ABSTRACT

Title of Document: NEWLY QUALIFED TEACHERS' VISIONS OF SCIENCE LEARNING AND TEACHING

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This study investigated newly qualified teachers' visions of science learning and teaching. The study also documented their preparation in an elementary science methods course. The research questions were: What educational and professional experiences influenced the instructor's visions of science learning and teaching? What visions of science learning and teaching were promoted in the participants' science methods course? What visions of science learning and teaching did these newly qualified teachers bring with them as they graduated from their teacher preparation program? How did these visions compare with those advocated by reform documents?

Data sources included participants' assignments, weekly reflections, and multi-media portfolio finals. Semi-structured interviews provided the emic voice of participants, after graduation but before they

had begun to teach. These data were interpreted via a combination of qualitative methodologies. Vignettes described class activities. Assertions supported by excerpts from participants' writings emerged from repeated review of their assignments. A case study of a typical participant characterized weekly reflections and final multi-media portfolio. Four strands of science proficiency articulated in a national reform document provided a framework for interpreting activities, assignments, and interview responses.

Prior experiences that influenced design of the methods course included an inquiry-based undergraduate physics course, participation in a reform-based teacher preparation program, undergraduate and graduate inquiry-based science teaching methods courses, participation in a teacher research group, continued connection to the university as a beginning teacher, teaching in diverse Title 1 schools, service as the county and state elementary science specialist, participation in the Carnegie Academy for the Scholarship of Teaching and Learning, service on a National Research Council committee, and experience teaching a science methods course. The methods course studied here emphasized reform-based practices, science as inquiry, culturally responsive teaching, scientific discourse, and integration of science with technology and other disciplines. Participants' writings and interview responses articulated visions of science learning and teaching that included aspects of reform-based practices. Some participants intentionally incorporated and implemented reform-based strategies in field placements during the methods course and student teaching. The strands of scientific proficiency were evident in activities, assignments and participants' interviews in varying degrees.

NEWLY QUALIFIED TEACHERS' VISIONS OF SCIENCE LEARNING AND TEACHