thus, Teri described talk more sophisticatedly and was referring to scientific talk as the action of debating evidence, engaging in problem solving, and questioning validity.

Teri's views of public reasoning contrasted with her views toward the end of the study and showed some significant differences. Although her ideas had not changed, she grounded public reasoning in a teaching context and the foreground of the scientific aspect of reasoning. Thus, Teri described talk within the context of teaching and what it means to help children acquaint themselves with scientific understandings. That is, science talks are viewed as a teaching tool for children to think aloud about claims and connect them with evidence.

A closer examination of Teri's views regarding public reasoning across units revealed that she viewed public reasoning and discourse as a central tenet in inquiry. Thus, public reasoning was highlighted in Figure 4.1 across time. She described talk as a pivotal aspect in challenging students' points of view, helping them compare evidence, analyze evidence, and "regulate" their understandings. These ideas, as with other framework constructs, were intertwined in Teri's self-reports. For example, during the Simple Machines unit she described that students' abilities to have public discourse is not innate and that teachers need to scaffold the process. Thus, she problematized this aspect with how to scaffold, in the process, the

construction of evidence-based explanations, and further, how to assess students' explanations. On the other hand, during the Rocks and Minerals unit, Teri focused her attention in how to help students' use public reasoning as a vehicle to justify their explanations while questioning evidence validity and comparing collection procedures. Interestingly, when Teri's views were contrasted with her self-reported practices these appear to be in-sync. Tables 4.6 and 4.7 provide a comparison between her views and her self-report practices across units.

Teri's Views and Enacted Reports on Science Talks 1st Unit (Simple Machines)		
Week	**Views**	**Practice**
One	No available evidence	
Two	Is a place for students to formulate explanations based in evidence collected; however this process is not innate to students. The process of formulating explanations allows teachers to informally assess students' understandings. These conversations can occur within small groups, but the teacher needs to allocate time for these to occur.	Provided a scientific oriented question to ground students' explanations and prompted students with well planned sub-questions that fostered the discourse about the evidence and explanation. In order to use appropriately science talks, carefully planned lessons and modified practice accordingly.

Table 4.6 Teri's Views on Science Talks during the Simple Machines Unit

Teri's Views and Enacted Reports on Science Talks 2nd Unit (Rocks and Minerals)		
Week	**Views**	**Practice**
One	Justifying explanations during the science talk can lead toward students' understanding the main concept since it continuously focuses students' attention on the content.	Walked around listening to students' conversations in an attempt to notice incorrect scientific ideas while also focusing students back to the main scientific concept in study.
Two	It is a place for discussion and debate about evidence and explanations. Engaging in science talks allows students to understand general conclusions or "big ideas." However, it is important to take the appropriate time to do the talk in order to ensure that these goals take place.	Prompted students to look at data for pattern and discern how evidence supported specific claims.
Three	A vehicle for students to reason out loud with each other.	Did not mentioned how she accomplished this task but said that she requested students write down their explanations and justifications.
Four	An opportunity to assess students' understandings.	Used probing questions to assess students learning.
Five	No reference to talk	Used graphic organizers, charts, and questions to focus students thinking and discussion.
Six	When performing science talks, students have to be comfortable in order to not be afraid of contradicting each other.	No reference
Seven	No reference	

Table 4.7 Teri's Views on Science Talks during the Rocks and Minerals Unit

4.2.4 Influence of Reflection Protocols in Science Planning

Multiple aspects of reflection protocols influenced Teri's planning and teaching. As evidenced by data, Teri valued the construction of explanations. Thus, apparently, protocols helped her think about multiple relationships, such as experiment-explanation, explanation-scaffolding, and data-claim. Evidence for this claim emerged by contrasting excerpts from the entrance and exit interviews. For example, Teri stated at the end of the study that when experiments, procedures, and data are not that obvious to children they encounter difficulties in

understanding the concepts intended in the experiments, and therefore, students struggle to use the evidence collected in constructing explanations.

An additional influence of the protocols with respect to science planning was the influence of using an inquiry scale. The use of this inquiry scale elicited participant's in-depth thinking. For example, self-rating lessons enactment provoked Teri to question her beliefs about what was effective science teaching. By effective science teaching she described questioning scientific content, lesson components, and how lessons aid children in developing scientific explanations. This questioning was evident at the beginning of the study when she claimed that she was just trying to recreate what she learned during the science methods course. However, further examinations of her self-reports revealed Teri was doing more than just trying to recreate what she learned in the science methods course and that she was indeed being critical and reflective as a result of the protocols. This appeared to be the case when she said,

> For instance, when we were having a science talk at the end of the "Fiddling and Fulcrums" lesson, I got out a model of a lever so the students could come up to the front of the room to explain what they were thinking. I found that this helped the students express their thoughts and helped their classmates understand their thinking. I also knew that I wanted the students to focus on thinking critically about the evidence they were collecting, so I provided the students with a graphic organizer to organize their findings. I didn't want the students spending too much time trying to figure out how to organize their evidence instead of actually collecting the evidence and thinking about what that evidence told them about the question they were trying to answer. (Teri, 3/1/06, Continuous-weekly reflection)

This notion of protocols challenging Teri's thinking was evident when she said,

> For instance, I mentioned in previous reflections I was questioning whether some lessons I was teaching were inquiry based on the essential aspects of inquiry chart we used in 458. I think that reflecting on lessons I am teaching and thinking about the essential aspects of inquiry has helped me grow as a science teacher because my beliefs about teaching science inquiry have been challenged. (Teri, 4/24/06, Follow-up)

As Teri continued to reflect on her self-reports she said,

> I believe even more so now than I thought in 458 that emphasizing evidence and explanation are key factors to fostering scientific understandings. Understanding in students during inquiry lesson, inquiry should be based around collecting evidence because this is what students should be using to formulate their own explanations or understandings. (Teri, 4/24/06, Follow-up)

All the previous quotes demonstrate that Teri developed robust understandings of supporting evidence-based explanations. Therefore, she was espoused to support students to make claims that were directly connected to evidence while questioning validity and developing scientific understanding.

4.2.5 Context Elements' Influences on Teaching Science as Argument

4.2.5.1 Science Methods Course

Many elements appeared to be influential in Teri's understanding of effective science teaching. Furthermore, these influences also appeared to affect her planning and teaching decisions. These influences were the science methods course, TESSA cases (see Chapter 3 for a description of these cases) provided in the science methods class, and the National Science Teachers Association (NSTA) Teacher's Journal (*Science and Children)*.

Apparently the science methods course (SCIED 458) influenced Teri's planning and teaching decisions for both units. Evidence supporting this comes from the fact that at the beginning of the study she reported a desire to copy what she observed and experienced from the science methods course. Subsequently, at the end of the study, she shifted her attention to wanting to retain the elements learned in the methods course rather than copy them. This is exemplified in the following entrance interview excerpt,

> Interviewer: Oh, just about how your thinking about science teaching is different than it might have been when you started?
>
> Teri: I think mostly like doing the activities in class [SCIED 458] and seeing the difference between, you [interviewer] didn't sit up there and lecture, like I did sit inside college classes, a lecture; I didn't just sit there [SCIED 458] and learn about these things, we actually did the experiment and learned. We went through the process of learning

> what scientists learn and how they learned it, which is different from what I think what I thought I would have been doing. (Teri, 1/25/06, Entrance interview)

Another example demonstrated that Teri was trying to replicate the science methods course attributes was when she said, "I feel like I'm repeating, you know, a lot of what I learned in that class [SCIED 458], but it is how I hope to teach" (Teri, 1/25/06, Entrance interview).

In addition to Teri's engagement as a learner, TESSA cases were also influential in her teaching. Teri used these cases to compare and contrast her own teaching with her mentor-teacher's. Thus, she holds TESSA cases as standard of critical elements to attain when teaching science as inquiry. She said during the entrance interview,

> That's why I thought TESSA was really important, like the combination [activities and TESSA], and the readings, and then actually going through it, and applying everything we had learned about, um by doing those experiments and by watching TESSA. Like I've said, I don't know if I would have really paid attention to what you were doing after [the experiments], like, in a couple of lessons, I realized that you would like pose a question or induce some something to get us to, you know, some problem we needed to solve or something that we disagreed upon, or something we didn't think would happen. And I kind of picked up on parts that you would do each time, and we would always come back together and things like that. But then the TESSA cases helped me see the teacher's role actually went after seeing everything up and organizing it; that's what you did, while the kids were doing their exploration. (Teri, 1/25/06, Entrance interview)

An additional example of TESSA's influence on Teri's teaching was self-explained by Teri when she said,

> And that was really important for me to see what the teacher was doing in the TESSA cases. I didn't really stop and think "What's the instructor doing now while we're doing this?" Or "She is going around and talking to us and asking us questions." I don't think I would have ever picked up on that but by seeing the TESSA cases I always saw the teachers in the cases going around and asking questions. In all the clips the teachers were sitting there with groups and asking questions and paying attention to the argument and getting students to go back to the evidence. (Teri, 1/25/06, Entrance interview)

4.2.5.2 Professional Development School Peers

Influences from Teri's peers were somewhat limited in her reports; however, some specific instances appeared in which changes to lesson plans or her decision-making toward teaching was greatly influenced by her peers. For example, in her metacognition process of trying to understand what inquiry is and how to best help students construct evidence-based explanations, she referred to what her peers were doing. She said,

> I also brainstorm and discuss science lessons with other interns to get more insight and possibly ideas for lessons. I talk to my roommate about the lessons she is teaching as well to get an idea about how other concepts and units are taught. (Teri, 4/24/06, Follow-up)

This idea of talking to others about lessons was also repeated later when she referred to a problem's solution by what other interns did. She said,

> Other interns had placed soda cans in the freezer to explode to simulate what would happen to rocks. So we used that as another example, also the fact that water bottles don't sit flat after freezing. (Teri, 5/2/06, Continuous-weekly reflection)

Thus, although only two instances described her peer interaction as an influence, these appeared to be powerful incidents for her teaching.

A final influence within the context of the Professional Development School was Teri's interaction with her mentor-teacher. Although this interaction appeared to be insignificant in Teri's reports, the mentor-teacher provided an open environment for Teri's teaching. This was noticeable because Teri reported,

> I also feel that my mentor is very supportive of my science teaching. She is always open to discussing my ideas for altering lessons or for my questions about whether or not I think something would be appropriate or something would make the lesson more inquiry based or engaging for the students. (Teri, 2/20/06, Context/initial questions)

In addition, the mentor-teacher allocated time for substantial discussions about pedagogical decisions, thus arguably influential there were influential to Teri. This was apparent in Teri's description during the exit interview. She said,

> We [my mentor-teacher and I] always had conversations about whether it was better to switch around the order of things, especially in this last component we were teaching with the soil where we tried to actually incorporate the extending of the knowledge to scientific understandings…Rose and I talked a lot about when we thought like the lesson should go and the progression of the lessons throughout the unit and the progressions within lessons. (Teri, 6/12/06, Exit interview)

Thus, the quote above demonstrates that possibly some of Teri's interactions with her mentor were influential for how she appropriated components of teaching science as argument.

4.2.5.3 Children's Ideas

Student's understandings and misconceptions were an influential factor in Teri's science planning and acquisition of components for teaching science as argument. During the unit on simple machines, apparently, Teri was aware of students' misconceptions and deliberately tried to provide familiar experiences to students while confronting the science misconceptions. Hence, she diverged from the school district's curriculum; in her understanding, students were knowledgeable about examples of levers. Thus, Teri thought that providing more examples was redundant. As a result of Teri's understanding of students' misconceptions and prior knowledge, she planned science talks to address these issues. Teri described the latter as,

> I spent more time having students talk together in a science talk than I had initially planned. I did this because I felt that the students had enough evidence after testing the location of the fulcrum in three places to make evidence-based explanations about where they should place the fulcrum to make it easiest to lift a load. I did not think they needed to continue to test the three other holes before holding a discussion. It was not until I was teaching the lesson that I was able to judge the time I felt would be adequate for these students to analyze their evidence and draw conclusions. (Teri, 3/1/06, Continuous-weekly reflection)

Teri's understanding of students' misconceptions and prior knowledge intrinsically retro-fed back into utilizing educational research to infuse her science planning. However, this planning activity appeared to be a result of the influence of the science methods course. That is,

the science methods course stressed the importance of literature in helping teachers understand what is known regarding content, teaching, and students' misconceptions. Thus, literature from NSTA and other websites became a central part of Teri's decision-making process. For example, articles that focused on misconceptions helped her structure experiments and what concepts to emphasize. In addition, she sought articles regarding rocks and mineral content as a guide to critical concepts for learning. Thus, what kind of claims she could have expected children to articulate? The idea of researching journals came from a project during the science methods course. During the course, prospective teachers designed and implemented a three-day teaching practicum. In fact, prospective teachers had to do a content research assignment from the literature to investigate children's misconceptions about the topic. Teri described these events; she said,

> I think the concept interview was cool, because I'd never really, I mean, I've thought of that, and I don't know if I'd really be able to do that as a teacher, take kids out, but it was nice to know, like, what they really knew, where their misconceptions were and where to start from; I think is important. I thought that [the concept interview] was worthwhile to get experience and realize that you can do that or in different ways you can kind of get, like the KLEW chart, get an idea on what your kids already know. I mean the whole lesson project [the three day teaching], I think was really important just actually getting into it and figuring out and working with the group was important for me because we debated a lot, "well, is this engagement?" or you know, where's their explanation here, where are we going to have them do this and it was kind of thinking about like how are we going to incorporate all of these things into the lesson, and we don't just want to tell them [students] things, so that was important. (Teri, 1/25/06, Entrance interview)

This notion of research was prevalent throughout the study, since during second unit, she also referenced it in her self-report. She said,

> I'd read in research on teaching students about rocks and minerals and the formation of rocks that a common misconception among elementary and middle school students is the fact that they tend to think of rocks, think that rocks are man made because they perform experiments in classrooms that deal with food and other common materials to model the process of how rocks and different types of rocks are formed…Although these seem obvious and common sense, I read that it was a common misunderstanding, so I made

> sure we discussed these differences at the end of the lesson and throughout the lesson. (Teri, 4/3/06, Continuous-weekly reflection)

Likewise, research knowledge was powerful enough that she changed aspects of the curriculum to coincide what she learned from educational research. This was evident when she said,

> In the next few lessons we're learning about the rock cycle, and I want to make sure the students understand that this is not really a process of forming rocks but more of how the three types of rocks are related and how they go through changes in the different rock types. Again, this is based on the research I've read this week on teaching rocks and minerals to students. (Teri, 4/3/06, Continuous-weekly reflection)

4.2.6 Summary

Teri's story is extraordinary. Throughout the study she demonstrated an orientation towards inquiry that reflected its core an emphasis in helping students construct evidence-based explanations. Likewise, she demonstrated sophisticated thinking about what counts as evidence and placed as a central tenet the scientific content in the process of meaning making. Furthermore, she attended to research in order to ground her views and enacted teaching practices. Finally, Teri's story depicted the importance she placed in the teacher role's and public discourse and reasoning.

4.3 Angela's Story

4.3.1 Description Classroom Context and Teaching

Angela was placed in a first grade classroom. Her classroom had nineteen students: seven Caucasians, and twelve representing other races. Of the nineteen students three were ESL students; one was physically disabled; one spoke no English, and one had an Individualized Education Program (IEP). The gender ratio of the students was eleven females and eight males. The physically disabled student left the classroom each day for learning support; the ESL students left the classroom most of the morning for reading support; and the student with an IEP left the classroom for social skills therapy but not for academic support. Three children were in the process of litigation to formalize participation in learning support. Furthermore, these three children spent most of their time working with a classroom paraprofessional since they were unable to read or work independently.

In general, science was not taught on a regular basis, but when it was taught it did not have a designated time. Angela's mentor-teacher incorporated science during "read aloud times" by sharing articles from a children's science magazine. In addition, he often read factual information sheets to students and showed movies; however, these science-related materials were inconsistently administered during the months prior to the research. Angela's mentor-teacher provided most of these activities, and science was not a priority when planning weekly schedules and lessons. In addition, worth noting is that her mentor had not participated in science professional development as part of the Professional Development School.

Angela planned and taught two science units, Prehistoric Life and Magnets, during her student-teaching field experience following completion of a science methods course and during her participation in the current research. To suit her needs, Angela modified and adapted the units from those developed by other teachers. The two science units Angela taught spanned nine

weeks, Prehistoric Life lasted five weeks and Magnets four weeks. Table 4.8 shows a timeline for these units and a general overview of the goals for the units using Angela's words.

Student-teaching Field Experience Student-teaching Spring Semester/Science Teaching		
Date	**Unit Topic**	**Unit Foci Described by Angela**
2/27-3/3	Science Experiment in Social Studies Unit	Used plates and light source to describe how animals stay cool in the dessert by hibernating within insulated cactuses and underground.
3/6-3/10		Spring Break
3/13-3/17 (Week One) 3/20-3/24 (Week Two) 3/27-3/31 (Week Three) 4/3-4/7 (Week Four) 4/10-4/14 (Week Five)	Unit 1: Dinosaurs	1. Where are fossils found? 2. How paleontologists go about discovering things that cannot be directly looked at, what clues they use? [sic] 3. Get them [students] to understand how scientists use things we know to figure things out that happened in the past. 4. Get them [students] to understand the different layers of soil (3/17/06)
4/14-4/28		No Science
5/1-5/5 (Week One) 5/8-5/12 (Week Two) 5/15-5/19 (Week Three) 5/29-6/1 (Week Four)	Unit 2: Magnets	1. Magnets are useful to men. 2. There are many kinds of magnets an [sic] all most [sic] be handle [sic] with care 3. Magnets attract some objects. 4. Magnets attract objects through many materials. 5. All magnets have a south pole and a north pole. 6. Like poles in magnets repel each other, unlike poles attract each other. 7. North pole of the magnet points towards a magnetic pole of the earth.

Table 4.8: Angela's Units: Overview and Foci

4.3.2 Overview of the Units

The Prehistoric Life Unit revolved around identifying a dinosaur described in a series of fictitious letters from paleontologists that were excavating bones in South America, and provided scientific information regarding bone discoveries. This overall theme helped ground concepts about fossils as described in the school district's curriculum. These were the basis for five weeks of activities. Angela's self-reports were general when providing a summary of the activities

related to foci she was performing with children as presented in Table 4.8. The Magnets Unit mainly revolved around examining which materials are attracted to magnets and the properties of magnets (see Table 4.8). Tables 4.9 and 4.10 provide a summary of the activities as described in the curriculum guide.

Angela's Summary of Activities for Prehistory Life	
Week	**Summary of Activities**
One	Students investigated a mystery box in order to test models and inferences. Students simulated the Law of Superposition. Students simulated a petrifaction process.
Two	Students investigated what is the ratio for their own foot length, leg length and total height. Students used the mystery dinosaur's measurements to approximate the size of the dinosaur.
Three	Students created and interpreted their own foot tracks. Students interpreted animal tracks and determined how fast the dinosaur was moving. Students used clues about their mystery dinosaur's foot size and stride to infer if the dinosaur was walking, trotting or running.
Four	Students listed things that they could learn from looking at an animal's skull. Students examined animal's eye placement: stereo or monovision. Students examined their teeth by eating food and then they looked at skull pictures and inferred if the. dinosaurs were herbivores or carnivores which was later used to determine if the mystery dinosaur was herbivore or carnivore.
Five	Students assembled pictures of the mystery dinosaur's skeleton and glued them on a piece of paper. Students used evidence to identify their mystery dinosaur.

Table 4.9 Angela's Weekly Activities Overview for the Prehistoric Life Unit

Angela's Summary of Activities for Magnets	
Week	**Summary of Activities**
One	Students tested magnetic and non-magnetic objects.
Two	Students tested that magnets do not attract to all metals.
Three	Students tested magnets through multiple surfaces such as desks, theirs hands, books, and water.
Four	Students tested magnets' strengths as compared to their sizes.

Table 4.10 Angela's Weekly Activities Overview for the Magnets Unit

4.3.3 Representation of Framework Elements

Angela's interpretation and acquisition of the framework was fully examined throughout the teaching of the two science units. These analyses revealed that her reports on teaching science as argument developed in accordance with the current study framework as time progressed. In general analysis showed that her interpretation and acquisition of the framework at the beginning of the semester was less complex than at the end of the study. Nonetheless, Angela's views throughout the course of the current research were still more developed than the typical prospective elementary teachers portrayed in the literature (Appleton, 2006; Davis, Pettish & Smithey, 2006; Grossman et al., 2005). In synopsis, later fully described, Angela's espoused views were that science teaching is an engaging, interesting activity that helps students understand and explore particular questions and construct answers that are tentative. Furthermore, she viewed teacher's content knowledge as impacting children's ability to meet curricula objectives with the use of public reasoning. Hence, she believed that evidence collected in classroom activities helps students construct wonderings and scientific explanations need to match teaching goals.

Angela's views at the end of the study presented more sophisticated views from those just described. She continued to espouse that supporting evidence-based explanations in the classroom is central to science teaching. Furthermore, she stated that regardless of teacher-led or student-led teaching that in both cases science teaching required the teacher to understand subject matter, know students' prior knowledge, prompt for the construction of evidence-based claims, and provide data collection and analysis experiences, and thereby foster an appropriate environment for explanation construction. In addition, Angela's views at the end of the study can be summarized by stating that she continued to emphasize that evidence and explanations needed

to match teaching goals. This comparison among Angela's general views of science teaching at the beginning and end of the study are critical for understanding her appropriation of the features of the framework across the current study. Angela's development of views is illustrated in Figure 4.2. The figure illustrates how Angela, at the beginning of the study, emphasized identifying patterns in evidence while trying to help students coordinate the evidence with claims. However, at the mid-point of participation in the study, she further appropriated utilizing public reasoning; at the end she combined these elements while attempting to engage in meaning-making.

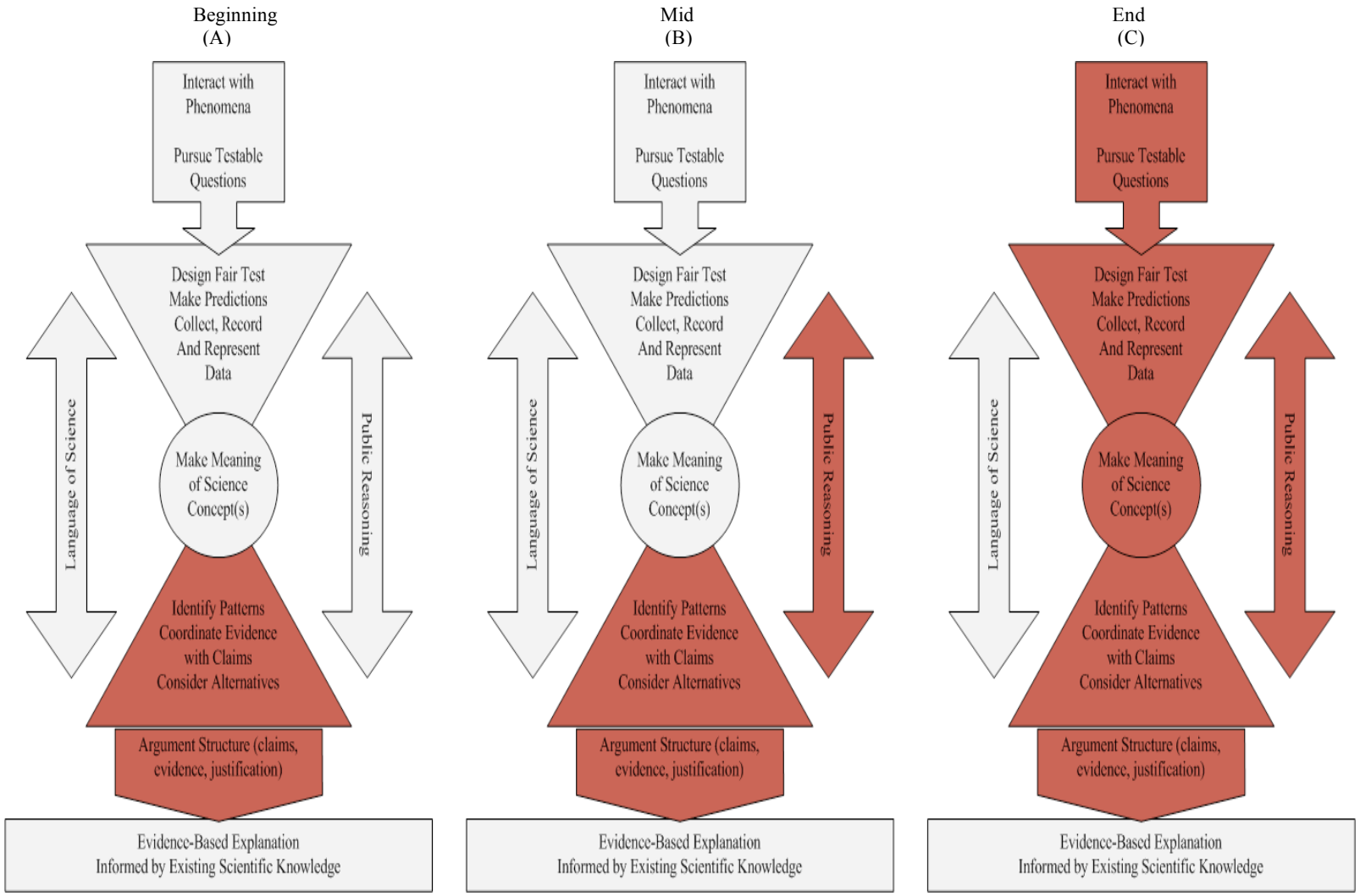

Figure 4.2 Angela's Emphasis of Framework Elements at Three Distinct Points

Placing Angela in these aspects of the framework is important because the literature suggest that prospective elementary teachers are often caught in an approach of "activitymania" (Moscovici et al., 1998). Accordingly, prospective elementary teachers teach a collection of activities that are disconnected from one another and that do not properly address science concepts. Furthermore, according to methods courses and field experience studies prospective teachers struggle to enact in field experiences what they learned in methods courses (Clift & Brady, 2005). Thus, the next sections explain what elements of the analysis framework Angela appropriated and how these relate to Figure 4.2.

4.3.3.1 Constructing Evidence-based Explanations

Appropriation of the component of helping students construct evidence-based explanations is very interesting in Angela's case. As observed in Figure 4.2 Angela was paying attention to the fact that claims need to be backed-up with evidence also, that they should be justified. However, throughout the first unit (Prehistoric Life) demonstrated a constant struggle to teach science consistent with her views. This struggle, although significantly less apparent during the second unit was still present throughout her participation in the study. Thus, this section attempts to capture the struggle Angela had between her views or commitments of what good teaching consists and what she described as her enacted practices.

Angela depicted an emphasis on students' constructing the explanations rather than the teacher. Furthermore, throughout her self-reports Angela deemed important to support explanations with evidence. However, this emphasis was inconsistent and very confusing throughout the first unit (Prehistoric Life) that she taught, thus demonstrating the continuous struggle Angela had between her views and practices of effective science teaching.

Angela's ideas about teaching science as argument translated into practice by how she attempted to support the construction of evidence-based explanations. Throughout the course of the study, references to supporting evidence-based explanations were less apparent when she struggled with the content of the unit and more apparent when she felt successful with the unit or appeared more content knowledgeable. This was apparent during the beginning of the first unit (Prehistoric Life) where Angela made some naïve references to evidence and explanation. Naive references means that she mentioned ideas that were related to evidence and explanation but failed to properly connect these or use them in a context that was significant to the process of meaning making. For example, she referred to observations children were making during the mystery boxes activity as a point of reference to represent how children were collecting evidence in order to arrive at an educated guess of what was inside the box. She said,

> I love the discussion that we had afterwards about what happened with the mystery boxes. Students were able to discuss different model possibilities among themselves without coming in big fights about it. Students were able to argue their point of views and say, "Oh, no I heard and it sounded like a ball rolling." So it was a ball. (Angela, 3/17/06, Continuous-weekly reflection)

However, she never described how this conversation about evidence connected to the explanation of the concept in the unit. During the second week of the unit she continued to struggle to help students formulate evidence-driven explanations. An example of a quote that demonstrates her difficulties between what she espoused to do and what she did is the following,

> The students got to draw a diagram of what the experiment was about with the sand and the sponge bone. And from that then they wrote "What do you thought [think] [sic] was going to happen and why?" (Angela, 3/23/06, Continuous-weekly reflection)

The quote demonstrates that she was trying to help students to record observations and start drawing some observations; however; she relied on predictions instead of evidence as a way to start formulating some explanations. Furthermore, she appeared to struggle with how to help

students collect data and use that data in the explanations. Hence, she focused her enacted practices on using questioning as a way to help students formulate explanations. She described,

> Students were able to look for patterns between the two sizes of feet. They knew that one foot was wider than the other so they were able to contrast four feet versus two feet. Students were also able to see the toes. When I asked or probed, students did a nice job discussing and explaining things and they were very excited to discuss. (Angela, 3/23/06, Continuous-weekly reflection)

Thus, the last quote also demonstrates that Angela was conscious of the positive yields in student's answers when she asked effective questions. Furthermore, the quote also demonstrates that Angela was sometimes able to use effective teaching strategies towards teaching science.

Although Angela was trying to help children use their observations for formulating explanations, she never described what counted as a good observation worth using in a scientific explanation. In other words, she wanted students to drive explanations from observations but did not help students consider the quality of observations. To complicate matters, she described contradictory ideas by describing the kind of explanations she was expecting from her students by saying, "I am looking for their opinions and their beliefs." But then shortly after, she said,

> I want them to feel like "I know the answer." I know [it] is right because a, b, and c as opposed to a situation. "I think I am right, the teacher is going to tell me I am right," and not having that self-confidence in and their believe in themselves. And as with inquiry they can back it up [student's answers] with evidence, and as they learn to discover that evidence [ended abruptly]. (Angela, 3/23/06, Continuous-weekly reflection)

This sudden back and forth on emphasis on the framework could be potentially linked to her pedagogical struggles in engaging children in practices consistent with argument in elementary science due to lack of content knowledge. Evidence to suggest this potential link is apparent during the third week of the first unit when Angela described how she was attempting help students collect and connect evidence to an explanation. She said,

> How the students collected evidence was by using yarn to represent the leg length and the body length. Then we put the foot beside it. Later, I had students draw what they thought their dinosaur looked like. I reminded students of the information they had, whether the dinosaur was two legged or four legged. I am not sure I did a good job having the students connect evidence with the explanation. I think that is something I really need to work on it. (Angela, 3/31/06, Continuous-weekly reflection)

In this attempt to help students connect evidence to explanation, she revisited the idea of using questions to guide students. She stated,

> I am not sure that the students are automatically looking for questions or trying to find evidence, so I am trying to constantly ask questions like, "Why? What do you remember? How does it work?" (Angela, 3/31/06, Continuous-weekly reflection)

Another example of her attempts to help students use evidence to back up their claims was evident when she described asking students to explain the "Why?" of their claims. She said,

> We proceeded with the letter; we read it over together; we looked over the skull, and the kids predicted whether it was herbivore or carnivore. The students did quite well and they were able to explain their reasons. Then we also started discussing about [what] we did know about their dinosaur, trying to get them ready for the final letter. (Angela, 3/31/06, Continuous-weekly reflection)

Angela's emphasis on the structure of the argument can be characterized in Figure 4.2 section B. By the end of the first unit as discussed above she started to emphasize public reasoning. As Angela started teaching the second unit (Magnets) she continue to struggle enacting her views of effective science teaching. However, these struggles were less apparent during this unit. In her self-reports she described more emphatically her interests in helping students construct evidence-based explanations. She reported that her planning revolved around students constructing claims and supporting those with evidence. Angela said,

> The students seemed to already have an understanding that all magnets have north and south poles. They were not able to say those specifically. I think how I am going to approach this now is rather than necessarily teaching this I want students to be able to see how they can make the claim and back it up with evidence. (Angela, 5/8/06, Continuous-weekly reflection)

Noticeably, this quote is different from previous quotes were Angela's focus on evidence-based explanations was scattered. An example that demonstrates more in-sync views and enacted practice in Angela's self-reports is when she gave specific examples of when and how children were constructing explanations based on evidence. She said,

> Students were able to explain how they sorted the materials. They were able to show me some things they did. For example, when a child said "Oh it attracts through my finger," this child spent a lot of time proving her point while her friend helped her. They were able to provide proof or provide evidence that magnets can attract through things. (Angela, 5/8/06, Continuous-weekly reflection)

As the unit progressed evidence suggests that Angela was able to better appropriate the element of helping students construct evidence-based explanations. Furthermore, she grounded the construction of explanations by also placing emphasis on experimental designs in relationship to the pursuit of a testable question (see Figure 4.2). Nonetheless, there were still elements contradictory to notions of inquiry. For example, she emphasized the notion of discovery through exploration. However, none of the descriptions of the activities led to believing that the lessons were discovery in their natures. Interestingly, in the midst of Angela's conflicting ideas she described how the explorations she was providing students lead to rich discussions among students. She said,

> We discovered that things that we thought were going to be magnetic weren't. For example, we thought that our white board and our whistle on wheels would be magnetic but they weren't. The students discovered as they were exploring. Then, we gathered together on the carpet and we discussed what were some of the things that were magnetic and what were some of the things that are not magnetic…. (Angela, 5/15/06, Continuous-weekly reflection)

As the emphasis was placed on discovery Angela also emphasized the notion of children's talking about their results and verbalizing their conclusions. She said,

> I encouraged science talk through asking kids questions. When the child indicated prior experiences with magnets and computers I asked questions. I had the child explain and give more details to share with the rest of the class. Students started sharing information

with each other, which I think is building upon their evidence and claims. (Angela, 5/15/06, Continuous-weekly reflection)

The sources for accepted explanations during both units were reported differently. For example, during the first unit Angela appeared to emphasize students' prior knowledge as the source of evidence; whereas, during the second unit, she emphasized students' evidence gathering through experiments. Although Angela was not clear about what she meant about prior knowledge, apparently, she was using the word to not only refer to students' experiences outside the classroom but also to refer to knowledge gained through activities. Table 4.11 compares these differences while maintaining the language that Angela used. In addition, the table clarifies Angela's self-reports from her views and her enacted teaching practices summarizing the disconnection in views and practice described earlier.

Angela's Views on Evidence-based Explanations Across Units		
	Unit One: Prehistoric Life	**Unit Two: Magnets**
Views	• Stated that observations and prior knowledge are acceptable forms of evidence. • Stated that evidence collection processes requires students to use inference skills. • Stated that explanations need to be connected to evidence.	• Stated that claims must be backed-up with evidence. • Stated that explanations consist of evidence. • Believed in sequencing lessons as experimenting, explaining and wondering. • Believed that children are more able to verbally state their explanations than to write them.
Practice Report	• Prompted prior knowledge as an evidence source. • Required students to explain claims by using the clause "I believe…because." • Asked numerous questions eliciting explanations. • Students collected evidence in various ways obtaining conflicting results. However, it was problematic for reaching consensus and evidence-based explanations.	• Prompted students to observe patterns in evidence. • Used students' evidence-based explanations to foster and pursue new scientific wonderings. • Allowed students to model phenomena as a tool for explanation development.

Table 4.11 Angela's Views on Evidence-based Explanations across Units

4.3.3.2 Notions of Inquiry

Angela's views of the role of the teacher directly influenced her reported views on inquiry, thereby impacting which elements of the framework she appropriated. Since Angela valued teaching science as argument, a critical examination involves her notions of inquiry. Overall, Angela's views of inquiry were naïve, however, self-reports demonstrated that she was very committed to inquiry. Angela attended to elements of inquiry at the beginning of the study; she thought of science teaching as inquiry as an inclusive endeavor that should connect to children's everyday lives while allowing them to explore, discover and participate in discourse about their thinking. She also described a relationship between hands-on to be and inquiry teaching and claimed to struggle with notions of certainty in science and how to translate her ideas into actual teaching practices. These ideas about teaching science as argument were evident during her entrance interview with quotes such as,

> I do not want to be up there just lecturing, I want it to be a group discussion I want it to be hands-on. I want to be interactive and if it's not that then, I need to move on to something else and find a way to make the lesson engaging and interactive. (Angela, 1/23/06, Entrance interview)

> I see them [hands-on and inquiry] as going together, because, inquiry is asking questions, like looking for answers. At this stage of the game I think students need to have hands-on; they absolutely need to have hands-on experiences. Because at this age students are so tactile, they're touching everything; Students need to touch it, need to feel it, need to see it. By exploring and doing hands-on experiments students will come up with questions. I think by just sitting down and talking about they are not necessarily going to come up with great questions I think I'll start the questions and then they can go back to their desks or stations to explore something and from there they can come up with more questions for discussion. I think I have to have hands-on experiments. (Angela, 1/23/06, Entrance interview)

As early as in the entrance interview, as demonstrated by the quotes above, Angela had some naïve conceptions of teaching when she said, "Students need to touch, need to feel it." These naïve views also attest to the argument that Angela continuously struggle between her

views and her enacted practices. Angela's views of inquiry were crucial in understanding how she interpreted some of the protocol questions that ultimately scaffold the framework acquisition. During the first week of the Prehistoric Life Unit, Angela rated her science lessons as a "strong 4." She claimed a four because lessons were not completely student driven. She said,

> As a teacher I came with predetermined lessons [from the curriculum] that I wanted to cover… I let the students ask the questions, from their comments and wonderings I went through the lesson. (Angela, 3/17/08, Continuous-weekly reflection)

Angela also viewed inquiry as students making discoveries. For example, during the first week of the unit she said,

> I am not sure that they had the connection that the salt and water was going to fill up the holes in the sponge; which is good because it was something that they would discover. (Angela, 3/17/08, Continuous-weekly reflection)

Although Angela never explains what she meant by discoveries, the interpretation based on her available data is that she was using the word to refer to explorations that had a specific purpose leading to an objective. This is important because she used the word frequently and does not refer to the classic definition of discoveries as acquiring something new or unknown, that is, the scientific context of discoveries as something unknown to the scientific field. Another example of Angela's views of inquiry was evident during the second week of Prehistoric Life as she continued to rate her science lessons as a 4. However, she expanded her rationale of what made a lesson a four as opposed to another number on the scale. In fact, this further explanation provided by Angela continued to reveal her naïve thinking and the struggles she was having between her views and enacted practices. Angela said,

> I was really letting the students discuss what they were discovering as opposed to putting ideas in their heads. At least I really tried; when they were making observations about the petrification [sic] the students could say what they thought happened. I was not trying to put it in their heads. (Angela, 3/23/06, Continuous-weekly reflection)

Furthermore, she explained that the lessons were not a five because it was teacher-led as opposed to children led, as evidenced in the following response.

> I also felt that it was very teacher-led because I or other adults had to read the letters to the students. The information was being presented to them and I am not sure they would automatically decipher it themselves. I am not sure that the students are able to decipher the information by themselves. At least, I am not sure I am trusting students enough to decipher the letters by themselves. (Angela, 3/23/06, Continuous-weekly reflection)

As the unit continued Angela rated her science lessons with a lower score. By the third week she rated them as a 3.5. She said,

> …because I was not getting much inquiry. I feel I was leading the questions when I was talking with the students about the different things we were doing. (Angela, 3/31/06, Continuous-weekly reflection)

This rating remained steady for the remainder of the unit as she rated the lessons as 3.5.

As Angela continued to teach it was evident that she was still struggling with teaching science. Meanwhile, she continued to demonstrate strong commitments towards teaching science as inquiry while struggling to teach it consistently, according to her views. During the follow-up to the first interview after Angela had taught her first unit, she reported that teaching as inquiry was really hard, but that she was still very committed to the broad idea that inquiry was about students answering their own questions. However, based on her reports, importantly, Angela's views of students' own questions were vague and on many occasions, apparently, she included in that phrase questions that arise with the help of the teacher. In fact, the lack of students' questioning during the first unit (according to Angela) led her to describe the unit as hands-on but not inquiry. She said,

> There were days when the Prehistoric Life Unit was hands-on. Although were using manipulative to measure the length of the dinosaur there was no questioning that was necessarily as a result of the activity. The students walked away from the hands-on activity without coming up with questions and lacking evidence to back it [explanations] up. (Angela, 5/2/06, Follow-up)

Thus, it appeared that Angela's frustration towards not being able to help students ask appropriate questions led her to accurately believe that inquiry was not easy to implement. Thus, by midway of the first unit she felt herself to be an unsuccessful elementary science teacher. Angela further described her views of inquiry as steady when compared to the first interview and added that her views on emphasizing evidence-based explanations had also not changed since then. She said,

> My views about inquiry have not really changed. I just think I didn't have an opportunity to use my views in an effective concrete way. It is still something I am struggling with. I saw the importance of inquiry when I was in SCIED 458, and I realize that is something my students would benefit from. Inquiry is something that carries over many areas of the curriculum and I would like students to be able to give an explanation with evidence for their beliefs, their views, and their learning. However, it is something we are struggling with. (Angela, 5/2/06, Follow-up)

In addition, she continued to emphasize the notion that in inquiry children need to be discovering something.

Analysis of data for the second unit (Magnets) that Angela taught revealed a different story as compared to the first unit (Prehistoric Life). During the Magnets Unit, Angela further explored the notion of inquiry when she responded to the question of what criteria she was using to self-rate her science lessons. In this she referenced the idea of who was presenting the information. She said,

> I am giving myself a three as opposed to another number based on who is presenting the information to the students. For example, I don't say to the students "Today we are going to learn about magnets' North and South Poles; here are the magnets." Because I am presenting the information in an inquiry-based way I am giving myself already a three. If I were asking a lot of good questions, I would bump it to a four. If the students are responding to the questions well, I might give myself a half point. If I felt that it was not successful, I start taking marks off. But sometimes I do not take off marks because there is a learning curve not only for myself but also my students as they learn to provide evidence and facts for the claims they are making. (Angela, 5/2/06, Continuous-weekly reflection)

This quote also demonstrates that Angela possessed limited notions of evidence.

Angela's ideas of supporting inquiry continued to be negotiated throughout the second unit. Interestingly, Angela was harder on herself during self-reports, yet her description of the enacted lessons were more consistent with contemporary perspectives on teaching science as inquiry. At the beginning of the Magnets Unit she described inquiry teaching according to how much it was student led. She said, "Students, through exploration and through their questions and wonderings, will decide how we approach this unit" (Angela, 5/8/06, Continuous-weekly reflection). In general Angela rated her science lessons during this unit lower as compared to the Prehistoric Life unit. In a cross-examination of her ratings for the second unit, observably, the ratings were conducted using an explanation-driven inquiry lens. That is, who was explaining the scientific concepts? During the first week of teaching magnets she rated her lessons as a 3 on the scale of inquiry because as she said, "Even though the students had to think, I gave them an explanation, a science explanation, and from there they were able to discover some things that would fit in with it" (Angela, 5/15/06, Continuous-weekly reflection). However, her report on her enacted lesson described a teaching episode were she was asking students to explain the concepts by using the materials used in the experiment. This new notion of rating the lessons based on who was doing the explanation repeats again during the second week of the unit when Angela said, "The reason I say this [3.5 out 5] is because students were allowed to use the magnets and experiment, and then were asked to provide me with evidence to their claims" (Angela, 5/29/06, Continuous-weekly reflection). Again, during the third week she engaged in similar thinking when referring to the rating but added who was leading the lessons. She said,

> The students did come up with some ideas on their own. Students were able to explain and provide evidence but a lot of the inquiry was still very much teacher led. I knew the experiments we were going to make students think. I provided most of the materials for

> the experiment and students had an opportunity to think outside the box. (Angela, 6/4/06, Continuous-weekly reflection)

4.3.3.3 Teacher's Role

Angela's representation of the teacher's role for science teaching highly influenced how she adopted elements of the framework. Furthermore, a relationship appeared between the difficulty of the content she was teaching and the roles she assigned to herself in order to aid students' construction of evidence-based explanations. This was evident by analyzing units' weekly activities in relationship to the emphasis towards evidence-based explanations. Interestingly, Angela's self-reports prior to starting the unit presented a prospective teacher full of fears and doubts on how to teach the content with an explanation-driven inquiry lens. Furthermore, she appeared to be somewhat uncomfortable because she had not taught a complete unit by herself. In addition, she demonstrated some common novice teachers' concerns, such as classroom management and content knowledge preparation. Analysis across units revealed that since Angela viewed the topic of Prehistoric Life as more complex and felt less knowledgeable, she was unable to enact an in-sync teacher's role with her views on explanation-driven inquiry. However, during the Magnets Unit, with which she felt more confident teaching, she was able to better synchronize her views on the role of teacher, explanation-driven inquiry, and enacted practices. Thus, it was apparent that Angela struggled with reconciling how to transform content and pedagogical knowledge into meaningful teaching practices that would help children participate in meaningful science learning.

Evidence to support the above claim was obtained by analyzing Angela's descriptions of how she viewed and enacted her role in aiding children's science learning. During the first unit

Angela thought that the role of the teacher was to teach the content fair-mindedly regarding the excitement and being non-judgmental of children's ideas. She said,

> I found, as a teacher, to support explanation development and science talk I need to keep asking questions. I specifically need to listen to students' answers while remaining non-judgmental and avoiding using yes or no responses. I would lean towards the students and listen and try understanding what they were saying. (Angela, 3/17/06, Continuous-weekly reflection)

However, these roles dramatically expanded when she faced a topic she was more knowledgeable with, magnets. For example, she described her role in a complex way attributing different roles at once. As a matter of fact, she described herself as an active participant of teaching and learning, a facilitator, mediator, and provider of specific activities, lesson sequences, science language, public discourse and reasoning. Furthermore, the described these roles in the context of helping students pay attention to evidence and use evidence in the construction of scientific explanations. Thus, depicting different roles from those assumed or viewed when teaching the first unit.

As mentioned earlier throughout the study Angela demonstrated conflicting views and self-reported practices, and her self-assigned role as a teacher was no exception. For example, when discussing the use and importance of questioning in science teaching she shifted her descriptions from (during the first unit) naïve generic views not specific to science, to (during the second unit) describing use of questions purposefully to help students predict and notice specific aspects of the physical phenomena in order to be able to make claims. This was generally characterize by statements such as, "I tried to ask questions that would get them to say they thought metal was going to attract" (Angela, 5/8/06, Continuous-weekly reflection). At the same time, she constantly devalued her accomplishments and thinking with quotes as the following:

> I feel like that I did not do a lot of teaching this week. I just provided an open space where students could explore and express their knowledge and get it down on paper.

> When I wrote students thoughts in the KLEW chart, this got students started about thinking about magnets. I don't believe I provided any new information, and I am not sure that students learned anything new this week. (Angela, 5/8/06, Continuous-weekly reflection)

Although, as described above, Angela struggled with synchronizing her views and enacted practices, multiple episodes during the second unit demonstrated that her views and practices were in-sync. Furthermore, her descriptions were consistent with current science teaching reforms. Evidence to support this claim was obtained from her self-descriptions such as when she said,

> I asked students whether the items I had on the table, on our science table, whether or not they were metal. And the students agreed they were metal and I tried to have students define what they meant by metal…I wanted to make sure that we were all talking about the same things and that students were familiar with the term metal. (Angela, 5/29/06, Continuous-weekly reflection)

Other examples of Angela being able to synchronize her views and practices was when she said,

> I don't think students necessarily realized that it was teacher lead. I think some of the students believed that they had come up with the experiment themselves, which is really wonderful; that is what I wanted to happen. (Angela, 6/4/06, Continuous-weekly reflection).

> This week I learned that the kids know a fair amount of information. I think how students began to provide evidence to the claims indicate to me that we could be successful. I just need to show students and model to them how a scientist makes claims and provides evidence. I think this is a great unit to do because of the claims. Students seem comfortable with the claims and the evidence; we just need to bring the two together. (Angela, 5/15/06, Continuous-weekly reflection)

The latter quote also causes a new issue to surface in Angela's notions of the teacher's role. This is so because although she mentioned the importance of modeling when constructing explanations, she did not provide an example of how exactly she was modeling explanations. Furthermore, Angela made constant reference to the importance of modeling scientific behaviors as a tool to guide evidence-based construction, distinctly from her reports during the first unit.

These ideas provide another element that demonstrates the dissonance between Angela's views and practices. Modeling explanations is important because according to McNeill and Krajcik (2008) teaching practices that explicitly demonstrate a scientific explanation and its reasoning help students build stronger scientific explanations.

4.3.3.4 Public Reasoning

An element of the framework that Angela continuously emphasized was the role of public reasoning through the use of science talks in the classroom. At the moment of her entrance interview Angela viewed science talks as an interactive place for students to predict, a share lesson's information and guess future lessons' outcomes. These views were apparent from the following excerpt,

> Interviewer: You mentioned the role of discussion as part of engagement so I am wondering how you view talk in the classroom as being connected to, or what role that plays.
>
> Angela: My favorite time was really when, one of my favorite times was when we were on the floor making predictions, discussing, and guessing and getting the students' ideas out. I just think that's really important. I've seen it work well in Emilia's class and Sarah's class and I felt it worked well in mine. I think it's not just when I say talking. I don't just mean talking; I really mean the class giving ideas. Because I found that when one child said one thing, then another child would say, "Oh yes," and they would bounce ideas off each other. (Angela, 1/23/06, Entrance interview)

Angela deemed important making sure that she understood what children were communicating and her responses to children's public reasoning was followed with questions that expanded what children were trying to explain. Angela described,

> When students would say keywords I would pick out those keywords and ask them "What do you mean by that?" So when student responded with, "It will get fat," I replied by asking the student, "What do you mean by fat? How would it get fat?" (Angela, 1/23/06, Entrance interview)

Based on the quote and additional evidence, apparently during the first unit, Angela was constantly re-defining the boundaries of aiding public reasoning and also what she valued as the most important things she needed to do in order to be successful. Furthermore, through the process of re-defining boundaries she was deciding, committing, and forming her definition of what counted as effective science teaching.

Angela's ideas of science talks evolved during the Prehistoric Life unit. In this unit her emphasis towards using science talks, as vehicle to aid explanation building was more robust than during the entrance interview. For example, by the fourth week of the unit she was using the science talks to ask students questions such as "Why do you think so?" "How do you know?" However, an important distinction is what her views appeared to be and what she was trying to enact in the classroom. For example, during the second week of the unit she described the use of a science talks as a vehicle to ask students to share evidence; however, when she described her enacted lessons, she was using the science talk to help students connect evidence to their beliefs and prior knowledge. Table 4.12 presents a description of the development Angela's self-reported views and self-reported enacted practice for science talks.

Angela's Views and Enacted Reports on Science Talks 1st Unit (Prehistoric Life)		
Week	**Views**	**Practice**
One	A vehicle to share evidence while allowing students to hear peer responses. This process can be an assessment tool and a place for reinforcing main ideas.	Asked students to state their activity results while listening to each other.
Two	Vehicle to share evidence.	Conducted discussions that helped children connect evidence collected to their beliefs and prior knowledge.
Three	Vehicle to acquire student's scientific wonderings related to the particular lesson.	Asked explicit questions to students about what they were interested in learning about the mystery dinosaur.
Four	Vehicle to review covered material while helping students think about the "whys" of the topics in discussion.	Prompted students' explanations with questions such as "Why do you think that?"

Table 4.12 Angela's Views on Science Talks during the Prehistoric Life Unit

Analysis of the second unit revealed that Angela's views and self-reported lesson enactments appeared to be more in-sync. However, she focuses more on talking about the enactment of the lessons rather than on her understanding of teaching science as argument. For example she reported science talks as an activity imperative for children talking about evidence, learning concepts, broadening their understandings, sharing results, making connections, and finally as a tool for the teacher to assess students' understandings. As observable in Table 4.13, Angela started using science talks as a vehicle for helping students connect evidence and claims and concluded the unit with meaning making in a complex way.

Angela's Views and Enacted Reports of Science Talks 2nd Unit (Magnets)		
Week	**Views**	**Practice**
One	• A vehicle to retrieve student's prior knowledge and topic wonderings. • A place to have iterative conversations about evidence collection methodologies. • A place for students to verbally state claims regardless of the correctness of these. • Discuss=thinking	• Asked students questions to retrieve prior knowledge and what were some wonderings about the topic. • Had a discussion about the different ways students were collecting evidence about objects' magnetism. • Once students collected evidence, had a discussion about what conclusions were possible based on available evidence.
Two	• A teacher's vehicle to help students explain their discoveries and any other idea related to the topic in study. • It serves as tool to review safety procedures, organize collected evidence and make claims. • Engaging in science talks allows children to be more successful because they don't have to write.	• Verbally collected student's evidence using the KLEW chart. • Discussed with students safety concerns. • Attempted to have children make claims.
Three	• A place to agree on experimental procedures. • A place where students can successfully make claims and provide their evidence.	• Engaged students in public reasoning regarding experimental methodologies and evidence-based explanation construction.
Four	No reference to views	• Defined concepts important in evidence collection. • Defined experimental procedures • Had children brainstorm possible ways to test ideas. • Helped students make meaning of evidence. • Helped students use evidence to draw claims. • Helped students make predictions. • Discussed and debated results and students' ideas. • Helped students "discover" new ideas and concepts.

Table 4.13 Angela's Views on Science Talks during the Magnets Unit

One probable cause for Angela's disparity between the first and second unit could be her confidence level in the content and the degree of difficulty in creating physical representations of the content. That is, the unit about prehistoric life was more difficult to recreate in actual time than the unit on magnets. For example, during Magnets, Angela's self-reports indicated helping students publicly reason about evidence collection methodologies. However, this kind of language was absent from the first unit's self-reports. Thus, arguably, the lack of references to

evidence collection methodologies during the first unit is as a consequence of the difficulty to arrive at the same evidence by multiple ways.

The complexity of ideas regarding the role of talk in an elementary science classroom was also apparent in Angela's final interview, in which she said,

> Interviewer: The talk seems to be an important part of explorations.
>
> Angela: Yes, it [science talks] brings things together. It brings ideas together; new understandings are brought up from that. And perhaps the students are not always understanding or always having those, ah, moments at the table by themselves but when they are experimenting they might start seeing, making some connections when we are on the floor. So, is not just students doing experiments at their own table or in their own groups and discovering basic facts, basic claims or seeing evidence. I think is that bind with group discussion on the floor later. (Angela, 6/7/06, Exit interview)

This previous excerpt also demonstrates that Angela started to appropriate the importance of scientific language and public reasoning within the context of building evidence-based explanations.

4.3.4 Influence of Reflection Protocols in Science Planning

An examination of Angela's representation of how reflections influenced her science teaching planning revealed that continuous prompting regarding what kind of evidence children were collecting influenced Angela's attention to what was the evidence available through the lessons which allowed children to create evidence-based explanations. This was specifically evident midway in the second unit (Magnets) when Angela said,

> The students had previously told me that metals do not always stick to magnets. I indicated to students that I wanted them to do some experiments today to come up with proof. Because students had previous knowledge that the metals would not stick to magnets, I wanted to provide students with metal looking objects that would stick and wouldn't stick so they could have evidence to back up their claims. (Angela, 5/29/06, Continuous-weekly reflection)

Despite the benefit of the protocols in helping Angela pay attention to what was the evidence students were collecting and how that related to the concept she was teaching, she struggled to help children connect evidence to explanations. However, apparently, the reflections helped her think about how to enact this idea with children. For example, she said,

> None of the students were willing to admit that they thought that since it was metal it would be attracted to the magnet. One student kind of let it slip and said that it was shiny. So I tried to go with that, I said, "Did anyone think that it would attract because it was metal?" Then 5 or 6 students put their hands up. I really wanted one of the students to say it but I could really tell that since they had experimented it was harder. Perhaps if I have had them explain why they chosen the objects before they had gone out to experiment maybe they would have said, "I think this is going to work because is metal." But because they had gone and found out that it didn't stick, then they weren't willing to admit that not all metal things attracted. So, that is something I would do differently next time. (Angela, 5/15/06, Continuous-weekly reflection)

Similarly, she underwent a thinking process during a following week when she said,

> Students felt that the idea of writing claims and then evidence on the bottom of the sheet did not necessarily matter. That evening, I took time and I re-wrote the sheet, and I wrote it so that the prediction and the experiments were in one sheet. Then on a separate sheet it was going to say: "Claim," and they would write their claim in and provide three examples or evidence for this claim. I am doing this worksheets with next experiment which is: Do magnets attract through objects? And hopefully, the students will have more success. (Angela, 5/29/06, Continuous-weekly reflection)

A further important element to the prior claim made regarding reflections helping Angela try to achieve better connections between claims and evidence can be supported by contrasting her self-reports of the enacted lesson with what the curriculum suggested. For example, the curriculum defined one of the scientific concepts as "magnets attract some objects"; however, her self-reports pointed towards an enacted lesson of helping students connect the evidence (some shiny objects stuck and some did not) to the claim that not all metal objects are attracted to magnets. Contrary, the curriculum stated, "Students will sort classroom objects into those that stick and those that do not stick to a magnet." Arguably, this concept presented in the

curriculum, although important, do not attain to the conceptual component that distinguishes the kind of materials that magnets attract. Attending to the concept that not all metals are attracted to magnets, Angela is able to help students pay attention to specific evidence that clearly links to a scientific claim.

Another example of differences in the curriculum and Angela's self-report enacted practices occurred during a suggested activity that instructed the teacher to provide specific objects for students to test magnetism. Every time an object was attracted to a magnet it suggested students should hang a paper clip in a magnet that represented a "yes" column and when it was not attracted to hang a paper clip in a magnet that represented a "no" column (as a charting method). Instead, Angela used displaying paper clips in a different way. She used them to test the strength of a magnet as compared to its size. Possible reasons for such activity derailing might be related to the protocol and a contextual element (SCIED 458). Based on Angela's framework acquisition, perhaps her pedagogical and content knowledge led her to believe that using that activity would provide a repetition of concept rather than the opportunity for students to make a claim and link it to evidence. On the other hand, collecting evidence regarding the number of paper clips a magnet can hold would yield evidence regarding a new claim. Another possible argument could suggest that she was using a recollection of her experiences during the science methods course where the instructor asserted, in line with the framework, some concepts appropriate and expected for elementary grades in relationship to magnetism.

Examination of the unit revealed that the curriculum lacked an explanation or guiding content that gave the teacher some initial questions to guide discussions to help students make connections between the fictitious letters and the content they needed to know in order to solve

the mystery dinosaur. The curriculum guides are atypical to the mass produced curriculum such as the Full Option Science System (FOSS) that gives the teacher step-by-step instructions.

Another influential component related protocols prompting participants to provide examples regarding students collecting evidence/observations, looking for patterns, constructing explanations, etc. Thus, Angela believed that the protocol questions, in a sense, were a standard of what children were suppose to be doing in science classroom. That is, the fact that the question asked for those specific elements she inferred that good science teaching contained those elements. This belief appears to lead her to pay more attention to elements of teaching science as argument.

4.3.5 Context Elements' Influences on Teaching Science as Argument

4.3.5.1 Science Methods Course

A contextual element that influenced how Angela taught her science lessons was her attempting to recreate consciously or unconsciously some of the components of the science methods course lessons and ways they were instructed. For instance, during the science methods course, the professor taught a nature of science lesson using mystery boxes. Thus, when Angela taught her students the mystery boxes activity, Angela had students use an empty box to model what they thought was inside the mystery box and infer a better prediction of the box's content. This self-reported practice was not in the curriculum guide, but she implemented it as she remembered and interpreted it from the science methods course. Angela said,

> So I was really pleased that students could compare the boxes. Giving the empty boxes was kind of a last minute thing that I thought. I can't remember whether [the instructor] had done it that way or if I have seen Sarah do it a couple of years ago. But I remember doing it that way and I thought that it was really great; my students were able to make guesses. (Angela, 3/17/06, Continuous-weekly reflection)

Later she added,

> The things that influenced or made me change my lessons plans was that I decided at the last minute to add the empty mystery boxes. I added the boxes because of prior experience and how I believed it could have a positive effect, and I believe it did. The fact that there were empty boxes for students to compare the weight and sound had a much greater impact than if the kids had just predicted. (Angela, 3/17/06, Continuous-weekly reflection)

An additional moment from the science methods occurred when she was recalling specific discussions in the class. Angela mentioned,

> I remember [the instructor] talking about it in the science class. I remember she saying that it had made a huge difference when she realized that science wasn't black and white. I believe that's important for us to help students understand science and is very hard for first graders. (Angela, 3/17/06, Continuous-weekly reflection)

Although, this recollection of events was misinterpreted, it was influential to Angela in understanding the tentativeness of science. This notion was influential during multiple points throughout the Prehistoric Life Unit when grounding her science lessons on the view that scientists do not always have the correct answer, thus helping students understand that scientists make educated guesses based on evidence. This was evident when she continued reporting upon the prior quote when she said,

> Students want to be right, so as we work in math, science, and sound spelling and writing I want students to realize that they can make predictions and good guesses. I want them to realize that these can be based on prior knowledge that their prior knowledge is valuable. That scientists, important people that write books and research papers that come up with these great discoveries, also make predictions. I want students to understand that the more knowledge they have the better their inferences will be. (Angela, 3/17/06, Continuous-weekly reflection)

Although in the previous quote she used knowledge, a closer look at the evidence in the context of the whole report and unit demonstrated that she was referring to knowledge as evidence.

A real pedestal moment from the science methods course that appeared to be highly influential in Angela's attention to teaching science as argument is her interpretation of how

important using evidence is when building explanations as demonstrated by the course. She said during the follow up,

> I saw the importance of evidence when I was in 458. I realize that it is something my students will benefit from because it is something that carries over many areas of the curriculum. I would like students to be able to give an explanation and evidence for their beliefs, their views and their learning's. But it is something we are struggling with. (Angela, 5/2/06, Follow-up)

This quote also demonstrates that Angela was able to at least understand the basics of the framework and attempt to recreate these understandings in her teaching.

4.3.5.2 Professional Development School Peers

An additional predominant contextual aspect influencing Angela's attention to teaching science as argument was other participants of the PDS programs whose pedagogical preferences were consistent with the current study's conceptual framework. For example, Angela continuously requested input from Steve[1], who was also participating in the current research, and she often acted upon his comments. Angela said,

> I spoke with one of the interns (Steve) in the building; instead of asking students what they want to know he is asking them what they want to know about their dinosaur. I think is a great idea, I think it is what I am going to run with next week. The idea of what do you want to know about your dinosaur. (Angela, 3/23/06, Continuous-weekly reflection)

Comments like the previous one were representative of how Angela approached feedback. She was very explicit about relying on peers (in-service and prospective teachers) to help her make decisions on how to plan and teach specific lessons of the unit. This was again observable during her participation in the study when she said,

> I am approaching Erica and Steve and asking them, "Have you done this; have you tried this; how are you planning to do this; what are your thoughts about this?" We are batting back ideas. This week I talked to Erica and we are trying to bat ideas off each other. We are making sure that whatever mistakes or changes another teacher makes we are taking that into play. So even though we are all teaching the same lessons we are definitely depending on each other. The other thing that I am using is past experiences. I am using

[1] All names are pseudonyms

> my experiences working in Emilia's and Sarah's classroom while they taught the Prehistoric Life Unit and also being a parent volunteer in the school. I've seen these lessons done before in different ways and I am pulling my prior knowledge when I am teaching these lessons. Also, I am definitely trying to read the students. (Angela, 3/23/06, Continuous-weekly reflection)

As the teaching progressed Angela also had a conversation with another prospective teacher who was also participating in the current research. She said,

> I am very comfortable discussing things... I like how Monika did it with her magnets, sort of in little blurs and little bubbles as opposed to a huge KLEW chart. And I think I might go with that idea only because the kids can see sort of the small knowing and the evidence breaking off as opposed to [the] whole unit knowing and evidence. As it is keeping it sort of small and manageable. (Angela, 3/23/06, Continuous-weekly reflection)

According to Angela the second unit (Magnets) was going to be taught as inquiry, a decision made in conjunction with her mentor-teacher. Throughout the unit other interns' ideas and experiences appeared to play a significant role in Angela's teaching. According to Angela, Monika had taught magnets successfully in another school and was excited; thus, Angela felt as enthusiastic. Angela said,

> I have seen Monika's excitement about this unit and how successful it was in her classroom. I am interested in seeing and providing an opportunity for my students to be successful scientists. I am interested in my students seeing very clear evidence and making claims. (Angela, 5/8/06, Continuous-weekly reflection)

In addition to the excitement from listening to Monika's stories Angela described how the content blended to "prove" things. She said,

> The dinosaur unit was fun but I don't know students were always able to make connections between evidence and claims. It was almost too much book information and not necessarily enough practical information. To me, the Magnets unit seems like a unit where students can see that magnets repel and attract. I know it is unit where students can prove things there on the spot. So I am excited about the unit for that. And that is going to affect my teaching. (Angela, 5/8/06, Continuous-weekly reflection)

Thus, she believed that she could successfully help students understand the concepts stated by the school district's guidelines.

4.3.5.3 Children's Ideas

An additional element that the previous quote elucidates is the intertwining in Angela's ideas and self-reported practices regarding her perceptions of children's capabilities being shaped by the quality of their evidence-based explanations. However, her children's perceptions impacted her own views of her role as the teacher. This claim can be supported by the fact that during the first unit she illustrated that student's lack of evidence-based explanations discouraged her from emphasizing such practices. She said,

> Today I was going to have each of the students cut out the foot and have each of the tables have either two feet or four feet so they could see them. I realized that there was no possible way that my 19 students could do that with one adult in the room. (Angela, 3/23/06, Continuous-weekly reflection)

This notion of "I can't do this" repeated again in the following week when she reported,

> Next week I will be doing the measurement of the hip, the leg, and the measurement of the body. Which I must say, I am kind of dreading. It's going to be a huge lesson and I am going to need to trust the adults in my room and trust that students can do it. (Angela, 3/23/06, Continuous-weekly reflection)

When this argument is contrasted with her acquisition of framework elements, an interesting claim can be made: A cyclical relationship exists between Angela's beliefs of students' abilities-emphasis towards elements of the framework-and modifications she made to the school district curriculum. Furthermore, analysis revealed, as previously stated, that her perceptions of student's abilities also had other ramifications in her views and enacted practices. These ramifications demonstrated that as Angela developed higher views of her student's abilities, the more emphasis she placed on the framework elements. In addition, this increase in attention to the framework also led to higher level of complexity in her story because she started placing more emphasis to teaching and planning which led to appropriating more elements of the framework.

A juxtaposition element to this complexity was when she viewed her student's abilities as low. For example, by the second week of the first unit (Prehistoric Life) Angela was frustrated by some of the answers students were providing when she prompted them to justify their answers. In her self-report, she then linked students' lack of justifications to her trying to figure out how to help children justify their answers, which led her to re-think her questioning strategies and to actually increase the number of questions she was asking. However, she also questioned students' abilities to engage in these scientific practices. This was evident when she said,

> My students, despite their ability level, had a really hard time wondering about their dinosaur. They were much more interested in telling me what they knew. My idea was to get all the students, what the program suggested, to write down what they wanted to know. Then come together as a group and talk about it. So that's what I was trying to do, but because it was done during language arts and the students are having a rough time is taking most of the week to get everybody's responses. Since my students seem to have a rough time, they would rather show what they know than think about what they don't know. The second thing we did this past week was a number of different worksheets dealing with petrification [sic] that were in Sarah and Emilia's book. The students draw a diagram of the experiment related to sand and the sponge bone. Students also wrote a response to the question, "What do you think is going to happen and why?" The students did really well on answering this question. But there was one student that was uncomfortable expressing his thinking while using terms so I had to do lot of probing. I was really trying to not give answers away and I think I did a pretty good job. (Angela, 3/23/06, Continuous-weekly reflection)

4.3.6 Summary

Angela's story demonstrated her early development of commitments related to teaching science as inquiry and argument. However, her self-reports clearly established that she struggled to enact her commitments to teaching science as argument. Furthermore, it appeared that this struggled was due to her lack of content knowledge. Her story, although disjointed, is important because it portrays a typical scenario teacher educators face with prospective teachers. That is, some future teachers develop strong commitments toward the elements of teaching science as

inquiry with strong emphasis in argument; but fail to enact commitments in ways that are consistent with current science education reforms.

4.4 Laura's Story

4.4.1 Description of Classroom Context

Laura's student-teaching assignment was a second grade classroom. Her group consisted of twenty-two students with racial and learning abilities homogenously distributed among twelve girls and ten boys, one of whom received learning support. Hence, this particular student left the classroom approximately two and half-hours each morning for learning support. In Laura's classroom science was taught three times per week and was scheduled for one hour. Although lessons were usually planned to last an hour, Laura said that students often became thoroughly engaged with the lessons and worked for longer than an hour. These science lessons were usually taught before lunchtime or just before dismissal time. According to Laura, science was planned as inquiry-based instruction since her mentor-teacher was a great inquiry advocate whose enthusiasm toward inquiry resulted in continuously guiding Laura toward planning lessons in which children asked questions and engaged in experiments. Since the mentor-teacher was excited about teaching science, Laura adopted the attitude toward the subject. This excitement was noticeable when Laura said, "I expressed to her and I wanted her to know that I really enjoy teaching science" (Laura, 2/22/06, Unit planning). Also noteworthy is that her mentor-teacher was actively involved in professional development within the context of PDS.

During Laura's participation in the current study, she taught two science units. The first was "Life under the Sea" and the second unit was "The Wonderful World of Nature." During the first unit, she co-taught with her mentor-teacher while for the second unit, she taught all the lessons. Table 4.14 provides a description of unit foci as described in the curriculum. However, according to Laura, modifications were made to the curriculum in order to attend to a special request from the science specialist of the school district. The science specialist had requested Laura's mentor-teacher re-write the curriculum.

Student-teaching Field Experience Spring Semester/Science Teaching			
Date	**In Charge**	**Unit Topic**	**Unit Foci (Described by the Curriculum)**
2/20-2/24/06 (Week One) 2/27-3/3/06 (Week Two) 3/13-3/17/06 (Week Three) 3/20-3/24/06 (Week Four) 3/27-3/31/06 (Week Five) 4/10-4/14/06 (Week Six) 4/17-4/21/06 (Week Seven) 4/24-4/28/06 (Week Eight)	Mentor-Teacher Laura Laura Laura Mentor-teacher Laura Mentor-teacher Mentor-teacher	Life Under the Sea	• Mammals are warm-blooded animals with hair or fur. • Birds are warm-blooded animals with feathers. • Reptiles are cold-blooded animals with scales. • Amphibians are cold-blooded animals that live in water or on land. • Fish are cold-blooded animals that live in water and have gills. • Insects are animal with a skeleton, three body parts, and six legs. • Humans try to manipulate plants or animals to fit their needs.
5/1-5/5/06 (Week One) 5/8-5/12/06 (Week Two) 5/15-5/19/06 (Week Three) 5/29-6/1/06 (Week Four)	Laura Laura Laura Laura	The Wonderful World of Nature	• Plants are living things that grow and change. • Leaves, stems, root, and flowers are parts of plants specific to functions. • Plants need air, sunlight, soil and water to live and grow. • Similarities and differences exist among plants. • Plants grow in many places. • Plants are useful to people. • Humans try to manipulate plants or animals to fit their needs.

Table 4.14 Laura's Units: Overview and Foci

4.4.2 Overview of the Units

The first unit Laura taught while participating in the study was "Life under the Sea." The overall theme of the unit was to expose children to the animal kingdom, and how the animal kingdom is critical to maintaining nature's balance. Laura described the "big ideas" or unit goals by using overarching questions:

1. How does an aquatic ecosystem work?
2. How are fish dependent on plants? And how do plants help fish?
3. What is a mammal?
4. What is a living thing?
5. What is a non-living thing? (Laura, 2/22/06, Unit planning)

These questions were supported by other goals that were implicit in the description of weekly activities of the unit. Hence, Laura included the concepts of every component of an ecosystem is

dependent upon something else within that system and of the nature of scientists' work. This was apparent when she said, "Scientists can use some of these tests, similar tests, to figure out how polluted the water is." (Laura, 3/13/06, Continuous-weekly reflection). She further said,

> I explained to them that they would never find out how many drops were in the cup because most of the time scientists do not get a definite answer, so since [they] were acting as scientists, they were not going to figure out how many drops were in the mystery cup. (Laura, 3/13/06, Continuous-weekly reflection).

Finally, she had other non-science content goals for the unit such as helping students learn how to make connections, how to interact in groups, and how to figure things out on their own while improving their writing skills. Table 4.15 provides an overview of the weekly activities for the unit.

Laura's Summary of Activities for Life Under the Sea

Week	Curriculum Description	Laura's Description
One	Students identified different kinds of mammals. Students described characteristics of mammals. Students compared likenesses and differences among mammals. Students observed and discussed the life cycle of a mammal. Students gave examples of various habitats of mammals.	Students created an aquarium.
Two	Students identified different kinds of amphibians. Students described characteristics of amphibians. Students compared likenesses and differences among amphibians. Students observed and discussed the life cycle of an amphibian. Students gave examples of various habitats of amphibians.	Students identified likenesses and differences among aquatic and land plants. Students identified the parts of a plant. Students described the functions of some plant parts.
Three	Students identified different kinds of fish. Students described characteristics of fish. Students compared likenesses and differences among fish. Students observed and discussed the life cycle of a fish. Students gave examples of various habitats of fish.	
Four		Students explained the impact pollution has on people, water and land.
Five		Students investigated filtration methods.

Table 4.15 Laura's Weekly Activities' Overview of the "Life under the Sea" Unit

The second unit that Laura taught was "The Wonderful World of Nature." For this unit Laura was responsible for teaching all the lessons. This level of responsibility was different from the previous

unit in which she taught a great portion of the unit, but her mentor-teacher still had an active role in the planning. She described the overall goals of the unit as:

1. What are the major characteristics of animals in the different animal groups?
2. What do plants need to grow?
3. What is a pest?
4. How do pests affect our environment?

A comparison between the curriculum guidelines and Laura's limited description of the "Life under the Sea" (first unit) demonstrated significant differences. Table 4.16 provides a summary of the curriculum described in the curriculum guidelines and in her self-reports. As mentioned before, Laura's mentor was requested to re-write the curriculum; thus, differences were expected. However, obtaining a copy of the new curriculum guidelines was not possible, thus inhibiting a description of an accurate depiction of the differences between Laura's reports and the new curriculum. In addition, since Laura only taught the aquatic animals, other related activities presented in the curriculum, related to the unit, are not included in this table. On the other hand Laura reported an intention to deviate from the curriculum because students were pursuing open inquiry, she said,

> We were not following sequentially what we were supposed to be doing every week because our kids have just come up with these wonderful ideas that we feel like we need to pursue. Each week we're thinking to ourselves "Where should we be within the unit?" but then we realize the importance of what we're doing too. We're still meeting the standards that we need to meet and we're still making the science lessons important. (Laura, 2/22/06, Unit planning)

Laura's Activities for The Wonderful World of Nature	
Week	**Summary of Activities**
One	Students categorized living and non-living things. Students described how plants and animals are alike. Students investigated plant reproduction from seeds, cuttings, and bulbs. Students observed and recorded how plants grow.
Two	Students identified and described the function of the roots, stems, leaves and flowers of a plant. Students explained how a plant makes food.
Three	Students listed four things a plant needs to live and grow. Students told why plants need air, sunlight, soil and water. Students described the effects of various conditions on plants.
Four	Students categorized plants according to their similarities and differences. Students identified trees as plants. Students named some unusual plants.
Five	Students observed and compared the natural habitat of various plants (bog, desert, water, house, meadow). Students stated that plants grow where their needs are met.
Six	Students identified a variety of foods that come from plants. Students listed products we use from plants (cotton, wood, rubber, medicine). Students described why people should take care of plants.

Table 4.16 Laura's Weekly Activities Overview of The Wonderful World of Nature

4.4.3 Representation of Framework Elements

Laura's interpretation and acquisition of the framework developed over time as she taught two science units. Her interpretation and acquisition of the framework can be best represented as in Figure 4.3 that demonstrates the framework constructs she emphasized at three distinct points.

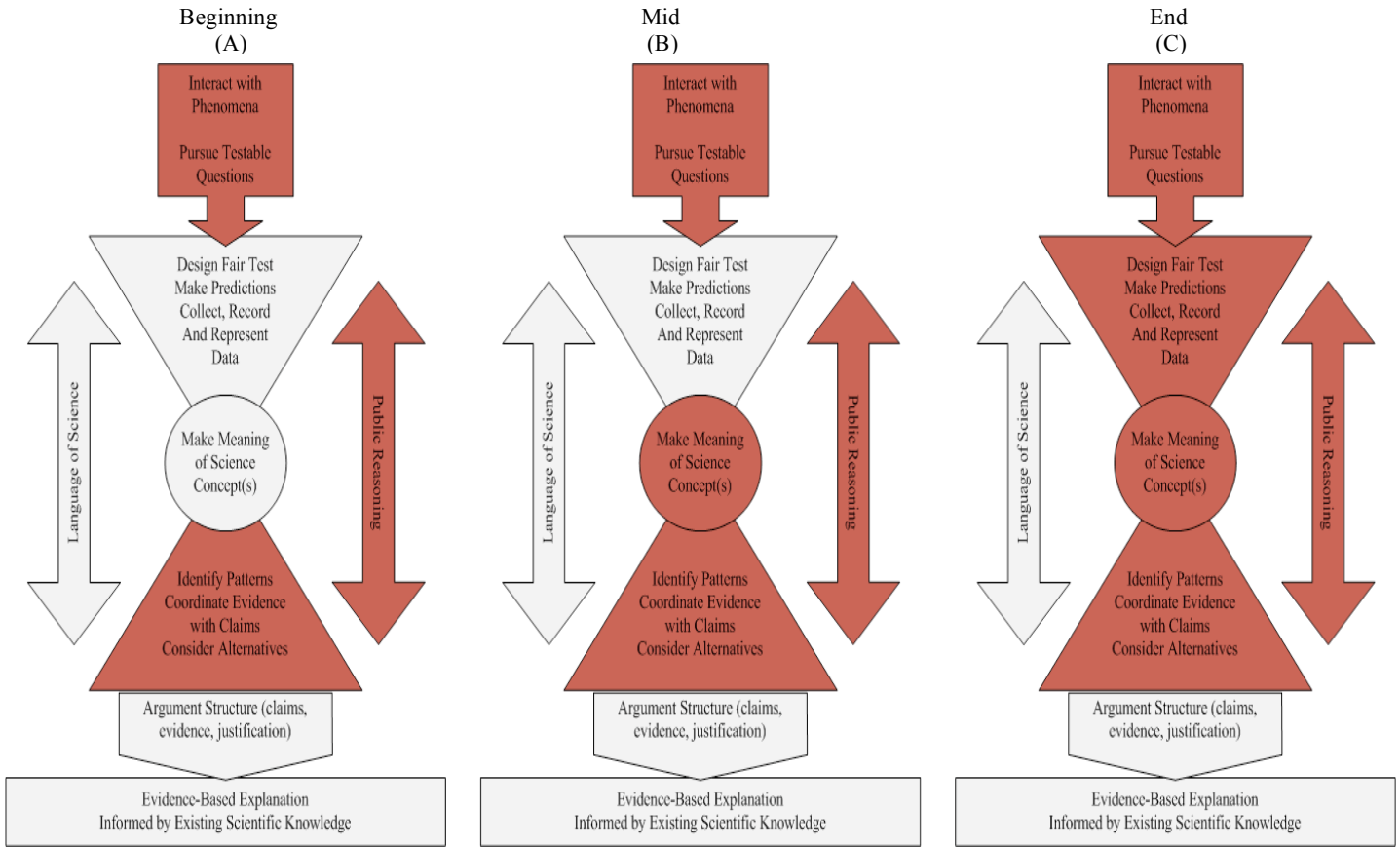

Figure 4.3 Laura's Emphasis of Framework Elements at Three Distinct Points

At the beginning of Laura's participation in the study, she described her views of teaching science as encompassing many elements. She said that teaching science required engaging students in hands-on activities while not telling the outcome of experiments, but letting students reach those by themselves. In addition, she described science inquiry teaching as "doing fun stuff while learning." However, she departed from the classic definition of fun teaching and explained that in the context of having fun, students engage in investigations to answer an overarching scientific question (see Figure 4.3). According to Laura this investigation process is self-determined, or teacher led, and is an interactive action that often requires students working in groups. These ideas can be demonstrated in the following excerpt from the entrance interview when asked about "big ideas" underlying her science teaching. Laura replied,

> Yeah, I am trying to think about that. Um, I guess one of the big ideas is not telling the information. Allowing the students to start to figure it out for themselves and helping to guide them when they're doing the science activity. Not telling them what's going to happen or why things are working the way they are. Having them start to make those connections and figure it out for themselves because it's so much more meaningful for them if they can figure it out for themselves rather than a teacher just telling them the information. So that was one big thing when I was planning my magnet lesson [during the Fall semester] that I really, really wanted was for them to make the connections and learn about it, not me tell the information. And then I guess another thing, especially with young kids, is just having it be hands-on experience 'cause young kids cannot sit still for longer than almost maybe 15 minutes, 20 minutes tops. So having the experience of them being able to feel things because they're such, you know, they're visual learners and they're hands-on learners so I really wanted all my activities to have them interacting with one another in groups and interacting with the magnets and that was just so important for me, for them to do it with hands-on. So, those are two of the big things for me. (Laura, 2/13/06, Entrance interview)

Further examination of Laura's entrance interview confirmed that she was a typical prospective elementary teacher. Although evidence revealed that she paid close attention to the use of questions as a tool for guiding students toward making connections and noticing phenomena and behavior she was a standard prospective teacher. For example, she said,

> Well, when I started to see my kids starting to make the connection between attract and repel, I didn't tell them that one side was going to repel. But then a few of them were like "Ms. C., look at what this magnet is doing to this side of the magnet." Then I said, "Well, what does it feel like?" Asking them types of questions, "Does it feel like its coming together or pushing away?" Then they started to make the connection that one side of a magnet attracts to one side and the other side repels. Then, just continuing with the questioning. "Well what are you seeing going on here?" "Why do think that's happening like that?" You know just questioning them and then you can ask the right questions to a young kid and then hopefully if they're not making the connection, then I'll guide them a little more with some more questions. (Laura, 2/13/06, Entrance interview)

When Laura was prompted about what she meant by asking the right question she responded,

> I really had to sit down and think through my lesson: What kinds of things I could start to come up with. What kinds of things are my students going to be wondering? My lesson planning took a while. It was a process 'cause you really have to think through what might happen in your lesson. 'Cause your lesson can go in all these different directions, but I was hoping through my initial questions: "What are we are going to be looking for today? What is our big question for our experiment?" to guide students down the path. Thus, it was a lot of thinking and predicting how my lesson was going to go. (Laura, 2/13/06, Entrance interview)

Furthermore, although not explicit, she reported early in the study to be paying attention to collecting evidence when she talked about the use of science talks in her science teaching. Consequently, she demonstrated an emerging attention to public discourse that carried over the course of the study as demonstrated in Figure 4.3. For example, during the entrance interview she said,

> Students are always, they're curious you know. I've noticed that in a lot of their conversations they would make the same observations and then some of them had background knowledge that they were able to share with the rest of their group members and be like "Well I know that magnets don't attract to certain metals because I've played with magnets before." So then they're able to share that with the rest of the group members and try to help them make those connections and see that, you know, magnets are not going to attract all metals. So then, when we get into a whole group discussion that group can then share with the rest of the class. So it's just so important that kids have that opportunity to talk with one another because it gives them a chance to piggyback off one another. (Laura, 2/13/06, Entrance interview)

When Laura's initial views were contrasted with her views at the end of the study, differences were apparent. Laura's attention and use of questioning at the end of the study was more purposefully used and was consistent with the teaching science as argument framework. For example, she referred to questions as a tool for helping students notice mistaken scientific concepts and connect them back to the

concept under investigation, thus, demonstrating some attention to meaning-making and content focus. These differences can be further observed in Figure 4.3. Furthermore, she placed emphasis on questioning as a scaffolding tool to aid better evidence collection methods and the connection of the evidence to the overarching question and claim. This was evident when she said,

> [Science talks] also serve as a time when the teachers can guide thinking. A lot of the science discussions I've had, I've put a question out there and kind of saw what I got back from that, and based off of that I have to think about other guiding questions. I know with my science discussion I had, I had to prepare a lot of them for thinking about what misconceptions might they have; what other questions should I have to help support their learning. (Laura, 6/12/06, Exit interview)

When prompted to further explain herself, Laura said.

> I went off of the big concept I wanted them to learn like with our magnet unit. One of the first things I wanted them to understand was the magnet vocabulary associated with magnets and after that I had that big objective that I could assess, I then thought of sub-questions. Like what are some little questions I can ask such as, "What do you notice the magnets doing? What does it feel like?" Or, "What does it feel like when you put one end of a magnet with another end of the magnet?" Just really sitting down and dissecting that big objective into small parts and seeing what subtopics you could get from that big objective. (Laura, 6/12/06, Exit interview)

Contrasting Laura's views at the beginning and end of the study provide insights in understanding how they developed over time and how they connect to the analysis framework. Furthermore, during the time of the study, several elements were transformational in Laura's development as a novice teacher. These transformational constructs, such as her views of the role of the teacher, the content she was teaching, and her perception of students' abilities, influenced her views and espoused teaching practices. Analysis revealed that Laura developed more in-depth views of supporting evidence-based explanation construction, the use of scientific public discourses as a tool and vehicle for explanation construction, and finally, complex views of her role as a teacher in aiding student learning.

4.4.3.1 Constructing Evidence-based Explanations

References to constructing evidence-based explanations throughout Laura's reports appeared to be limited; however, careful examination revealed that she used a combination of terms to describe evidence-based explanations. Thus, apparently, she went back and forth between using the term conclusions and the term explanations. During the first unit Laura appeared to give emphasis to the process of constructing evidence-based explanations rather than the explanation itself. For example, in her description of the first two weeks she said,

> We got into a great discussion about the needs of a plant so the students were able to understand the plant's needs, either aquatic or land plants. Students were able to make the connection that a water plant needs the same things that a land plant. (Laura, 2/27/06, Continuous-weekly reflections)

Laura also replaced the "claim" term with a more general language with the term conclusion. This was apparent when she said,

> As we started to discuss about microscopes students came to the conclusion that a microscope is used to look at really small things. (Laura, 2/27/06, Continuous-weekly reflections)

Interestingly, Laura was emphasizing evidence since the beginning of the unit. This was apparent when she said,

> I feel that looking at the picture, students were able to develop explanations. When I asked, "How do you know?" They were able to cite specific support from the pictures [of the inside of a plant] that were projected. (Laura, 2/27/06, Continuous-weekly reflections)

Analysis of all the instances in which Laura made reference to explanations revealed that emphasis towards the construction of evidence-based explanations appeared to be influenced by the scientific content. Although this apparent link between content and emphasis toward evidence-based explanation construction was apparent during both units; it was during the second unit that the link was more robust. One apparent link to the content was through Laura's described efficacy and confidence in the scientific content. For example, during the first unit, Laura felt comfortable with the topic; thus she made many references to enacting such emphasis. For example, she said,

> I feel that the research I did prior to this lesson really, really helped to support explanation development and science talk throughout my lesson. I was able to provide students with accurate information, and I myself had a really great understanding of how water did travel up a stem. (Laura, 2/27/06, Continuous-weekly reflections)

> I feel that there were really great examples of students constructing explanations from evidence during the lesson and students discussing or debating evidence and/or explanations throughout my lesson. With the explanation from evidence, I feel that looking at the picture, they were able to develop explanations. When I asked, "How do you know that?" They were able to cite specific support from the pictures that were projected up on the screen. When one of my students made a statement that the outside of the stem carries more water, and I asked, "How do you know that?" They [sic] were able to say, "The outside of the stem is a darker green. So I think that means it carries more water, and that's why it's a darker green." (Laura, 2/27/06, Continuous-weekly reflections)

This reference to content also portrayed Laura, as a prospective teacher, being extremely aware of subject matter. This was confirmed because Laura believed that supporting evidence-based explanations stemmed from a teacher who is knowledgeable on the topic. Evidence to support this derives from a quote previously used,

> I feel that the research I did prior to this lesson really helped to support explanation development and science talk throughout my lesson. I was able to provide the students with accurate information and I myself had a really great understanding of how water did travel up a stem. (Laura, 2/27/06, Continuous-weekly reflections)

Laura's views towards the construction of evidence-based explanations can be represented across units in Table 4.17.

Laura's Views on Evidence-based Explanations across Units		
	Unit One: Life Under the Sea	**Unit Two: The Wonderful World of Nature**
Views	• Stated that explanations need to be based on evidence. • Stated that a teacher who is not knowledgeable in the content cannot support explanation construction. • Believed that experiments are critical in collecting evidence.	• Stated that explanations need to be supported by evidence. • Stated that the explanation needed to connect with the "big idea." • Stated that is important for students to develop their own questions and procedures that lead to the collection of evidence, and thereby, explanation.
Practice Report	• Accepted prior knowledge as a source of evidence for explanations. • Extensively investigated the content she was teaching. • Emphasized aligning experiments' evidence with explanations.	• Prompted students to use evidence when forming explanations. • Prompted students to contrast evidence and observe evidence patterns. • Prompted students to connect evidence with the overarching questions and sub-questions. • Prompted students to develop a testable question.

Table 4.17 Laura's Views on Evidence-based Explanations across Units

4.4.3.2 Notions of Inquiry

Laura's view of inquiry and how it fits with the analysis framework impacted her espoused views and practices for teaching science. Laura's espoused views of the nature of inquiry drove her decision-making. Although Laura described specific activities and goals for each unit, further examination of her reports demonstrated that she did not describe many activities that took place in the classroom. Nonetheless, after examining Laura's self-reports the conclusion was that Laura did not follow the curriculum guides, and she constantly modified the objectives and lesson plans to meet the needs of her students. For example, she said,

> For instance, today we were going to have our students observe their aquariums and have them write about it[sic]. But today, they started asking questions about, well "Is a fish a mammal? How do fish make babies? How does that all work?" We completely changed that around to a hands-on research project where the students were able to use the Internet. We got materials from the library and they themselves were doing their own research to answer their own

> questions and they're developing these wonderful reports to answer their own questions. (Laura, 2/22/06, Contet/Initial questions)

At the beginning of the first unit Laura's definition of inquiry appeared to be based on two elements: the presence of an overarching question and an in-depth discussion. This definition was apparent when she said,

> I feel that the lesson I taught this week ranks at a four in relation to inquiry. I feel that it ranks as a four because I presented the kids an overall question we wanted to answer. That question was, "How does water travel up an Elodea stem?" (Laura, 2/27/06, Continuous-weekly reflections)

> I felt this was important for students to know because they have so many questions…and then, we got into a really great discussion about what do plants need in order to make food. (Laura, 2/27/06, Continuous-weekly reflections)

The presence of an overarching question and discussion as determining elements for considering an inquiry-based lesson appeared to be consistent across the unit; however, she expanded her report to include other elements. Laura emphasized the following elements: teacher gathers students' prior knowledge; the lesson is hands-on; students make some conclusions; lessons are connected or resemble what scientists do; and students build ideas upon each other. She said,

> I believe that these three days of teaching really were inquiry-based. Students were doing hands-on experiments that were meaningful to them. We had a pre-assessment discussion before any of these experiments took place and this pre-assessment gave me the opportunity to analyze what my students already knew, but it also gave my students the chance to build off of one another's ideas. (Laura, 3/13/06, Continuous-weekly reflections)

Note worthy, however, is that many of the elements that Laura mentioned are generic and not science specific. As evident in the examination of her views by week, Laura's ideas of inquiry continued to develop. As a matter of fact, Laura's ideas of inquiry during the last week of the unit also included the element of "discovery" when she said,

> I feel one of the essential elements of inquiry-based instruction is the idea that children discover new knowledge on their own or without the guidance of the teacher. (Laura, 4/3/06, Continuous-weekly reflections)

As in the case of Angela, Laura used the term "discovery" loosely. She also referred to discoveries as a synonym for explorations were students are pursuing a claim that is consistent with teaching objectives. In fact, Laura reiterated a teacher's ability to support these elements by being content knowledgeable.

An examination of the second unit, "The Wonderful World of Nature," regarding her views of inquiry demonstrated a mixture of ideas. These notions were evident while examining her inquiry ratings for this particular unit. Laura rated her lessons as a four because she focused on assessing students' prior knowledge and not teaching science content. In her own words, she said, "I did not have any real concepts this week that I wanted to teach my students about." During the second week of the unit Laura rated her lessons as a five because they had all the inquiry components. She said,

> My students develop a big question for the plant part of our unit and from that question they had the opportunity to design their own experiment using the scientific method, which is going to help them to create their own claims about their wonderings. (Laura, 5/12/06, Continuous-weekly reflections)

Unfortunately, as the unit progressed with students' independent work, she did not rate her -lessons but claimed that they were inquiry-based. She said,

> I do feel that these weeks' lessons have really been based on and around inquiry just because my students have been doing all the research themselves and have had just fun putting their projects together. They have been completing diagrams, some of them are doing riddles, and some of them are creating informational paragraphs about their animals' groups. (Laura, 5/30/06, Continuous-weekly reflections)

These ideas of students working by themselves demonstrate a naïve idea that is inconsistent with other views she expressed during the same unit. Yet, it provides incongruence or inconsistency with other views she provided in her self-reports regarding appropriation of the framework.

4.4.3.3 Teacher's Role

The teacher's role is critical in understanding Laura's story. Therefore, the assertion is that Laura's perceptions of the teacher's role in inquiry influenced her framework appropriation. The teacher's role can be directly linked to Laura's development in her understandings about the role of

questioning in science teaching. Subsequently, her generic understandings of the role of questioning helped her appropriation and development in helping children construct evidence-based explanations.

During the first unit, "Life under the Sea," Laura was not explicit about her role as an elementary science teacher; however, based on her self-reports, she prioritized the role of the teacher as a questioner. That meant that the teacher was responsible for asking numerous questions that elicited students' thinking and learning. For example, during the first two weeks of the unit Laura said,

> We started talking about, "How do we think these tubes carry the water?" I asked, "Do you think it carries it up the stem or do you think some of those tubes carry down the stem?" I asked, "Why are we seeing water in the middle of our picture?" (Laura, 2/27/06, Continuous-weekly reflections)

This questioning role was also evident during subsequent weeks when Laura said,

> On the first day, I spent most of the time collecting prior knowledge. I asked my children, "What do you know about pollution?" . . .[During the experiment] they [students] noticed that the cups that only had a little bit of cornstarch in it [sic] were more of a deeper purple. I asked them, "How can scientists use this test to try to figure out how polluted water is?"…The next day we did another color experiment…I asked them, "What would happen if you only put a little bit of chocolate in the milk?" (Laura, 2/27/06, Continuous-weekly reflections)

Later during the unit she said,

> One of my students said, "Ms. Laura, the cup that was filtered by the sand has a higher concentration of sand in it now than it did before it was filtered." When I asked how she could tell, she replied by saying, "Well I see particles of sand at the bottom of the cup and the water is cloudier than before." From this lesson, I hope to educate my students further about ground water and contamination. (Laura, 3/27/06, Continuous-weekly reflections)

Laura's description of what her role was during the second unit was not very explicit; however, based on the description of the kind of activities in which she engaged students, apparently she was primarily guiding students to become interested in answering a question and encouraging students in the process of self-guided projects while making sure students were successful in their quests. She said,

> After a brief discussion, we were able to conclude that they [wonderings] all dealt with what a plant needs to grow. After we came to this conclusion, I asked them if there was a bigger question we could put all these sub-questions under. After another discussion, my students were able to come up with the question: "What does a plant need to survive?" Once this question was

> developed my students got to pick which group they wanted to be in: the soil group, the water group, the sunlight group, or the air group. (Laura, 5/12/06, Continuous-weekly reflections)

Thus, Laura viewed her role as a "guide" that supported students learning in connecting content to the big picture, discovering new knowledge, and concluding, on their own, how to solve problems. In addition to guiding students through the research process of investigating a question, Laura appeared to continue to believe her role to be one of facilitator. This was apparent when she said,

> As I have been circulating around my classroom, my students have really been starting to understand the major characteristics of all the animals and their different animal groups. (Laura, 5/30/06, Continuous-weekly reflections)

However, these ideas are contradictory with other self-reports she provided when she portrayed an emphasis in supporting evidence-based explanations. For example, in an earlier week Laura was more explicit in her self-reports about supporting evidence-based explanations. Furthermore, she intertwined explanations with inquiry-based instruction when teaching the unit of The Wonderful World of Nature. She said,

> When using inquiry-based instruction, it is so important to develop a big question so that there is a purpose for what you are doing. The big question helps guides [sic] students' thinking and helps them connect evidence to their claims to support their answers when answering the big question. (Laura, 5/12/06, Continuous-weekly reflections)

Thus, when Laura's emphasizing evidence-based explanations contrasted with her views on the role of the teacher, the inference is that emphasis on evidence-based explanation was linked to her views of the role of the teacher.

4.4.3.4 Public Reasoning

Notions of public reasoning and discourse were elements that Laura demonstrated appropriation at the beginning of the semester and continued to develop across units. Laura's emphasis towards public reasoning was always linked to questioning, either by the student or the teacher. These questions were

always succeeded by a discussion. Thus, apparently, Laura also thought that her role was as discussion facilitator. In her reports she made constant reference to discussions. Some examples are,

> We first discussed the definition of a microscope, and then I asked them questions…As we started to discuss it, they [students] came to the conclusion that a microscope is used to look at really small, small things…We started talking about how do we think these tubes carry the water…I had really planned to have a great discussion about the function of the stem and how the water travels up the stem. Something that happened that I didn't expect to happen was all the wonderings to come about. (Laura, 2/27/06, Continuous-weekly reflections)

> Once the experiment was completed, I gathered them on the carpet and we talked about it (Laura, 3/13/06, Continuous-weekly reflections)

> Before the [filtration] experiment, we talked about which material we thought would work best and why. (Laura, 3/27/06, Continuous-weekly reflections)

> The discussions centered on connections that they were beginning to make during the [oil spill] activity. (Laura, 4/3/06, Continuous-weekly reflections)

These multiple references to discussions and the purpose to which these discussions were used suggest that she incorporated public discourse of evidence, claims, and justifications in her lessons. Although Laura made endless references to class discussions, the language used in her self-reports did not clarify who was doing the talking (the teacher or the students). Nonetheless, evidence suggested that Laura viewed her role as the vehicle for explaining certain concepts to children; whereas on other occasions, the student was leading the explanations. This was noticeable during the first two weeks of the first unit when she said,

> I noticed that students still had trouble connecting the content that had been presented to them. (Laura, 2/27/06, Continuous-weekly reflections)

Then, during the third week she emphasized the aspect of explaining a concept to children once again when she said,

> The next day, we did another color experiment where we dealt with the topic of concentration. I explained to them, using examples of chocolate milk, that concentration is when you mix two things together and you look to see. I used the example of chocolate milk to my children to understand what concentration meant. (Laura, 3/13/06, Continuous-weekly reflections)

4.4.4 Influence of Reflections in Science Planning

Based on available evidence, emphasis on evidence-based explanations was scaffolded through the protocols, drawing Laura's attention towards evidence collection, analysis, and claim making. Laura's references, in her self-reports, of students constructing evidence-based explanations were somewhat limited at the beginning of the first unit. However, arguably, she was attaining this construct at least to some degree since she was constantly making reference to necessary elements in the construction of evidence-based explanations, maybe because her views were superficial. For example, during the second week Laura referenced explanations within the context of evidence patterns in observations. She said,

> I didn't expect my kids to start to want to test the water plants and try to figure out what would happen if a water plant were outside of the water. (Laura, 2/27/06, Continuous-weekly reflections)

An additional example occurred during the third week when she said,

> I believe that on the two days that we did the experiments, and my children were doing these hands-on activities, they were really starting to look for patterns. One day, the one where we did the cornstarch, they were kind of starting to see connections to water pollution. But by the second day where the food coloring showed a vast color differences [sic], they were really starting to see that you can tell the difference between different amounts of pollution in the water. So then they were really starting to ask more questions, but then they were also starting to make more connections. I think that was a great example of my students looking for patterns in their observations because they were still pulling observations from the previous day when we had done the cornstarch experiment. So they were starting to see patterns. (Laura, 3/13/06, Continuous-weekly reflections)

Also evident was the rating protocol question had an impact in her teaching plans. Laura reported that thinking about what made a lesson, inquiry, improved her own teaching because it focused her in those inquiry elements. Those reflections in combination with feedback from her mentor-teacher "confronted" her thinking of what counted as good science teaching. Thus, study protocols influenced her espoused views of science teaching**.** Laura's attention to supporting and teaching science as argument evolved

positively over time. Protocol influences helped her become more interested in continuing to teach science. However, Laura attempted to meet the protocol questions by attaining these elements in her planning. These changes led Laura to provide students more opportunities to engage in discourse practices that led toward evidence-based explanations yet at a more superficial way as compared to Teria and Angela.

4.4.5 Context Elements' Influences on Teaching Science as Argument

4.4.5.1 Science Methods Course

As mentioned earlier, prior to joining the Professional Development School, Laura was not enthusiastic about teaching science due to her own experiences as a science learner. However, according to data in the entrance interview Laura's successful experiences during the science methods course provided a context for understanding that her experiences were related to specific teachers and not the subject itself. This was apparent when she said,

> A big thing that helped me change was just having your class last semester and seeing you doing all these experiments with us that I, even a 22-year old found enjoyable. Just being excited to think that it is possible to have an experience with science that's enjoyable is amazing. (Laura, 2/13/06, Entrance interview)

A perennial aspect of the science methods course evident in Laura's self-reports was specific elements of the science methods course such as assignments and class tools. For example, during the entrance interview Laura referenced the TESSA cases. She said,

> I think it was just doing those TESSA cases, observing and trying to figure out what the teacher was doing within the classroom and what role does questioning play during the science lesson. Starting to analyze, that helped me, when we started to plan our science lessons because I had to start to think what did I observe my mentor doing? What did I observe during the TESSA cases? How can I incorporate that into my lessons to make it a successful lesson? The TESSA cases definitely helped me begin to think about teaching science. (Laura, 2/13/06, Entrance interview)

Then she further explained,

> Then the reflections! Just hearing the teacher's point of view about what was going on in the class. Her reflections really helped to tie everything together. Even the questions that went along with the TESSA cases really helped you to really look at the video and think about what was

> really going on. Why was the teacher doing what she was doing? Why did she have one group share their findings with the whole class? Just seeing stuff like that really helped me to think about science teaching. (Laura, 2/13/06, Entrance interview)

During the exit interview, Laura also made reference to elements of the science methods course as influential in her teaching. For example, she mentioned the utility of the KLEW chart in uncovering students' misconceptions and providing important information to alter or plan science lessons. She said,

> I found that the KLEW chart has really helped. Just with the K column (what they already know). As I read through some of the student's ideas I actually found some misconceptions. I actually found things like "magnets stick to metals." That is a misconception that they had and I was able to pull the experiment we did from that. My KLEW chart wouldn't always do that for me but luckily the past couple of units I found misconceptions in that column just because I make all my students write down something that they know and then we put it up. (Laura, 6/12/06, Exit interview)

This notion of misconceptions learned from the methods course repeated again at a later point in the exit interview. However, on that occasion Laura made reference to also pursuing learning students' misconceptions by other means similar to what she learned in the methods course. She said,

> It helps students learn from those misconceptions that they had. If I didn't get that from a KLEW chart I got it from discussions or just walking around and talking to my students while they were working. I could get the misconceptions by doing a brief interview maybe not so formal like we did for science but just asking students a couple of questions, and seeing what their answers are. You could pull from that. (Laura, 6/12/06, Exit interview)

Another influential element of the science methods course was learning how to locate meaningful resources. During the exit interview Laura was asked, "Are there certain kinds of resources that you tend to rely on more than others?" to which Laura made explicit reference to educational research. She said, "I am going to continue with my science magazine [*Science and Children*]. I really enjoy getting that science teaching magazine."

4.4.5.2 Professional Development School Peers

Laura made few references to her peers as a source of influence. However, these references were in the context on how other interns viewed and defined inquiry. For example, during the exit interview Laura questioned how to teach certain content as inquiry and related a conversation with Peggy. Laura said,

> I know the 5th grades have been doing the human body, and I have talked to some of my friends like Peggy. Peggy has been thinking about how she could use inquiry for the human body, and I even started to think about how to make it inquiry. I don't think there's a really good way that you can do that. I really think it's one of those topics, not that it is memorization, but I don't know how to you can make it inquiry. With the animal groups you have specific groups that have specific characteristics and you can't really do an experiment on an animal, and it is the same with the human body. (Laura, 6/12/06, Exit interview)

An aspect that is related to the professional development school yet not about Laura's peers is her interaction with her mentor-teacher, which appeared to be instrumental in her development. Hence, she constantly made references to her mentor-teacher and how they interacted in planning, developing, and assessing science lessons. Thus, apparently, the mentor-teacher-intern interaction influenced Laura's conceptions of teaching science as argument.

During the exit interview, Laura made a reference to how conversations with her mentor-teacher led to some modifications to the lessons. She said,

> Maura and I had to sit down together and really think about the lessons because the more traditional classrooms in the primary division were just doing a more traditional approach. What is a plant? What is a mammal? And just having students find facts. I talked to Maura and I didn't want to take that approach. Not that there is anything wrong with it, but we came up with this really cool idea where we cut out different magazine clippings of all six animal groups and gave them to the groups. We asked students to sort them however they wanted to and they came up with their own categories… (Laura, 6/12/06, Exit interview)

Another example of Laura's reference to her mentor-teacher's influence was toward the end of the exit interview when she attributed her success during science talks to Maura's interventions. She said,

> Sitting down with Maura in the beginning process of each unit, thinking about how we wanted to approach science has really helped me. Her ideas are just amazing. I mean she come up with some of the most creative things. She helped me a lot in the beginning. She really sat down with

> me during our discussions and helped me with a couple of my magnet lessons. She was sitting in that circle with me, helping me. She would ask questions too and I would think about the questions that she asked and be like "Wow, those are good questions that I should definitely know." She gave me wonderful feedback and constructive criticism, which really helped me break down my first couple of magnet lessons. (Laura, 6/12/06, Exit interview)

4.4.5.3 Children's Ideas

Laura's teaching was greatly influenced by students' responses to her teaching. For example, during the first two weeks of the unit, students' written descriptive observations were not as detailed as she expected. Therefore, she made explicit comments to children on how to improve their observations. Another teaching influence was the content connections students made. She said,

> As I was looking through the ecosystem notebooks that they write in, I noticed that they still had trouble connecting the content that had been presented to them. So then I thought to myself maybe using a microscope would help them to make these connections and help them understand better. (Laura, 2/27/06, Continuous-weekly reflection)

Other influences during this unit were students' ideas and questions. She said,

> But before I knew it, my students were presenting predictions and were asking wonderful questions that really helped the rest of the class start to see connections and start to look at the picture [of an Elodea] in a different way. (Laura, 2/27/06, Continuous-weekly reflection)

Moreover, students' engagement influenced her comfort level and impacted her desire to continue teaching science. This excitement was observable when Laura said,

> I wasn't sure how excited my kids were going to be about this topic. I had put so much work into it that I almost expected that my students were not going to respond at all, and they weren't going to be excited about the picture. But as soon as that picture was put on screen, all the "oohs" and the "ahs" and all of their reactions just really helped me feel better about the lesson. (Laura, 2/27/06, Continuous-weekly reflection)

Finally, observable in her self-reports is the influence students' misconceptions had on her planning of subsequent unit lessons. For example, during the third week she said,

> I want to make sure that I begin to think about misconceptions that some of my students might be having and think about how I can address those misconceptions for my next lesson. (Laura, 3/13/06, Continuous-weekly reflection)

Many of the teaching decisions Laura made were based on students' wonderings, especially during the first week of the unit. However, she was not specific in describing what exactly changed in her teaching as a result of students' questions. She said,

> The students had the opportunity to ask questions that dealt with both topics [plants and animals]. These wonderings were also posted on our KLEW chart. I did not used [sic] a lot of my students' knowledge to influence my teaching for science this week. I listened to their ideas and we talked about what they were sharing. We had the opportunity to record their knowledge onto paper and post it on our KLEW chart. We also discussed wonderings that they had for both topics. These wonderings are what influenced my teaching for the next week (Laura, 5/5/06, Continuous-weekly reflection)

Moreover, apparently Laura's understanding of inquiry was also highly influential in her decisions. For example, she thought that students needed to create their own experiments in order to be more inquiry-based, causing her to plan accordingly.

4.4.6 Summary

Laura's story depicts prospective teachers that focus on explanations or conclusions, as she called them, and who was doing these explanations. She deemed important learning content and placed attention on questions and discussions about children's ideas. However, these emphases that Laura placed were most of the time described in a generic way and somewhat detached from the specifics of science teaching and learning. Nonetheless, Laura's story demonstrates a prospective teacher who, otherwise not participating in these experiences, would have continued to place no interest or attention on teaching science in elementary classrooms.

4.5 Chapter Summary and Preview

This chapter presented a detailed description of each of the science units Angela, Teri, and Laura taught while participating in the current study. Although emphasizing different aspects of the protocols, these participants all presented their views of effective science teaching and giving priority to evidence-based explanations. Evidently, all three participants' progressed in thought complexity regarding

teaching and regarding more detailed representations of their roles for supporting inquiry and evidence-based explanations. Thus, the following chapter provides a cross-participants' analysis and provides substantive theory derived from evidence.

CHAPTER 5: CROSS CASE ANALYSIS AND DISCUSSION

5.1 Introduction

As described in chapter 4, Teri, Angela, and Laura provided different and unique stories about how they appropriated elements of the framework and how protocols and other contextual elements of the teacher preparation program influenced their attention to specific science constructs emphasized during the science methods course. Although the three participants were unique, several aspects of their experiences were consistent. An understanding of such commonalities aids teacher educators' efforts to improve teacher education experiences such as science methods courses, student-teaching experiences, professional development practices, and policy changes.

Teri's story revealed an in-depth understanding of teaching science as argument and strong awareness of the need to reconcile her understanding with her actions. She also demonstrated an inquiry orientation with a core emphasis on talk and evidence-based explanations. Angela's story, on the other hand, revealed an early commitment to teaching science as argument. However, she struggled constantly with the content and her teaching practices. Finally, Laura's story was more typical of a prospective teacher with a general understanding that was developing in an important way. That is, she was beginning to focus on children and pay attention to the importance of science in children's development. These three stories, although different in many ways, shared a number of commonalities across important ideas associated with teaching science as argument.

An examination of data for these three participants demonstrated that Angela, Teri and Laura had adopted framework elements at distinctly different times. In addition, findings

based on the data demonstrated that specific aspects of the protocols as well as other factors influenced science planning, teaching, and participant's views of effective science teaching. Hence, a cross-examination enabled the development of several assertions. First, analysis revealed that participant's emphasis on evidence-based explanation was affected by the presence or absence of opportunities to interact with phenomena and collect data first-hand. Second, participants viewed science talks as an essential component in aiding students' construction of evidence-based explanations and attempted to enact science talks as a vehicle for meaning-making. Third, analysis protocols positively influenced participants' views of effective science teaching. Fourth, participants developed more in-depth understanding of science content through teaching. Finally, participants' perceptions of students' abilities influenced their attention to elements of the analysis framework.

These assertions help to answer the research questions outlined in the study. Table 5.1 provides an overview of each assertion and the research question to which they are linked.

Research Questions	Assertions
1. What are the ways in which PST take-up components of teaching science as argument during their student teaching field experience following the methods course?	Assertion #1: The presence for interacting with phenomena and collecting first hand data helped participants increase their emphasis on evidence-based explanations. Assertion #2: Participants viewed science talks as an essential component in aiding students to construct evidence-based explanations, and they attempted to enact science talks for the purpose of meaning making. Assertion #3: Participants demonstrated attention to the scientific content they were teaching rather than solely the inquiry process.
2. To what extent do components from PST reflections influence planning for science teaching?	Assertion #4: Scaffolded protocols positively influenced participants' attention to helping students construct evidence-based explanations during science planning and teaching.
3. What elements from the context influence PST attention to teaching science as argument?	Assertion #5: Teachers' beliefs about children's science capabilities influenced their attention to and adoption of specific components of teaching science as argument.

Table 5.1. Assertions linked to research questions

Each assertion is presented using the following format: assertion – description – evidence – discussion. In order to better describe the function of the components of each assertion, Table 5.2 provides descriptions.

Assertion Component	Description
Assertion	Provides a relationship derived from all three participants
Description	Provides a short paragraph that describes the assertion
Evidence	Provides multiple data points in the form of quotes that were utilized in Chapter 4 for each participant's story. These quotes attest to the validity of the assertion.
Discussion	Provides a context for the assertion using available literature. Also addresses how the assertion is different or similar to what is known in the literature.

Table 5.2. Descriptions of Assertion Components

5.2 Assertions, Evidence, and Discussion

5.2.1 Assertion One

The presence of opportunities for interacting with phenomena and collecting first hand data helped participants increase their emphasis on evidence-based explanations.

5.2.1.1 Description

Participants' focus on helping students construct evidence-based explanations was influenced by instructional content. That is, emphasis on evidence-based explanations and the practices supporting this endeavor were more present in participants' self-reports of their teaching when lessons provided opportunities for interaction with children and allowed them to collect first-hand data. First-hand data in this case are defined using Hug and McNeill's (2008) characterization of data "that occur when students investigate phenomena using

various hands-on inquiry practices" (p. 1726). Conversely, second-hand data are defined, using Hug et al.'s (2008) definition as data collected in others' investigations. However, for the purposes of this study models were also used to describe certain phenomena. The term "model" refers to the use of physical or graphical representations to acquire data. For example, using a light source, an orange fixed on a pencil can be used to represent the phases of the moon. For the purposes of the current study, models are categorized as second hand data. Hence it is worth noting that the use of first- and second-hand data is important in elementary school settings since certain phenomena may not be studied through first-hand investigations due to a variety of factors. A common factor in engaging in first-hand data collection in elementary school classrooms is limited resources. These limitations often inhibit the ability to engage in physical experimentation. Physical experimentation is the degree to which a phenomenon can be physically tested rather than examined using models or inferring information. Thus, the current assertion suggests that the more abstract the content, the more difficult it was for participants to provide students with meaningful opportunities to construct evidence-based explanations. On the other hand, the more concrete the content, the more meaningful the opportunities to scaffold and emphasize the construction of evidence-based explanations.

5.2.1.2 Evidence

An examination of participants' self-reports revealed greater emphasis on aiding students to construct evidence-based explanations when the topics they were teaching allowed the acquisition of first-hand data and thus the content permitted "simple real-time" physical representations of the phenomenon. These "simple real-time" physical representations were present in various units such as Magnets, Simple Machines, and

Wonderful World of Nature. These units allowed for evidence-based explanations since experiments, results, and patterns were observable to students. For example, students were able to test first-hand whether a spoon was attracted to a magnet or where to place the fulcrum in a simple machine. On the other hand, the data showed that participants struggled with explanation-building when teaching the units Prehistoric Life, Rocks and Minerals, and Life Under the Sea. All of these units presented a common characteristic—that it was harder to use first-hand data in the classroom and so second-hand data were often used instead.

The implications of emphasizing the construction of evidence-based explanations were raised by participants. During the process of responding to scaffolded protocols, participants characterized the content at times as an obstacle to emphasizing evidence-based explanations. For example, Angela stated:

> I believe that my science lessons were effective in supporting students' learning in the sense that I believe I previously mention in other reflections my students came to a pretty solid knowledge of magnets. They understood a lot of the basic concepts that we were planning on teaching in this unit. What I believe I have provided through these lessons though, is a way of testing their knowledge and providing evidence for what they know. And I think that's so exciting, that's why I was so frustrated before with the Prehistoric Life. I felt like I was spoon-feeding them the answers but they were not discovering anything. With this, I feel they are rediscovering or their understanding is at a deeper level. They know that magnets, or they believe they know, but now they have proof. Now they can say "oh, when we did these experiments with Mrs. Angela or in first grade we found that magnets stuck through our skin or magnets stuck through wood and that not all large magnets are strong and that not all small magnets are weak." These are things students have visually seen, touched, thought about, discuss, written about and now have a more solid knowledge, understanding which is what excites me. (6/4/06)

In this quote, Angela refers to "testing" as a way to describe how the unit on Magnets allowed students to use first-hand data to construct explanations. She also felt that the unit allowed students to gather "proof" to support their ideas. On the other hand, when she referred to the Prehistoric Life unit, she described it as spoon-feeding and did not refer to

"testing" or having "proof." In the case of the latter unit, as described in the previous chapter, students used second-hand data to make meaning of the scientific concepts.

Teri's self-reports also attested to a similar scenario. She referred, too, to the effects of certain content on facilitating the construction of evidence-based explanations. For example, during the exit interview she noted the content and its direct correlation with the kinds of evidence that can drive an explanation. She said:

> I think with the rocks like we were trying to come up with a definition of a rock, and we did a sorting activity and the kids were focusing on the wrong components of the rocks. Like they're like, "well this is wood, it's a wooden block so that's not a rock." I'm like "well, what else about it." You know, it was just, I guess it was just harder to pull that information out. The activities weren't as obvious like an experiment or something else were they're collecting pretty obvious data, so it was a lot of directing and trying to figure out like on my feet what kind of questions I could ask about what the students were focusing on like their understandings I wanted or the observations I wanted them to make. (Teri, 6/12/06, Exit Interview)

According to Teri, "The activities weren't as obvious like an experiment or something else where they're collecting pretty obvious data…" This demonstrates the difficulty experienced both by her and the students in the absence of first-hand data. Furthermore, she explicitly stated that it was difficult to help students understand the meaning of data not drawn from first hand tests. References to the struggles with explanation-building as a result of the content were repeated in Teri's comments when she said,

> Some of the concepts for the rocks were harder to make inquiry and we tried, you know, even with the soil like mixing soil on water, we tried, you know what happens when you do that. But it didn't layer out as you know, much as you wanted so it was hard to connect it, like is this silt, this is ----[not audible] because you couldn't see it, wasn't obvious. I think that I struggled more with the rock component and like the coal component of it, trying to come up with activities that would lead the kids to some sort of understanding. I think the soil is definitely more, it's easier to come up with lessons for inquiry. (Teri, 6/12/06, Exit Interview)

Correlations between content and evidence-based explanations were also found in Laura's comments. Although she was more superficial in her reports, several elements seemed to suggest that the content she taught also helped children construct evidence-based explanations. For example, during the first unit (Life under the Sea) Laura stated that some of the lessons were inquiry-based because there were concrete scenarios. During her exit interview she shared the following:

> Effective science teaching…I think I still stand where I stood at the beginning of the year. Getting the children involved in their own science learning and really I think it's so important to get them engaged. Before you start a lesson I think its important to come up with an engaging activity that really sparks their interests and you can go based off of their prior knowledge where you should lead the next lesson and I think its so important not just to have hands-on activities but have activities and discussions that really relate to the questions that they're having, the prior knowledge that they have already but then asking them what their wonderings are and then looking at those wonderings and trying to see how can you connect those wonderings to a science lesson that matches the unit that you're doing and I just really have learned to go off what my kids are doing or saying because I found that they get so into their science lessons when they fell like they've had a part in creating what they're doing in the classroom. (Laura, 6/12/06, Exit Interview)

Later during the interview Laura also recounted the following:

> Interviewer: So they had evidence to support that. How hard had that been? To get kids to think in terms of evidence and explanation? It seems like you place a high premium on them backing up what it is that they're saying.
>
> Laura: It was very hard in the beginning. Getting them to, just the difference between an observation and something that they know. Getting them to become observers was so difficult because a lot of them want to write down something that they already know. During our plant experiments, which were coming up at the end, students were divided into groups and they each got to formulate their own question that was a sub question of our big question; what do plants need to survive? Having them make observations at first was very hard and it has been a difficult thing to just say, "Look at just what you're seeing." You know, don't say that the plant is smaller because you're not seeing and that is your data that's going to help support your conclusion in the end. And we had to do a lot more of that than even with my pollution and magnets experiments. (Laura, 6/12/06, Exit Interview)

In these quotes it is observable that Laura talked about experimenting as a way to guide the construction of evidence-based explanations. Furthermore, when she provided more details and an example it was apparent that she was more successful when students were provided opportunities to interact with the phenomena and collect first-hand data.

All of these examples highlight each participant's conclusions about the effects of the presence or lack of first-hand interaction with phenomena. Furthermore, these excerpts also attest to the notion that each participant's ability to provide these interactions was constrained by the content, which influenced their attention to and enactment of teaching science as argument.

5.2.1.3 Discussion

According to the recent NRC (2007) report, it is difficult for students to engage in explanation construction if there is no content linked to it (p. 19). A similar claim could be made for teachers; it is difficult for elementary teachers to foster students' construction of evidence-based explanations when there is a lack of scientific content. Furthermore, teachers often struggle with effective science teaching, if there is an absence of appropriate data from which to generate claims. Fostering students' explanation construction is difficult because, according to Krajick, Mamlok, and Hug (2001), teachers lack the appropriate expertise to engage students in inquiry environments when they themselves do not master the content. Thus, it was not surprising that participants struggled with topics that required second-hand data or had limited opportunities to interact with phenomena first-hand.

One way to explain the importance of content is by utilizing Millar and Ametler (2006) statement that there are specific concepts (e.g., energy) that require students and teachers to coordinate epistemological and ontological notions of scientific and everyday

views. This notion is aligned with Driver et al.'s (1994) ideas that students struggle to accept scientific models and find applicability in "known" contexts. Driver et al.'s (1994) ideas may be extrapolated to support the assertion that specific scientific content is more difficult for student teachers to teach, let alone enable teachers to assist students in constructing evidence-based explanations. Furthermore, according to Windschitl, Thompson, Braaten (2008), preservice teachers struggle to understand models since "most have learned about models as visual aids to help explain unproblematic ideas to others rather than as scientific tools to predict phenomena, generate hypotheses, or test ideas" (p. 311). Windschitl et al. (2008) further assert that teaching in alignment with current science education reform "requires an understanding of the role of models in representing and evaluating ideas in inquiry contexts" (p. 311). These statements by Windschitl et al. (2008) provide an additional connection to studies of participants' difficulties with certain topics. Windschitl et al.'s claims are based on previous assertions by van Driel and Verloop (2002), who stated that teachers struggle to understand how models help in the gathering of data when the use of first-hand observations is not possible. Subsequently, findings from these studies show us why participants in the current study struggled with topics that required the use of models to generate evidence or the use of second-hand data to construct evidence-based explanations.

Prospective elementary teachers must learn to use second-hand data and models in their science lessons. According to Kanai and Millar, as cited in Hug et al. (2008), "…having students understand the role of data uncertainty in data collection is critical for the scientific reasoning that follows" (p. 1727). Thus, it is important that our students learn these skills and gain this knowledge. Nonetheless, when participants were faced with engaging children with scientific concepts that required the use of second-hand data, they struggled (more or less

depending on their knowledge) to help students reason and construct evidence-based explanations. Thus, if we are to improve scientific literacy in order to address prospective elementary teachers' understanding of second-hand data and models, we must ensure that students are provided with opportunities to interact with second-hand data and are prepared to use first-hand data (Palincsar & Magnusson, 2001).

Finally, McNeill et al. (2008) asserted that students often have a difficult time selecting data to use in making claims. Although the emphasis of the assertion is not on students' abilities to make claims, there is something to be said about the relationship between the ability to understand and use data and the ability to make claims. The NRC report (2007) asserts that "…many adults never seem to master the heuristics for generating and interpreting evidence" (p. 42). Furthermore, these statements force us to think of preservice teachers as learners and question their own ability to select and interpret data and make claims. If these teachers as learners were unable to do this, it is not surprising that when the content was difficult to represent using first-hand data, they struggled in their teaching.

The literature confirms the assertion that it is not uncommon for adults in general to struggle with evidence and thus with the construction of scientific explanations. In addition, evidence from participants' self-reports in light of the literature confirms the likelihood that prospective elementary teachers will struggle to emphasize the construction of evidence-based explanations when units are founded on concepts that require the use of second-hand data and models. Thus, it is important to further analyze the consequences of these difficulties and their impacts on teacher education.

5.2.2 Assertion Two

Participants viewed science talks as an essential mechanism for engaging students in the construction of evidence-based explanations and as being fundamental to meaning-making.

5.2.2.1 Description

All three participants decided to focus on science talks during the current study. In doing so they revealed their preference to emphasize the construction of evidence-based explanations. Although it is not the intent of this study to analyze the depth or sophistication of each participant's ability to conduct science talks, I did examine the practices adopted by each participant as they sought to use science talks as a discourse practices that included scientific content, public reasoning, scientific literacy, and scientific language acquisition.

5.2.2.2 Evidence

As demonstrated in the individual stories of each participant in Chapter 4, all three interns relied on science talks. In general, Laura's views and description of the use of science talks was the most generic and lacked depth and connection to the meaning-making process. On the other hand, Angela's views of science talks were more sophisticated compared to Laura's but her self-reports of enactment revealed messy practices and somewhat unsuccessful attempts to connect evidence to claims. Finally, Teri's views and self-reports of practices associated with science talk described them as a way to elicit evidence-based explanations across units. Her ideas were very sophisticated and depicted a thoughtful and intentional use of science talks.

Since Teri's views were sophisticated, an examination of the particular elements in her development is worthwhile. A review of Teri's self-reports and interviews reveals that

her descriptions of science talks evolved over time during the current study. For example, during the entrance interview she described the use of science talks as a way to look at patterns, make experimental comparisons, and debate ideas. This was evident when she said:

> We had the big discussion at the end and came back and sat down and put all of our data on the table and looked at it and said, what patterns do we see… (Teri, 1/25/06, Entrance interview)
>
> I guess I would just have to have a discussion with them about that and just stop and just talk about it and then do another experiment and see and compare. (Teri, 1/25/06, Entrance interview)
>
> I guess just like debating and proving. I think it requires them to use what they're seeing because they have to prove to their friend, because even when they're like sitting there working on like even the levers like we were just doing some of the kids were like oh no the fulcrum is here oh no, it is not, look that's moving, like showing them and using like their evidence and observations to back it up. I think they're learning to do that on their own without me even being there saying you know what, how do you know. I think the interaction made them do that, made them consider and consider questions they have or if there's a debate to have. (Teri, 1/25/06, Entrance interview)

These ideas about using science talks evolved over time so that by the end of the first unit she viewed science talks more deeply and was thinking about ways to make better connections between science talks and evidence-based explanations. The following examples support this point.

> For instance, when we were having a science talk at the end of the Fiddling with Fulcrums lesson I got out a model of a lever so the students could come up to the front of the room to explain what they were thinking. (Teri, 3/1/06, Continuous-weekly reflection)
>
> I spent more time having students talk together in a science talk than I had initially planned. I did this because I felt that the students had enough data after testing the location of the fulcrum in three places to make evidence based explanations about where they should place the fulcrum to make it easiest to lift a load. (Teri, 3/1/06, Continuous-weekly reflection)
>
> For instance, some groups were discussing and debating where they thought the fulcrum would be on a broom and had to explain to their friend why they felt that

> way. Most students ended up showing each other the way they were using the broom or lever and pointed to certain parts of the broom or on their bodies to illustrate where they thought the parts of the lever would be. They also had to justify their explanation to their friends. I noticed as I walked around that most groups were in the process of explaining or proving where they thought the fulcrum, force or load was on different levers. Furthermore, because there were varying rates and some level of confusion among students, we discussed and debated the locations of the lever parts we had at the end of the lesson as well. (Teri, 3/1/06, Continuous-weekly reflection)

> I think the first lesson had a little bit more discussion and debate concerning the evidence or explanation because each student had brought in different rocks to break and they were observing different things concerning the characteristics and properties of the rocks. I'm not sure that it was a debate but it took more convincing for the students that some rocks do break into small pieces and some break into large pieces or some dusty or grainy pieces. We had to come to a more general conclusion about what you find when you break rocks to account for the fact that rocks are different from each other because they break into different size pieces or have different size and colors. (Teri, 3/23/06, Continuous-weekly reflection)

Although it is difficult to claim a specific reason for such change, it may be appropriate to suggest that the content she was teaching at the beginning, Simple Machines, may have positively influenced this shift, as discussed in Assertion One. Other examples that demonstrated Teri's notion of science talks as a way to help students reason about evidence while constructing explanations include the following:

> I think the best example of students discussing and debating evidence and explanations occurred during the part of the lesson that I taught where the students were using what they learned about forming sedimentary rocks to explain why the rocks I showed them at the end of the lesson were sedimentary. Students were observing the rocks and comparing what they observed during the food model and discussing their reasoning with their classmates. (Teri, 4/3/06, Continuous-weekly reflection)

This quote also attests to the idea that Teri developed sophisticated ways of thinking and talking about the role of science talks. One piece of data that exhibits the importance placed by Teri on science talks is her reference to them as a core component of her teaching. She stated that students expected science talks during lessons, and then said:

> In order to support explanation development in science talks, as I've mentioned in other reflections, I actually have a time for science talks, which is important in that kids expect it now, after we do a lesson to have a science talk where they discuss their evidence and explanations. I also tell them throughout the activity that we will be discussing later so make sure they have in mind their evidence and the claims that they're making…I also asked questions to focus their observations throughout the lessons, and I think this helped foster explanation development in science talk. (Teri, 5/2/06, Continuous-weekly reflection)

Teri's notion of science talks as a core idea and practice in her science teaching was also demonstrated in her descriptions of her teaching during the exit interview. She stated:

> Having the science talk and connecting the evidence and the explanations they made is essentially making sure that they're accomplishing what I wanted to be accomplished in the lesson. And I think it helps kids to hear their, you know, their friends' ideas and sometimes the students might not recognize patterns or you know have made the same observations and it is a time for them to share those with their classmates so that everybody has like a scaffolding opportunity so that everybody understands, and then again like I said, there like you know assessment usually after we have these science talks, they have to go back and answer some, actually write it down so I think verbally it is easier for them to think about and like you said sometimes there might be misconceptions that arise or you know trying to figure out what counts as an explanation or you know making sure they have the evidence to tie it but again I think it's a huge component of knowing whether or not they are understanding why they did the investigation and to make sure that they're you know connecting it to answering the questions so I think its very important, it ties, it brings everything together." (Teri, 6/12/06, Exit Interview)

This quote further supports Teri's stated desire to continue developing her understandings of science talks as a tool in support of students' construction of evidence-based explanations.

Angela's views and practices provided a different story. While she demonstrated great commitment to specific ideas about teaching science, such as using science talks, her self-descriptions of her enactment of such ideas were inconsistent, problematic, and confusing. Nonetheless, she adopted science talks as a tool in aiding the development of evidence-based explanations. Early descriptions of her understanding of science talks were more about the notion of discussing observations, ideas, etc. In other words, Angela viewed

science talks at the beginning of the semester in a more rudimentary fashion, focusing on sharing rather than questioning information. This notion of sharing was evident when she said:

> My favorite time was really when, one of my favorite times was when we were on the floor predicting, making predictions and discussing and guessing and getting the students' ideas out. I think that is really, I just think that's really important. I've seen it work well in Emilia's and Sarah's class and I felt it worked well in mine. I think it's not just when I say talking. I don't just mean talking; I really mean the class giving ideas. Because I found that when one child said one thing then another child would say, "Oh yes", and they would bounce off each other. (Angela, 1/23/06, Entrance Interview)

In addition, her early descriptions of science talks characterized them as an opportunity to ask questions and assess students' thinking rather than to make meaning of scientific concepts, negotiate, and reason ideas as a class. This was evident when she said:

> I found, as a teacher, to support explanation development and science talk I need to keep asking questions. I specifically need to listen to students' answers while remaining "non-judgmental" and avoiding using yes or no responses. (Angela, 3/17/06, Continuous-weekly reflection)

> I was really letting the students discuss what they were discovering as opposed to putting ideas in their heads. At least I really tried; when they were making observations about the petrification [sic] the students could say what they thought happened. I was not trying to put it in their heads. (Angela, 3/23/06, Continuous-weekly reflection)

Although Angela's self-reports were consistently confusing, by the end of her participation in the study she was demonstrating more depth in her attention to and use of science talks during science teaching. This attention was evident when she said:

> I encouraged science talk through asking kids questions. When the child indicated prior experiences with magnets and computers I asked questions. I had the child explain and give more details to share with the rest of the class. Students started sharing information with each other, which I think is building upon their evidence and claims. (Angela, 5/15/06, Continuous-weekly reflection)

Despite her inconsistencies, evidence from the exit interview suggested that she was attempting to enact science talks as part of the meaning-making process.

> Yes, it [science talks] brings things together. It brings ideas together; new understandings are brought up from that. And perhaps students who are not understanding or are always having those, ah, moments at the table by themselves when they are experimenting might start seeing, making some connections when they are on the floor. So is not just students doing experiments at their own table or in their own groups and discovering basic facts, basic claims or seeing evidence I think is that bind with the group discussion on the floor later. (Angela, 6/7/06, Exit Interview)

Laura's case differed from Teri's and Angela's, yet evidence suggests that she still viewed and attempted to a small degree to enact science talks as meaning-making. Furthermore, Laura's case also illustrated a progression or development in her views. For example, during the entrance interview Laura's reference to science talks was superficial and unspecific. She said:

> It's just so important that kids have that opportunity to talk with one another because it gives them a chance to piggy-back off each one another. One person says one thing and then another person starts to see that same thing and they're like "Oh, I see that too." (Laura, 2/13/06, Entrance Interview)

As Laura began to teach her first unit, Life under the Sea, she still demonstrated views that were not specific to science. Nonetheless, several more specific elements began to surface during her self-reports. For example, she started to think about science talks as a place for not only "piggy backing off each other" but also for beginning to make predictions about the phenomena in the study. This was evident when she stated:

> This was really my first really big science discussion and I was kind of scared that my questions were not going to lead where I wanted them to. But before I knew it, my students were presenting predictions and were asking wonderful questions that really helped the rest of the class start to see connections and start to look at the picture [of an Elodea] in a different way. They were really starting to get excited and really starting to understand what the stem does and they were able to not only does a stem

> provide support for the plant, but it is also its main sources for water. (Laura, 2/27/06, Continuous-weekly reflection)

In addition, during the same week she began to refer to science talks as a forum for debate (although she did not understand the concept of debate, likening it to disagreement). Her lack of understanding of the term debate was evident when she said:

> And then, the students were also getting involved in debates. One situation in particular was when I told them that the two pictures were of the same piece of Elodea stem. I asked them, "Well, which one do you think is the middle of the stem? Which one do you think is the outside?" For a while the kids were going back and forth and I let them lead their own discussion. I let them speak one at a time and vocalize their ideas. One of my students thought that the greener picture was the middle of the stem because it needed to carry more water and the outside of the stem didn't need to carry as much. One of my students contradicted what that students had said and as they started to make connections about the tubes needing to branch off the leaves, they were able to answer their own question. They were able to answer their own discussion and come to their own conclusion about which pictures was [sic] the middle of the stem and which picture was the outside of the stem. (Laura, 2/27/06, Continuous-weekly reflection)

Although this quote demonstrates Laura's generic views, it also shows her initial attempts to emphasize meaning-making in science talks. Further examination of Laura's self-reports at later times during the study also revealed the emergence of ideas about science talks that expanded her views of them as also occurring in small group. For example, midway through the first unit she said:

> Once the experiment was completed and the children saw that the cornstarch in the water, or their polluted water, turned purple, they started to observe color differences. As they were in their groups, I walked around and heard a lot of them talking about [saying] "The one with the less corn starch in it is a darker purple and the one with more corn starch in it is a more white and purple color." Once the experiment was completed, I gathered them on the carpet and we talked about it. My kids were able to come up that the more corn starch, or the more polluted the water was, the more iodine reacted with it and caused it to become more of a milky color rather than a deep purple like the cup that had no cornstarch. (Laura, 3/13/06, Continuous-weekly reflection)

This notion of "debating" also was present in Laura's descriptions several times over the remainder of the study. This was most evident in the following quote:

> Several groups did not agree with some of the other groups about which material they believed worked the best. This led into a great debate about which material we all thought worked the best and why. We talked about what factors might have caused the sand and carbon to work best for some groups while the gravel worked best for others. The groups were able to see that sometimes factors called variables can affect the outcome of an experiment. (Laura, 3/27/06, Continuous-weekly reflection)

Subsequently, each time she attempted to describe how she used science talks to gain a greater understanding, she was arguably demonstrating her early attempts to view science talks as meaning-making.

5.2.2.3 Discussion

The meaning and use of science talks in classrooms has changed over time. In the 1950's, for example, talk was viewed as the action that teachers did with their students without reciprocal exchange. That is, lecturing/talking to students in a monolithic way. Although the uses of talk within the boundaries of a classroom have proliferated and varied across disciplines, talk continues to be implemented in many schools as a teacher-directed action. Unfortunately, engaging in science talks in this way deviates from the nature of science and hinders students' opportunities to develop scientific understandings.

In elementary school science, talk is critical because it allows for meaning-making regardless of a child's writing or reading abilities. According to the NRC (1996), talk is a vehicle that allows students to engage in discourse that prompts for critical thinking while eliciting the use of evidence in formulating explanations. The importance of talk, as argued by many (e.g. Driver et al. 1994; Ogborne et al., 1996), is a central component in the process of doing and thinking about science. Thus, talk is a necessary action in developing understanding of the nature of science and scientific concepts.

The importance of science talks in elementary classrooms, regardless of the focus of the science talk, is rarely debated among scholars. In particular, science talks are seen as a crucial and sophisticated element in teaching science as argument (NRC, 2007; Zembal-Saul, 2009). The importance of science talks stem from their key role in the process of meaning-making and supporting explanation building. Enabling students to construct evidence-based explanations requires the teacher to not only acknowledge the importance of language but also the importance of public reasoning and how these aspects play a role in science talks. In addition, it requires teachers to shift classroom norms (Driver et al., 2000).

Prospective elementary teachers in the current study, as stated in the assertion, valued and attempted to enact science talks in ways consistent with teaching science as argument. However, available literature often describes novice teachers as being unable to focus their attention beyond superficial aspects of teaching (e.g., classroom management). According to Gee (1994), teachers often struggle enacting science talks. Lemke's seminal work (1990) described how secondary teachers often engaged in discourse practices with their students that follow a conservative use and structure of language that did not situate learning in ways consistent with theoretical perspectives of social learning. In fact, he stated that teachers often follow a question/answer/question approach when engaging in "talk." This approach that Lemke described is also frequently observed in elementary classrooms. Participants in the current study described giving attention to science talks in ways that were significantly different than what Lemke observed. On the contrary, participants demonstrated awareness and attempts to engage in science talks in ways more consistent with Gee's ideas. According to Gee (2005) it is through social interactions that discourse occurs allowing students to appropriate science language and master the acquisition of concepts. Contrary to what was

observed with study participants, teachers often view talk as a vehicle for students to merely share results. Often, avoiding science talks because it makes them vulnerable to weaknesses in content knowledge since they may not necessarily feel equipped to answer questions.

Participants' attention to science talks was notable since available literature suggests otherwise. Although the literature does not help us understand why these participants were able to adopt these views on science talks, it does helps us realize the significance of this assertion and the urgency to continue to investigate it further.

5.2.3 Assertion Three

Participants demonstrated attention to scientific content during instruction rather than merely focusing on inquiry processes.

5.2.3.1 Description

All three participants grasped the content they were teaching from both a teacher and student perspective. From the students' perspective, participants' self-reports illustrated their intentions to enable their students to learn content. From the teachers' perspective, they understood the content because they researched it ahead of time and focused science lessons to revolve around scientific concepts, which served as the substance of the explanations they aimed to have students construct.

5.2.3.2 Evidence

Evidence to support this assertion was found in all three participants' reports. Although the emphasis on content varied among participants, all three attended to content in their planning and teaching. In Teri's case, her attention to content was high across units—she intertwined content while attending to elements of teaching science as argument. In

Angela's case, her attention to content varied during her two science units but she attended to it although other factors (e.g., content knowledge) diverted some of that emphasis at times. On the other hand, Laura's self-reports also demonstrated her attempts to pay attention to content during planning and teaching.

Evidence from Teri's self-reports revealed that her attention to content was directly linked to her core ideas about evidence-based explanation as a central tenet in science teaching. This attention was evident from the beginning. For example:

> I thought that [the concept interview] was worthwhile to get experience and realize that you can do that or in different ways you can kind of get like the KLEW chart, get an idea on what your kids already know. I mean the whole lesson project [the three day teaching], I think was really important just actually getting into it and figuring out and working with the group was important for me because we debated a lot "well, is this engagement?" or you know, where's their explanation here, where are we going to have them do this and it was kind of thinking about like how are we going to incorporate these all of these things into the lesson and we don't just want to tell them [students] things so that was important. (Teri, 1/25/06, Entrance Interview)

She also said,

> I think that effective science teachers are those who engage students in the process of science by encouraging and motivating students to actually do science. I think these teachers allow students to experience science and produce their own understandings of scientific concepts and processes. (Teri, 2/20/06, Context/Initial Questions)

Teri's attention to content was sophisticated and intertwined with science talks. For example, she used the science talks to stimulate student discussion, to compare and debate data, and then to aid the construction of evidence-based explanations through public reasoning and dialogue. She claimed that when students were aware of the concepts that they were learning, they observed more sensitively, collected better evidence, and constructed better evidence-based explanations. This was evident when she said:

> I think is important for students to be aware of the concepts they are learning because it encourages them to pay attention to certain observations and certain evidence they

> are collecting and it gives them a direction in their own investigations and a purpose for investigating. (Teri, 3/1/06, Continuous-weekly reflection)

A pivotal moment that demonstrates Teri's attention to content occurred during the exit interview when she said:

> So that was part of the problem too, because I'm like well lets think about in the earth and how long does it really take and its just a hard concept for them to realize that it doesn't happen you know overnight and there were misconceptions like walking on the earth might be pressure and its like, well that wouldn't be enough really to cause the amount of pressure that you would need and there were still a lot of misconceptions around the formation of rocks and I don't really know how you could address it with those demonstrations. (Teri, 6/12/06, Exit Interview)

Here, she demonstrated a concern for what students were learning and how to maintain the accuracy of the content.

During the entrance interview Laura said:

> I am trying to take the pollution aspect that is kind of incorporated in. There's a little bit mentioned about when we, especially when we get into the marsh lands and talk about how their habitat is being destroyed and I am interested to see if there's a way to teach something like pollution to kids conceptually. Young kids. 'Cause I feel like they, it could help build a community within a classroom because a couple of the experiments that I've found, or that Maura found for me have them working together to clean up an oil spill, have them working to try to figure out how polluted is this water. One of my big questions is if I introduce a puppet into my classroom, would that help my students learn about pollution conceptually and you know, and put it on their level because its such a big topic. (Laura, 2/12/06, Entrance Interview)

Laura also attended to content by paying attention to students' content conceptions. This was evident when she said:

> I feel that my next few lessons, I'm going to continue to think about questions to use and I'm also going to start to think about some misconceptions. Not saying that I haven't been thinking about them, but pollution is such a tough topic, I think, for young kids to understand. I want to make sure that I begin to think about misconceptions that some of my students might be having and think about how I can address those misconceptions for my next lesson. (Laura, 3/13/06, Continuous-weekly reflection)

Another example that points to Laura's intentions to help students learn content was found in her self-reports when she described wanting students to be able to notice and understand the "big idea." This notion of the "big idea" was clear in the following quote:

> Through their [students] hard work and science discussions, I feel that I really helped to support my students understanding of oil spills through the use of literature and a hands-on experiment. I hope to use this lesson as a tool to build on the upcoming unit, which focuses on nature. I would love to take this idea of contamination and try to build some science lessons that focus on the big picture. By big picture, I mean how a little bit of contamination affects the whole planet; the humans, the animals, the plants, the various ecosystems, and everything that makes up our earth. I would love for my students to discover how connected everything really is. (Laura, 4/3/06, Continuous-weekly reflection)

Although superficial, Laura demonstrated some attention to content. She said:

> I hope in the future that my lessons will go as good as these ones did, but I know it that it is also going to be a lot of work and that I'm going to need to put a lot of time into and do my homework. I need to do my own background research, especially for such a specific topic such as water moving in the stem of a plant. (Laura, 2/27/06, Continuous-weekly reflection)

Despite that, Laura attended to content during the study as illustrated earlier. However, her views were somewhat naïve. An example was revealed during her exit interview:

> The scientific language and stuff; which is what a lot of my lessons have been about learning. [I am] Not saying that they're going to be responsible for knowing a word like concentration. When I was doing my pollution lessons I wanted them to kind of understand what concentration was and maybe you know, they're going to remember it a year from now but you know, a few months into the unit they could still remember what the word concentration was 'cause we did an experiment where they could actually visually see what it meant to have a high concentration or a low concentration and that helped. That stuck in their minds so much 'cause they could recall from that experiment that we did, well I remember when we used to food coloring in the bottles of water you know, I remember the darker the color the more concentration it had of food coloring in it and it just was really cool to see that they [students] were retaining that big word. You know, that they probably wouldn't normally know. (Laura, 6/12/06, Exit Interview)

Thus, based on this quote it is clear that although at times she did attend to content, at the end of the study she was displaying more superficial thoughts when she emphasized students' ability to define terminology and relate it to prior experiments.

5.2.3.3 Discussion

Many scholars, such as Hinman (1998), have criticized inquiry by stating that science teaching often focuses on skills and processes of science rather than content and conceptual understandings. Scholars often concur with Hinman when he stated that "some teachers now practice science education, the process of doing science becomes almost the sole focus" (Hinman, 1998, p. 26). This critique is often more frequent and strong when referring to elementary teachers due to their lack of subject matter knowledge. The importance of subject matter knowledge in teaching in undeniable, however, prospective elementary teachers knowledge is often limited. According to Ball and McDiarmid (1990) elementary teachers feed their knowledge on out of school experiences rather than knowledge obtained through their formal teacher education programs. Therefore, it is understandable that prospective teachers have limited understandings of science. Others have documented notions of limited subject matter knowledge in prospective elementary teachers as well. In an empirical study with 167 undergraduate students, Wenner (1993) found that on average prospective elementary teachers had low knowledge of science and a lack of confidence for teaching science. Similarly, Feistritzer and Boyer (1993) reported that elementary teachers posses a great fear of teaching science and that subsequently little time is allocated or used to teach science.

Despite evidence in the literature that prospective elementary teachers subject matter knowledge is limited and that when given the opportunity teachers shy away from teaching science, participants in the current study emphasized scientific content in their teaching. For example, in Teri's case the available evidence demonstrated steady attention to content, accuracy, and representation, which were extraordinary since the literature suggests that prospective elementary teachers poses "unorganized, superficial and inaccurate knowledge of subject matter areas" (Cochrane & Jones, 1998, p.711). Thus, the fact that Teri attended to content beyond the scope of merely engaging students in inquiry activities provides insights to the benefits of teacher education programs with cohesive frameworks.

The fact that participants attended to scientific content is also significant in light of arguments that advocate the specialization of elementary teachers. Appleton (2006) argues that elementary teachers have difficulties attending to content because they are generalists and that this problem will not improve unless teachers become specialized in subjects and only teach that particular subject. Although I do not endorse transforming elementary school systems into subject-specific, "mini-high schools" it might be the best way to increase literacy across subjects. In fact, as described in the evidence section, these participants' attention to content contrary to the literature suggests that when appropriate scaffolds are provided prospective elementary teachers can problematize/plan/reflect/enact teaching in ways that emphasize content and move beyond inquiry skills.

5.2.4 Assertion Four

Scaffolded protocols positively influenced participants' attention to enabling students to construct evidence-based explanations during science planning and teaching.

5.2.4.1 Description

Participants used protocols as "guidelines" as to what to include in their science teaching—this was apparent in data sources for all three participants. For example, the protocols continuously pressed participants to describe examples of their teaching in terms of how participants were providing opportunities for the construction of evidence-based explanations. Since participants used the scaffolded protocols as "guidelines" these protocols influenced thier thinking during science planning and teaching and focused their attention to elements of teaching science as argument.

An essential aspect of the scaffolded protocols, which was connected to their positive influence, was that the protocols were adopted by participants as science reflection tool. For the purposes of the current study reflection is defined using Schön's (1983) constructs of "reflection-in-action" and "reflection-on-action." That is, participants reflected on their practice using the questions provided in the protocols, both during and after teaching.

5.2.4.2 Evidence

Evidence for this assertion was present at distinct points in the data for all three participants. In Laura's case, it was clearer during the exit interview. For example, Laura talked about the reflection process and the way in which it enhanced her thinking about fostering discussions and emphasizing data collection.

> Interviewer: What do you think are sort of the big changes in you with respect to science teaching across this year? …I mean has there been anything that you can point to and say "I'm really different in the way I either teach/do something or the way I think about it?"
>
> Laura: Well one of the first things that jumped out at me was when I did my engaging activity where I stuck tow magnetic objects or two magnets in my pocket and then two objects that stuck to my pocket. Instead of letting them [students] figure out what was different about me, I just immediately said, "Oh this student over here noticed what was different about me" and I didn't let the class figure it out… I didn't in the

> beginning really know hot to put emphasis on [having students] collecting data [in the lessons] but now I really know how to help them [students] collect data with whatever experiment we're doing. I know how to help them [collect data] cause it can be difficult for second graders sometimes to think about "Well what am I supposed to be seeing?" in an experiment and I don't want to tell them [the answers]. When we did [the] pollution experiments [I knew how to help student] noticing the different colors when we did concentration and thinking about [the experiment. I asked questions such as] "Well how many food coloring drops did you put in this one compared to this one?" and just the questioning I think has gotten better too so.
>
> Interviewer: You had talked about that previously, in terms of wrap up discussion, but it sounds like even in these early discussions where you try [experimenting] and help them. Here is our question, what should you be paying attention to [in order to] be able to answer that question, has [your teaching] really changed?
>
> Laura: Which I didn't do [help students collect data] in the beginning cause I didn't know, and I've learned a lot just from watching previous teaching and just thinking about, reflecting on my lessons after I do them has really helped too. (Laura, 6/12/06, Exit Interview)

This past quote demonstrates that Laura started the current study without paying much attention on how to help students observe phenomena, such as the example of the magnets, and instead rushed to give students the answers. However, as time progressed she was able to refrain herself and rather help students notice phenomena and collect data. She referenced the pollution experiment as an example where she helped students collect data rather than give them the answers right away. Although, Laura did not point to a particular aspect of the protocol as a key influence in this transformation she did mention at the end of the previous quote that it was the process of reflecting that helped her think about how to restrain herself from giving the answers and allowing students to observe the phenomena and collect data. Consequently it could be argued that the protocol task of identifying the best example of children collecting data/observations influenced Laura's thinking in reference to how her science lessons adjusted for such activity.

Laura's process of rating lessons also impacted her emphasis on teaching science as argument. During the exit interview she claimed a deeper level of reflectivity as a result of participating in the current study. She said:

> I probably wouldn't have [been that reflective] and I don't know if I'd be at the same level. I feel so comfortable with science right now and I really think that breaking down my lessons at the end of the every week has really helped me to think about well how inquiry based have my lessons been, what have I liked, what have I not liked and its something that I plan on carrying into my future teaching 'cause I think its really benefited my teaching. (Laura, 6/12/06, Exit Interview)

This quote also demonstrates that the scaffolded protocols influenced Laura's attention on how her lessons fit within the notions of inquiry. Although these two examples do demonstrate the scaffolded protocols positive influence, self-reported changes in Laura's thinking continued to demonstrate a more superficial and generic emphasis in Laura's views of effective science teaching when compared to Teri's and Angela's thinking.

In Teri's case, the impact of the scaffolded protocols was much more powerful in terms of demonstrating the relationship between the protocol tasks and their influence on planning and teaching. Analysis of Teri's data revealed multiple descriptions of the influence of the protocols on her thinking. Hence, it appears that every time Teri was reflecting on and questioning her understanding of what counts as inquiry in order to rate the lesson on an inquiry scale, she was "forced" to re-think what counts as effective science teaching.

> My view of teaching science as inquiry has not really changed since I've been teaching more science but, they have been challenged. For instance, I mention in previous reflections I was questioning whether some lessons I was teaching were inquiry and not based on the essential aspects of inquiry chart we used in 458. I think that reflecting on the lessons I am teaching and thinking about the essential aspect of inquiry has helped me grow as a science teacher because my beliefs about teaching sciences inquiry have been challenged. (Teri, 4/24/06, Follow-up)

This quote demonstrates that as a result of responding to the protocols, Teri questioned her understanding of science teaching and therefore questioned her planning as well.

Teri's case demonstrates one extreme point on the continuum of influence of the protocols on planning and teaching. That is, in Teri's case they mainly elicited two outcomes. First, they led Teri to question content, lesson components, and how these aid children as they build scientific explanations. This was evident when contrasting her views at different points of the study. Teri claimed that when experiments were not obvious to children, they had difficulty using the data collected in meaningful ways. Second, continuous responses to the protocols led her to question the content of the topics she was teaching, and how it was linked to the claims and explanations provided by students. In fact, as described in Chapter 4, Teri decided to modify the lesson assessment suggested in the curriculum in favor of an assessment more consistent with the practice of constructing evidence-based explanations. That is, the curriculum suggested a traditional form of assessment (recall factual information through a written test) and she decided to assess children's ability to articulate evidence-based explanations that justified a main claim.

In contrast to Laura and Teri, Angela's self-reports did not directly cite the protocols as a challenging avenue to her views about teaching science as argument. However, the fact that Angela was constantly making references to aspects of the framework provided evidence that the scaffolded protocols influenced her thinking. Nonetheless, there were specific moments in Angela's self-reports that attest to a sophisticated level of reflection. For example, during the initial self-reports Angela focused her attention in a naïve conception of classroom management as evident when she said,

> Some problems that I think I might face in terms of planning and teaching of these lessons [Prehistoric Life Unit] is definitely classroom management…I worry that I may not have the time needed to get it all done. I am worry that, you know, the kids might need almost a silly time to adjust. (Angela, 2/16/06, Context/Initial Questions)

On the other hand as time progressed her science planning focused on the elements the protocols were prompting. That was evident, for example, when she focus one of her exit interview responses in the idea of what where the "big" claims she was attaining during the science lesson. She said,

> I am not a type of teacher that writes up a script and then follows it; I am all over the place. And I like that about myself. I like that [about] my teaching and saw that in my teaching video [from SCIED 458] before. The things that frustrated me about the video [from SCIED 458] and still [frustrates me is] that I am finding hard [to do] are the KLEW chart, though I am getting [better] and with the magnets [unit is becoming more] clear, it [the Magnets unit] made it so much clearer. I think [that during the 3-day teaching in SCIED 458] I was looking for this huge unbelievable technical claim and I am in 1st grade and the claim was "seeds are similar" or "seeds are different". To me, when I did it [these seeds lessons] I thought it can't be what we [the seeds] are, it got's [sic] be bigger than that, so I was looking throughout my stuff to find something bigger and more grandiose. It wasn't there, and so I was frustrated and now during the magnets unit [the claims were] "magnets attract", "magnets attract through things" that's what we are doing. (Angela, 6/7/06, Exit Interview)

> I don't feel like I had those basic ideas when I did the dinosaur unit [Prehistoric Life Unit, but] with the magnet unit because I had to [do] the reflecting and when I did the unit planning [reflection] at the beginning and did the [audio] recording and I believe one of your questions [was] what are the main points, and I was like "what?" I am going to get the standards, what does the district wants? (Angela, 6/7/06, Exit Interview)

This last quote although difficult to read at times, demonstrated that Angela had moved from initial attention to aspects of teaching, such as classroom management, to thinking about the "big" ideas of the Magnet unit.

5.2.4.3 Discussion

The effects of the reflective process have been well studied over the years (Borko, Livingston, McCaleb, & Mauro, 1988; Schön, 1983; Zeickner & Liston, 2006; Zembal-Saul, Blumenfeld & Krajcik, 2000). One clear benefit cited in the literature about prospective teachers' engagement in reflective practices is that doing so involves them in "interpreting their experiences and expanding their repertoire, so that they can continue to learn how to

become effective rather than infer the wrong lessons from their early attempts at teaching" (Hammerness et al., 2005, p. 375). As described in the evidence section, participants engaged in cognitive processes of questioning their own practices in order to attempt to answer the questions posed through the protocols. Hence, participants "interpreted" their teaching and engaged in complex thinking like that described by Hammerness et al. in the earlier quote, and in doing so expanded their teaching repertoire. This process took them beyond the interpretation of experiences—it also elicited what Flavell (1979) termed the "metacognitive regulation" (p. 906). Metacognitive regulation is defined by Hammerness et al. as "being able to define learning goals and monitoring one's progress in achieving them" (p. 376). Although participants did not exactly meet the definition, they did monitor their progress with respect to inquiry. In addition, evidence demonstrated that through this process of "metacognitive regulation," participants rendered their teaching problematic—specifically, in Teri's case (very problematic) and Laura's case (less problematic).

An element of the planning affected by the protocols was participants' attention to students' potential responses and how they related to the "big" science ideas. However, there is not standard for this response, according to the literature. Scholars, such as Hammerness, et al. (2005), believe that novice teachers usually become overwhelmed by students' responses and do not know how to react, therefore reverting to the "apprenticeship notion." Conversely, participants in the current study sometimes did not know how to react to students' responses but they did not revert to the "apprenticeship notion." On the contrary, participants used the "big" ideas and their teaching views to guide discussion toward evidence-based explanations. Students' ideas were used and affected planning for the next lesson. The continuous prompting of the protocols arguably produced these actions.

According to the literature, novices have difficulty deciding what to adopt and what to abandon from assigned school curricula. Explicit questioning of participants about specific elements of the framework in relation to their planning and teaching may compel them to question aspects of the curriculum. Furthermore, it may motivate them to change certain components of the assigned curriculum in generative and productive ways.

The protocols in the current study were also effective because they reflected the notion that teaching science is not easy and therefore needs to be well planned. This conclusion stems from the fact that none of the participants rated their lessons as a "5" (highest level) on the inquiry scale. Since they thought their practices were not "excellent," they paid more attention to practices that supported helping students construct evidence-based explanations. According to Hammerness, et al. (2005) prospective teachers "tend to focus on affective qualities of teachers (for example, caring), teaching styles, and individual children, with little appreciation of the role of social contexts, subject matter, or pedagogical knowledge" (p. 368). However, evidence from the current study suggests that Angela and Teri departed from a traditional view, previously described by Richardson and Placier (2001), and paid attention to important elements of effective science teaching. This notion is consistent with what Thompson et al. (2008) described, "At the heart of reflective practice is the process of becoming aware of the knowledge that informs our practice-making it more visible" (p.12). On the other hand, evidence also suggests that Laura, although more "generic" in her attention to elements of effective science teaching, still paid attention to important elements of teaching that at the beginning of the semester were not present in her self-reports about teaching science.

During the discussion of this assertion many attributes have been linked with the protocols. That is, it has been argued that the protocol positively influenced participants' attention to enabling students to construct evidence-based explanations. However, some scholars (Shulman, 1986) have argued that elements, such as content knowledge make a difference in teaching practices. Although content knowledge is critical, as is experience, other factors such as pedagogical content knowledge (PCK) is critical in effective science teaching (Loughran et al., 2006). Moreover, this knowledge must be coupled with reflective practice in order to be a force for change in teaching practices.

These notions of reflectivity as an effect on protocols are very important because according to some scholars, it is difficult or rare for elementary school teachers to engage in such practices. According to Harlen (1997), elementary school teachers usually teach science in a manner that makes them feel comfortable and "do not see their science teaching as problematic" (Abell, 2007, p. 497). However, study findings attest that participants problematized their teaching in response to the protocols. According to Zohar (2008), teachers need to carefully think about ways to guide students' development of argumentation practices. In a study of a teacher implementing aspects of argumentation Zohar (2008) found that the teacher's reflections helped her create a sense of awareness of what she was teaching and how her behaviors helped students have argumentative discussions at a higher level of thinking. A final aspect critical to the reflection protocols is the fact that according to Zohar (2008) when teachers engage in metacognitive processes they are more likely to reach higher order thinking that ultimately translates to teaching practices that are more likely to mediate complexities involved in argumentation practices.

5.2.5 Assertion Five

Teachers' beliefs about children's science capabilities influence their attention to and adoption of practices associated with teaching science as argument.

5.2.5.1 Description

Participants' beliefs about whether children are capable of engaging in the construction of evidence-based claims influenced their attention to elements of the teaching science as argument framework.

5.2.5.2 Evidence

While Angela was teaching the first unit (Prehistoric Life), she expressed concern about students' ability to investigate and develop claims by themselves. This was apparent when she said:

> Today I was going to have each of the students cut out the foot and have each of the tables have either two feet or four feet so they could see them. I realized that there was no possible way that my 19 students could do that with one adult in the room. So I choose to bring the whole group together in a circle put the paper in the table and start talking about it. (Angela, 3/23/06, Continuous-weekly reflection)

On another occasion she referred to students' abilities and how they might affect lesson development when she talked about the importance of terminology in teaching. For example, she said:

> So next week I think is really important that I am defining the terminology that we are working so my kids are learning that because I believe that's important (Angela, 3/23/06, Continuous-weekly reflection)

During that same week Angela also made a teaching decision based on what she believed would be most manageable for students. For example, she thought it would be better to break claims into separate KLEW charts as opposed to having all of the claims on one KLEW chart. This was an interesting decision since the KLEW chart was designed to have all the claims within the same chart, allowing children to note a content story line and match

specific evidence to the claims and perhaps one piece of evidence to multiple claims, as often happens in science. Angela said:

> I am very comfortable discussing things but I am always pleased with group discussion but I don't know that I am always connecting the evidence to the beliefs and the knowing. I like how Monika did it with her magnets sort of in little blurts and little bubbles as opposed to a huge KLEW chart. And I think I might go with that idea only because then kids can see sort of the small knowing and the evidence breaking off with it as opposed to [the] whole unit knowing and evidence. As it is keeping it sort of small and manageable. (Angela, 3/23/06, Continuous-weekly reflection)

5.2.5.3 Discussion

According to Millar et al. (2006), a teacher's decisions about how to teach and/or implement specific practices are influenced by his/her perceptions about learners. However, as demonstrated by the data, teachers' perceptions of students' abilities also influence the selection of elements of teaching science as argument used in classroom instruction.

According to Zembal-Saul and colleagues (2000), "prospective teachers have difficulty developing opportunities for children to learn content in meaningful ways" (p. 318). However, it was observed that these protocol questions led participants to think and helped them to develop ideas about how to provide learning opportunities to students more quickly.

Zembal-Saul et al. (2000) linked preservice teachers' instructional difficulties to their inability "to anticipate what students already know, what topics they find difficult, how they might respond to instruction and what questions they might ask" (p. 319); in this case, however, it appeared that participants began to pay attention to students' ideas by thinking about specific aspects of classroom discussions. Furthermore, Zembal-Saul et al. (2000) concluded that field experience paired with in-depth reflection can help prospective teachers focus on content. This notion was demonstrated in the current study when prospective

teachers' substantial reflections enabled them to focus on students' practices that feed back on planning and to attempt to enact practices consistent with children's capabilities when engaging in inquiry practices.

Although this study did not seek to evaluate the science methods course nor the TESSA cases, it is reasonable to deduce that they contributed to the development of participants' views and understanding of teaching science as argument.

According to Vosniadou and Driver as cited by Millar et al. (2006), "Learning demands can also arise from differences in the epistemological framing of explanations. Thus, the ways of generating explanations using scientific models and theories that are taken for granted in school science are not part of the everyday ways of talking and thinking of most learners" (p. 64). Thus it was not surprising that teachers' perceptions of students' abilities affect opportunities to engage in evidence-based explanations. In an empirical study, Raudenbush et al. (1993) found that teachers who perceived their students as high achievers provided more opportunities and challenges to engage in higher-order thinking than did those who perceived their students as low achieving. This notion of teachers' perceptions of students' abilities affecting their teaching is not new. In studies by scholars such as Brickhouse (1990) and Nespor (1987), teachers' beliefs about students have been shown to affect their teaching practices. Such a finding should not be handled lightly since it has strong implications for the current assertion. For example, Zohar (2008) found that teachers often elected not to engage students in higher-order thinking activities when they believed that the students were unable to engage in such practices. Although in the current study it is not possible to provide evidence that participants held such beliefs, or even had assessed their

students as capable or incapable of engaging in evidence-based explanations, it appears that daily teaching practices were indeed influenced by such perceptions.

5.3 Chapter Summary and Preview

This chapter provided five key assertions about the participants' commonalities as these related to the study's research questions. In general, engaging with physical phenomena was viewed as important and science talks were acknowledged to be a vehicle for engaging students in meaning-making. In addition, a comparison of participants' views revealed that all believed in the importance of scientific content—a view contrary to that reported in the literature which often classifies prospective teachers as focusing on "activity-mania." Also, all three participants were influenced by protocols and children's ideas. Despite the fact that these cross-case findings are specific to the three study participants, there are implications worth noting. While critical to the field of elementary science education, there are also implications for teacher education programs. Thus, in the next chapter the implications of the study's findings for teacher education, science methods courses, and student-teaching field experiences are discussed. A series of recommendations are proposed.

CHAPTER 6: CONCLUSIONS

6.1 Introduction

The current chapter provides a series of implications as a result of the findings in the study. Before these implications are described the importance of the study is reviewed, as well as the research questions that guided the work and the main findings. Educational inquiry informs practicing teachers, administrators, teacher educators, policy makers, and community members, providing tools and understanding to link members' efforts across educational fields. This study's literature review delineates contemporary views about what it means for K-8 school students to be proficient in science and how helping students become scientifically proficient lies at the heart of educational reform for science instruction. The processes of helping school students become scientifically literate and proficient requires making evidence and explanation central in teaching practices as stated by the latest report of the National Research Council (2007). As a result of making evidence and explanation central in science teaching practices other elements, such as discourse and the nature of scientific investigations, are also foregrounded in educational reform.

Expectations and challenges associated with teaching science are inherently amplified for prospective elementary teachers. During student-teaching experiences, prospective elementary teachers face many obstacles that often inhibit their abilities to enact their beliefs. Utilizing a Professional Development School to conduct the study reported in this document provided a setting were participants were allowed to take risks in their science teaching and attempt to enact aspects of teaching learned in the science methods course. The research questions that guided this work were: 1) What are the ways in which preservice elementary teachers appropriate components of "teaching science as argument" during their student teaching experiences? 2) To what extent do components from preservice elementary teachers' reflections on their experience influence planning for science teaching? and 3) What elements

from the teacher education context influence preservice elementary teachers' attention to teaching science as argument?

A *Teaching Science as Argument Framework* guided the analysis. Findings revealed that the consistency, depth, and extent to which the framework elements were appropriated varied across the three participants. In fact, appropriation varied according to the content of the units taught, perceived abilities of students, and participants' own views of effective science teaching. Additional evidence suggested that analysis protocols scaffolded participants' thinking in appropriating elements of the framework and created an arena for metacognition about science teaching practices. Finally, it was concluded that elements from the teacher education context influenced prospective elementary teachers' appropriation, planning, and attention to teaching science as argument.

Findings of the current study provide insights into four main areas that deserve further exploration. That is, the need for a coherent framework to inform teacher education experiences, development of images of practice attuned with current reform, professional development opportunities that support social networks, and research that continues to enhance our understanding of teaching science as argument in the context of elementary school science.

6.2 Using a Coherent Framework to Inform Teacher Education Experiences

Participants' attention and adoption of elements of the framework for teaching science as argument were evident in the study findings. It was observed that participants attended to science talks, evidence-based explanation, subject matter knowledge, and children's ideas. The attention to these elements of the framework was related to the continuous and early exposure to the framework through class experiences, assignments, and field experiences. During the study it was noticeable that the framework provided a coherent and consistent set of concepts for contextualizing participants' thinking about science teaching. Study findings such as assertion four (pp. 192) demonstrated that scaffold

protocols influenced participant's attention to teaching science as argument. Hence this suggests a strong relationship between utilizing a coherent framework and supporting participants' attention to critical aspects of effective science teaching. Literature indicates that the aspects of the framework that participants adopted are not common practices for novice teachers (Appleton, 2006). For example, the fact that participants focus their attention on children's talk is important given what is known in the literature. Attending to children's talk is a complex task regardless of the level of experience of the teacher; however, it is much more difficult for novice teachers. In fact, the literature suggests that teachers in general struggle to attend to children's talk in ways that are consistent with the nature of science (Dawes, 2004). Similarly, novice teachers often focus on aspects of literacy and basic skills not related to science. Their beliefs and ideas are often centered on conceptions of nurturing children while maintaining control and order from a pedagogical perspective. In contrast, participants in the current study moved beyond nurturing conceptions and focused their attention on important elements of teaching science effectively, such as science talks. Another aspect that is worth considering is the fact that focusing on the framework helped prospective teachers attend to subject matter knowledge. According to findings, participants attended to content beyond engaging children in inquiry skills or doing hands-on activities. As in the case of attending to children's talk, a subject matter emphasis is not typical of prospective elementary teachers. Furthermore, the literature suggests that prospective teachers have limited subject matter knowledge and shy away from teaching science (Cochran et al., 1998). The fact that the participants in the current study attended to subject matter knowledge is notable.

Calls for attending to a coherent framework in science methods courses is not necessarily a new idea (Grandy and Duschl, 2007; Hayes, 2002; Zembal-Saul, 2009) however, the implications of what a coherent framework can do for prospective teachers is not well understood. The power of engaging in a coherent framework is critical for teacher educators in multiple contexts. Arguably, as demonstrated by

the findings of the current study, the argumentation framework was a critical component because it leveraged fundamental features known in the literature about effective science teaching. Therefore, if a coherent framework provided such benefits the necessary question to further pursue is what can a coherent framework do in the context of teacher education programs at large. In fact, insights provided by the findings of the current study warrant an appeal that teacher educators should pursue such an initiative by brainstorming and mapping ways to coordinate elements of teacher education programs to reflect a coherent framework among courses. For example, developing and using a coherent framework in science content courses and in the science methods course would likely extend the findings of this study. Therefore, by the time students enter the science methods course not only would they be comfortable with the framework but they also would likely be able to engage in deeper thinking and pedagogical discourse that revolve around the framework. In such way it would be possible to help prospective teachers move beyond superficial and naïve conceptions of science teaching and help them align their thinking and practices with current science education reform.

6.3 Developing Images of Effective Science Teaching

Throughout the course of the study participants demonstrated a commitment towards teaching science as argument that was guided by a set of standard images and ideas they developed during the science methods courses. Participants often talked during self-reports about their difficulties or successes in implementing their science teaching views. A common thread among these self-reports was the notion of contrasting personal stories to scenarios from the TESSA cases. The current study emphasis was not to specifically examine the influence of TESSA; however, it was evident in the findings that TESSA cases were a highly influential factor in participants' adoption of teaching science as argument. As a matter of fact, TESSA cases provided participants with a set of images and standards

for what effective science teaching looks like. In other words, TESSA cases informed and impacted participants' thinking. Available literature suggests that prospective elementary teachers rarely develop sophisticated views of science teaching (Davis et al., 2006). Thus, the fact that participants developed images and beliefs of refined aspects of teaching science in elementary schools is surprising.

"Images of possible" can be a powerful tool for supporting the development of prospective teachers' knowledge and practices (Darling-Hammond et al., 2005). It is important for teachers to have appropriate standard images because it provides a model of effective science teaching and learning. In the current study, images of science teaching and learning were developed through the TESSA cases and other interactions within the science methods course. In fact, findings demonstrated that these influences were commonly cited in participants' self-reports. It was noticeable that participants developed views of what counts as effective science teaching during the science methods course. More specifically, it appears that the TESSA cases were the most powerful element when coordinated with related course experiences. These cases, as stated in previous chapters, provided participants an opportunity to observe children successfully engaged in science learning in ways that were consistent with the framework.

One example that supports the fact that appropriate images of science teaching and learning are crucial in prospective elementary teachers development is the fact that participants were influenced by children's ideas and connected these to their standard images. Even when children's ideas were somewhat in conflict with teaching science as argument participants contrasted these ideas with the images created through the TESSA cases. Thus, participants continued to attempt to teach in ways that were consistent with teaching science as argument. For example, in Angela's case evidence suggested that although at times she perceived students as lacking abilities to engage in meaningful science learning she weighed these views against her science teaching images and attempted to structure her teaching around those standard images of what children indeed can do. This notion of weighing

experiences against standard images as in the case of Angela also relates to the fact that participants were constantly exposed to a coherent framework.

The development of participants' images and the implications it had on their teaching should not be taken lightly. Literature suggests that the most powerful source of change in prospective teachers' knowledge during field experiences is their mentor teacher. Furthermore, literature suggest that even when prospective teachers are committed to the idea of teaching science in effective ways, the influence of their mentor teacher is more powerful and overcomes those views. However, as found in the current study when prospective teachers develop appropriate standard images it does not matter whether their mentor teacher is teaching in this way because they already have developed a core belief that children can learn when engaged in inquiry.

As a result of the impact of the images of effective science teaching created by the TESSA cases, is imperative that scholars attempt to develop similar resources for prospective elementary teachers. It worth pursuing the development of resources that provide multiple examples of images of children successfully engaging in science learning in ways that are consistent with a coherent framework that is used in their teacher education program and methods courses.

6.4 Establishing Social Professional Development Networks

While examining the effects of establishing social support networks was not the focus of the study, findings revealed that it played an important role in participants' development. Participants' stories revealed that each one of them relied on a social network for support. Remarkably, participants sought out practicing teachers and peers whose views were aligned with teaching science as argument. Furthermore, findings demonstrated that participants believed that it was important to brainstorm, discuss, and reflect with others whose ideas were compatible with how they were attempting to teach science. The fact that the three participants demonstrated such strong commitments and were aware of

the importance of maintaining a coherent framework for contextualizing science teaching is remarkable. Given that social networks played a significant role in participants' stories it warrants further examination into how professional development can support prospective elementary teachers' development once they finish their field experiences.

Professional development for practicing teachers is not a new idea (Burden, 1994; Gabel, 1994; Wallace and Loughran, 2003). In fact, professional development has been extensively studied and the benefits demonstrated in terms of developing, transforming, retaining, and encouraging novice and experienced teachers (Renyi, 1996). Professional development has and continues to be a great tool for helping teachers enhance subject matter knowledge. Similarly, professional development can aid the development of social networks, allowing practicing teachers to connect, develop, and maintain communities of colleagues. Future empirical studies should investigate the nature and best practices of appropriate social supports for novice teachers in the context of teaching science as argument. Finally, it is important to consider and further investigate how these social networks can be created and maintained when teachers enter schools where these social networks are not within reach.

6.5. Future Research

The aforementioned areas (using a coherent framework, developing images of the possible, and building social networks) require further investigation. Extending research in these areas will provide a better knowledge base to develop high quality teacher education programs that not only attend to prospective elementary teachers' needs but are also aligned with current science education reform. One aspect lacking understanding that warrants further examination is how to engage prospective elementary teachers with scientific phenomena that permits collection of first-hand data and interaction with the phenomena. This aspect was visible in the findings since participants' emphasis towards evidence-based explanations was impacted by the presence or absence of opportunities for interacting with phenomena

and collection of first-hand data (Assertion #1, pp.170). Therefore, future research needs to determine the best approaches for engaging prospective elementary teachers with phenomena and collecting first-hand data that promotes acquisition and understanding of teaching science as argument.

A second aspect of future work is the investigation of the research questions that guided the current study in the context of a longitudinal data collection process. Engaging in a longitudinal study will allow us to better understand patterns of acquisition of the teaching science as argument framework. Therefore, it might lead to the possibility of creating patterns of prediction for other prospective elementary teachers. The latter, patterns of prediction, also require that future work consider increasing the sample size in order to attend to issues of validity. In addition, the goal of the current study was to develop substantive theory, which it was unable to do with the current sample size. Thus, augmenting the number of participants will contribute to the development of substantive theory. Finally, an aspect that warrants further investigation is the incorporation of enacted practice as a data source. In the study it was not possible to use video data from the participants. However, in order to better understand participants' appropriation of teaching science as argument it is important to be able to contrast participants' self-reports with their enacted practices. This information elicited by video analysis will yield findings that guide understandings for enhancing a coherent framework, classroom elements, and professional development needs.

6.6 Conclusion

The current chapter provides recommendations for the field of science education. Teri's, Angela's, and Laura's stories demonstrate a spectrum of views of teaching science as argument. These three stories allowed for the development of some assertions that should be carefully addressed among the science education community. The assertions revealed aspects of teacher education programs that

might be hindering prospective elementary teachers development when overlooked. In addition, it supplied evidence to make recommendations to teacher educators. Finally, the current study supported the need to further understand teaching science as argument in the context of elementary science classrooms. Hence we ought to continue a scholarly discourse around these ideas since it is vital for pursuing and achieving scientific proficiency and literacy.

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F A L L 2 0 0 5

pds SCIED 458

TEACHING SCIENCE IN THE ELEMENTARY PDS

EDUCATE

As an intern the Elementary PDS, you will receive an Apple iBook computer through the EDUCATE project (Exploring Directions in Ubiquitous Computing And Teacher Education). To make the most of this opportunity, we have integrated exciting new technologies for teaching and learning science into course activities and assignments.

Beyond Hands-On

The *National Science Education Standards* (NRC, 1996) recognize that inquiry is at the heart of science learning and "seek to promote curriculum, instruction, and assessment models that enable teachers to build on children's natural human inquisitiveness" (p. 6). The renewed emphasis on scientific inquiry reflects a distinct shift from science as *exploration and experiment* to science as *argument and explanation* (NRC, 2000, p. 113). From this perspective, priority is given to evidence and the development and evaluation of scientific explanations. During all phases of the inquiry process, "Students and teachers ought to ask *what counts?* What data do we keep? What data do we discard? What patterns exist in the data? Are these patterns appropriate for this inquiry? What explanations account for the patterns? Is one explanation better than another?" (NRC, 2000, p. 18). It is this vision of reform in science education that we hope to help you achieve through the course.

A word about course development…

SCIED 458 PDS was developed collaboratively by a planning team that consists of mentor teachers, curriculum support teachers, administrators, and university faculty and graduate students. Great care is taken to ensure that each revision of the course reflects the best of what we know about how to support your preparation and growth as a teacher.

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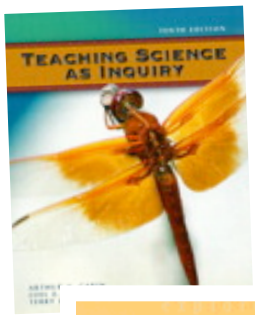
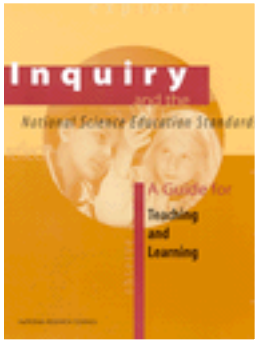




Required Resources

There are 2 main texts for the course:

Carin, A., Bass, J., & Contant, T. (2005). *Teaching science as inquiry* (10th Edition). Prentice Hall.

Olson, S. & Loucks-Horsley, S. (Eds.) (2000). *Inquiry and the national science education standards.* National Academies Press. Also available online at:

http://books.nap.edu/catalog/9596.html

You will need a student membership in the National Science Teachers Association (NSTA), with a subscription to *Science & Children*. Visit the web site below to apply:

http://nsta.org/memstudent

* Other readings will be assigned throughout the semester. These will be free of charge and available via the web.

Learning Outcomes

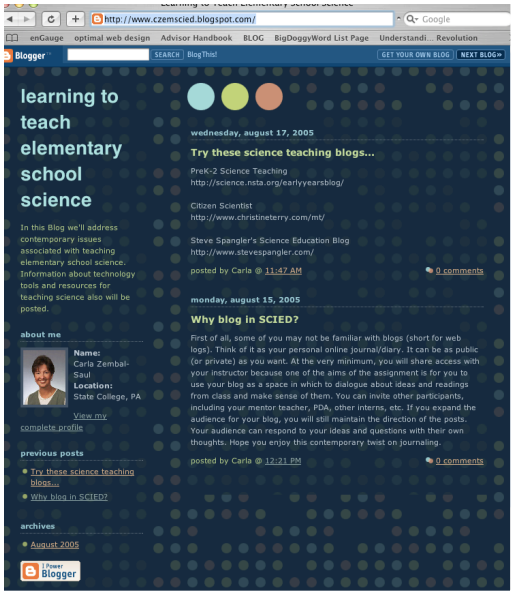
The goal of SCIED 458 is to assist you in developing approaches to supporting children's meaningful science learning and scientific inquiry that are consistent with reform-oriented science teaching. The following learning outcomes have informed our selection of class activities and assignments.

- Capitalize on children's natural curiosity to promote positive attitudes toward science.
- Use appropriate resources and strategies, such as concept mapping, to develop an in-depth understanding of the science concepts you will teach.
- Integrate the nature of science, scientific inquiry, into the science learning experiences you prepare for children.
- Develop subject-specific pedagogy for teaching science to children in ways that enhance conceptual development and explanation-driven inquiry.
- Use principles of learning and assessment information about children's prior knowledge to design differentiated science learning experiences that are developmentally appropriate for all students.
- Promote classroom discourse, both small group and whole class, and "sciencing" activities that authentically reflect the nature of science - evidence-based, subjective, etc. - and support science learning.
- Create and/or adapt instructional resources, including applications of technology, for supporting meaningful science learning and scientific inquiry.
- Systematically collect assessment data about children's science learning and use it to analyze the effectiveness of your teaching and prepare for future instruction.
- Become a critical consumer of technology, particularly that which is aimed at supporting learning through simulations, modeling, and other science-specific applications.
- Develop a stance toward teaching that involves continued professional development in science through professional organizations and/or online resources for science teachers.




Assignments & Grading

We have worked hard this year to streamline course assignments and incorporate emerging technologies. All assignments for the course will be submitted and evaluated through TaskStream.com except responses to TESSA cases and your weekly blog. Detailed descriptions of each assignment can be found in the SCIED 458 Folio in TaskStream.



Weekly Blog (15%)

Think of your blog as a personal online journal/diary. It can be as public (or private) as you want. At the very minimum, you will share access with your instructor because one of the aims of the assignment is for you to use your blog as a space in which to dialogue about ideas and readings from class and make sense of them. You can invite other participants, including your mentor teacher, PDA, other interns, etc. Although you may expand the audience for your blog, you will still maintain the focus of the posts. Your audience can respond to your ideas and questions with their own comments. Hope you enjoy this contemporary twist on journaling.

To get a sense of what blogging is all about, visit Carla's blog, Learning to Teach Elementary School Science at: http://www. .blogspot.com/

Blogs will be reviewed 3 times during the semester and assessed based on the following criteria:

1. Reflections on class activities organized by the "big ideas" in science education presented that week.
2. Integration of assigned readings.
3. Responses to guiding questions provided by the instructor.

TESSA Cases (15%)

TESSA: Teaching Elementary School Science as Argument is a research project funded by the National Science Foundation. One of the aims of the project is to develop electronic resources for supporting teachers as they learn to give priority to evidence and explanation in their science teaching. Throughout the semester, you will be asked to login to the TESSA web site (http://tessa.ed.psu.edu/), view video-based cases of science teaching, and respond to reflection questions. You will do this 8 times throughout the semester.

Greenwood Furnace Project

Each fall, as part of their science and social studies curriculum, 5th grade students in SCASD take a field trip to Greenwood Furnace (GWF). The science component of the trip requires them to investigate the question, "How healthy is the stream?" PDS interns support this trip by accompanying students to GWF and facilitating two investigation stations – (1) pH and turbidity, and (2) temperature and macro-invertebrates.

During Jump Start, our class will visit GWF and participate in the investigation of the stream as learners. This will allow you to experience the field trip as the students will. You will have an opportunity to sign-up for a particular date and station well in advance. To prepare for the trip, you will work in small groups to do some background research on your station and modify an existing lesson plan for your station. After all interns have completed the trip, we will reflect on what was learned from the experience through in-class discussion and a blog assignment.

GWF Background Research Podcast (10%)

This assignment will introduce you to an emerging technology for producing and publishing content. You will be doing background research associated with the Greenwood Furnace field trip, preparing a brief script for a radio-type broadcast for 5th grade students, and recording/producing the show.

In this assignment, you will need to research, write and produce an audio program that has solid content intended to enhance the 5th grade unit, is concise (5-7 minutes in length), is age appropriate for 5th graders, is interesting and engaging (question driven), and includes supplemental materials (script, pictures, maps, graphs, etc.). You will work in small groups organized around the following topics:

- Measuring water quality: Temperature and macros
- Measuring water quality: pH and turbidity
- Geology of central PA (and its influence on water quality)
- History of the iron industry in PA (and its influence on water quality)
- The central PA watershed
- Ecosystems (plants and animals and their influence on water quality)
- Agriculture and recreation (and their influence on water quality)

Have fun! This assignment puts you at the cutting edge of technology use!

To learn more about podcasting, visit the links below:

Understanding the Podcasting Revolution
Podcasting in Education

GWF Lesson Plan (5%)

You will be provided with lesson plans for the stations at GWF by the SCASD curriculum support teachers. It is important to follow these plan closely as you teach. However, there is room for some personalization in the form of questions, and possibly visual aids to assist with data collection.

The written portion of this assignment is not the plan itself, but your responses to the following questions about the lesson:

1. How will you introduce the investigation in a way that engages children in thinking about the important science ideas?
2. What questions will you ask throughout the lesson to keep children engaged and provide you with insights into their thinking?
3. How will you help children consider their observations as scientific evidence from which an explanation about the health of the stream can be constructed?
4. How will you help children compile their evidence across stations and construct a scientific explanation about the health of the stream?

GWF Follow-up & Analysis (10%)

There are 2 components to this aspect of the assignment.

1. Data Collection Follow-Up
   a) Bring the data that was collected by students on the field trip you attended back to class and use it to update the data table.
   b) After the data table is complete, analyze the data and represent it graphically, and generate 2-3 evidence-based claims. Be sure to attach your graph/representation and claims.

2. Analysis - Reflect on the GWF Teaching experience in your BLOG. Be sure to address the following questions:
   a) What did students learn at your station? How do you know (what's your evidence)?
   b) What patterns in the thinking of 5th graders did you notice?
   c) What kinds of responses did they provide? What kinds of questions did they ask? How did they behave?
   d) Were gender differences observed? Describe and attempt to explain.
   e) What aspects of your approach to teaching the station changed during the day and why?
   f) Other important observations, revelations...

Science Teaching Project

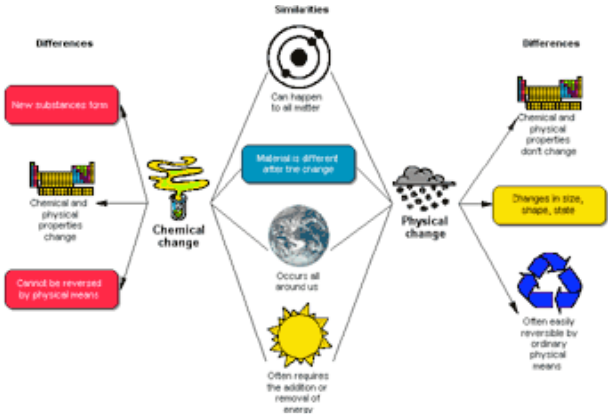
The purpose of the teaching project is to involve you in planning and teaching a single science concept in-depth. It is expected that you use appropriate applications of technology (if possible). The basic idea is to support children in developing meaningful, conceptual understanding of a particular science concept while incorporating science talks, giving priority to evidence and explanation, and using approaches and instructional strategies that you have been introduced to during the semester. The project has several components that are described in detail below.
NOTE – All teaching should begin after the beginning of November and be completed by Thanksgiving Break.

Target Concepts & Teaching Dates

You and your mentor teacher will need to spend some time discussing which science concept will be appropriate for this project. Once you have decided on a target concept, you will need to negotiate teaching dates. The earlier you do this the better. TRY TO ESTABLISH YOUR TEACHING DATES DURING THE WEEK OF NOVEMBER 7th or 14th. Your cooperating teacher already knows the schedule of science units that will be taught during the year, so don't feel shy about discussing this project with her/him as soon as possible. You will need to specify the science concept you will be teaching in class by mid-September.

Subject Matter Research (10%)

Developing a solid understanding of the subject matter you are teaching is an important aspect of preparing to teach. Prior to planning your lessons, you should try to learn everything you can about the concept you will be teaching. Learning should extend beyond reading about the concept to experimenting with and investigating the concept in hands-on ways.



Your subject matter research should include the following components:

1. 4-5 Big Ideas related to your topic. Provide about 1/2 page description/elaboration for each idea.
2. Evidence of having attempted 2-3 experiments/investigations related to your topic. How did they contribute to your understanding of the subject matter?
3. A bibliography that includes some adult level resources, some web sites, some trade books, etc. You should include a minimum of 10 resources.
4. A concept map (using Inspiration) that unpacks the components of your big ideas and related them to one another.

Concept Interview Podcast (10%)

The purpose of this assignment is to help you develop a better understanding of what children think about the concept you will be teaching. What you learn about children's understandings, and possibly areas of difficulty, will inform the development of your lesson plans.

Your concept interview should be designed to elicit children's thinking about the target concept. Tasks, such as demonstrations, drawings and experiments, are particularly useful for this purpose. Once you have designed your concept interview, select 3-4 children from your class (with the help of your mentor teacher). Be sure these children are as different as possible in terms of their science learning. During the interviews, make attempts to understand the thought processes behind the children's responses. Record the interviews on your laptop for analysis purposes.

The final product for this assignment is a podcast designed for an audience of practicing elementary teachers. As with the GWF podcast, your script should be for a 5-7 minute presentation that is interesting, engaging, and conveys important and accurate content. The format should be modeled after the OPPS videos you viewed in class: identify the concept, describe the task(s), summarize you findings, and make 2-3 recommendations for instruction. Whenever possible, you should integrate existing research findings on the topic.

Lesson Plan & Justification (10%)

Planning is a critical phase of the instructional process. It is where your understanding of the science content, children's conceptions of the content, and instructional strategies come together. By the time you actually write your lesson plans, you will have been engaged in the planning process for weeks. A lesson plan template for teaching science (modeled on the 5 E's) is available through TaskStream. In addition to your lesson plans, you will be required to write a justification that explains the ways in which your approach to teaching reflects fundamental ideas about giving priority to evidence and explanation.

Note that this assignment does not have a specified due date. Rather, submission dates are based on your teaching dates – more specifically, lesson plans are due 1-2 weeks prior to your teaching. BE SURE TO SCHEDULE AN APPOINTMENT WITH KIMBER OR CARLA TO DISCUSS YOUR LESSON PLANS PRIOR TO TEACHING. Failure to submit final lesson plans at the planning meeting may result in the postponement of your teaching dates.

The Lesson Justification should include the following components:

- What are the big science ideas you plan to address in your teaching?
- Provide a 1 paragraph overview of the lesson sequence.
- What do you want students to know and be able to do as a result of engaging in the lessons you have planned?
- How do you plan to engage students with the big ideas?
- What opportunities will students have to explore the concept (collect data)?

• How will you help students organize their data and look for patterns?
• How will you scaffold students as they construct explanations from evidence?
• What opportunities will you provide for students to extend their learning to new situations and/or elaborate on the claims they develop?
• How will you assess students' learning? What kinds of evidence will you collect?

Teaching

The actual enactment aspect of the teaching project is not graded. Our intent was to minimize the anxiety associated with early teaching experiences and provide you with an opportunity to take risks without the fear of failure. We do require that you videotape your teaching for the analysis phase of the project. It is highly recommended that you do this in a digital format (mini-DV). There is at least one PDS digital video camera at each school. Other cameras are available through your school library or at PSU through Instructional Support Services in 26 Willard Building. Successful taping of your teaching is your responsibility, so be prepared. ***Prior to teaching you will need to: arrange for a digital video camera, purchase mini-DV media for the camera, recruit someone to tape you (mentor, PDA, intern), and collect video permission from parents.*** Things will go more smoothly if you practice using the camera in advance and make sure the battery is fully charged.

**** Reminder – All teaching should begin after the beginning of November and be completed by Thanksgiving Break.***

Lesson analysis iMovie (15%)

Dewey once referred to reflection as the "hallmark of intelligent action" – for it is through substantive reflection on practice that we develop new understandings of teaching and learning. Therefore, the purpose of this aspect of the project is to learn from your teaching experiences. Get feedback from your mentor teacher and classroom PDA on all lessons that you teach. Watch your teaching videotape and use the analysis guidelines (generated in class) to guide your inquiry into children's learning and professional practice.

Part of your written analysis will require you to provide evidence of student learning. Evidence should come from at least two sources. These sources may include (but are not limited to) samples of student work, follow-up interviews, tape-recorded responses from a class discussion, and an application task assessment. Be prepared to collect evidence of student learning either during or after your teaching.

A relatively new component of the assignment is to engage in re-teaching. Using the assessment data you collected, modify your instruction for the purpose of teaching it again. Possible opportunities for re-teaching include (a) working with another intern at your grade level and teaching a follow-up lesson in each other's classrooms, (b) teaching one or more of your lessons in another classroom, (c) identifying a group of students in your class that had difficulty with the concept you taught and provide remediation, or (d) identify a group of

students who excelled during your lessons and provide enhancements. You will need to document your re-teaching as part of the write-up.

Your analysis of teaching will be completed in an alternative format. You will be creating an iMovie! Specific guidelines are forthcoming and we will dedicate an entire class session to the project in late November.

Participation, Professionalism & Attendance

This course operates on the premise that meaning is co-constructed within a community of learners. Therefore, your presence and participation is essential to the development of the group's understanding of learning to teach science.

As it pertains to the course, professionalism refers to your overall attitude and approach to learning. Dimensions of professionalism include, but are not limited to, your preparation for class (including readings and mini-assignments), the quality of contributions you make in class and online, the nature of your collaborative efforts with peers and other members of our developing learning community, and the enthusiasm you convey with regard to your personal professional development.

High quality participation is expected with consistency. Your instructor reserves the right to deduct points from the final grade if expectations for participation/professionalism, as described here, are not met. No absences are "allowed." Absences will result in your course grade being lowered.

APPENDIX B
Interview Protocol

PRIMARY INTERVIEW QUESTIONS	FOLLOW-UP PROBES/PROMPTS	INFORMATION ANTICIPATED
Part I: Establishing the interview setting		
A. Describe the purpose and format of the interview B. Start by recording date, time, and participant's name		Put the participant at ease. Assist them in understanding the goals of the interview and time requirements for their involvement.
Part II: Understanding the context		
A. What grade level are you currently teaching?	Is this similar to or different from your PDS internship experience? Explain.	Explore similarities and differences in 1st context and PDS experience. Prompt to get the context of where they are teaching and the classroom conditions in terms of what kind of kids she has.
B. How many students do you have in your classroom? Boys vs. Girls? C. Do you have students with special needs? D. Do you have ELL students? E. Do you have a teacher aid in your classroom? F. What is the socio-economic background of your students and the community? Any in reduced lunch? G. What are your students like?	A. Do you have students with learning disabilities? Explain.	
A.What was your experience as a science learner in elementary, middle, and high school?	A. Follow-up with their experiences as learner during College courses	
Part III: Science teaching beliefs		
A. When you think in effective science teaching, what does comes to your mind? B. What do you think are some of the big ideas about teaching science?	Why? Ask for specific examples	Trying to get a general approach on how they view effective teaching.
Part IV: Science teaching practices self-description		
A. Tell me about your science teaching	In this section, follow-up with references to terms	Start with general approaches to

in general. How do you approach teaching science in general? B. How do you prepare for teaching/ C.	like hands-on, inquiry, evidence, etc. What does the teacher mean when she uses these terms? Prompt for very specific descriptions: A. Do you typically provide opportunities for kids to participate in science investigations/experiments? B. What kinds of question do students investigate? C. Where do these questions come from? D. How much guidance do you provide? E. How do you determine how much guidance to provide? F. Do students collect evidence? Can you give me examples of the kind of evidence they collect?	teaching science and get more specific. Attempt to get at teacher's philosophy of science teaching (orientation).
A. What are you proud about your science teaching?		Try to get a feel for the nature and role of investigations in science teaching.
A. What is the role of talk/discourse when you teach science?	B. What is the nature of small group discussion? C. What is the nature of whole group discussion? D. Are there rules/norms that students are expected to use when teaching science (like supporting claims with evidence)? E. Do you talk to your kids about patterns in the evidence? F. What happens when kids disagree about the conclusions of their investigations?	Try to get at whether kids are talking about evidence and forming explanations from evidence.
E. How do students respond to your science teaching?		
F. How important do you think it is for your students to learn science?		
Part IV: Sources of teacher knowledge		
A. What things, factors and experiences are responsible on how you currently teach science?	If SCIED 458 PDS is mentioned, as about which aspects of the course continue to influence thinking and practice. Some former interns also may mention their	What are the Sources of teachers' understanding of science teaching? To what extent are the "big ideas" from SCIED 458 still driving science

	mentor teacher. If so, then probe for more detail about this.	instruction?
A. If you would have to pin point the things that were the most beneficial from the SCIED course what would that be and why? B. Do you think that these things you mentioned have transformed into your science teaching? How?	Ask them to give them a hierarchy and prompt for an explanation of why.	
V. Science content knowledge		
A. Do you think that the content you teach has something to do with the way you teach it?	Prompt for explanation.	
B. How comfortable have you been with the science subject matter you taught this year?	What was the extent of your prior knowledge of the content?	
C. How do you prepare to teach science content that is new to you? D. Where are you getting the science content?	Prompt for an explanation and specific example if possible.	
A. How important is it for teachers to understand the subject matter they are teaching?	Prompt for explanation.	
VI. Concluding thoughts		
A. Have your ideas about science teaching have change since you started the PDS?	Prompt for explanation.	

VITA

Reizelie Barreto graduated with a degree in physical science from the University of Puerto. Before enrolling at The Pennsylvania State University to complete her master and PhD degrees in Curriculum and Instruction she taught 4th and 5th grade. Reizelie is a highly creative, professional, and peoples person. Her research interests revolve around helping preservice elementary teachers learn how to teach science as inquiry with an emphasis in argumentation. In addition, she is constantly involved in developing authentic science experiences for middle and high school girls in informal learning contexts. Her future research agenda focus on the relationship between assessments, knowledge gain and scientific models in the context of informal learning and teacher preparation programs. Finally, she accepted a tenured-track position at Towson University. Her teaching responsibilities will include teaching science content courses and science methods courses to prospective elementary teachers.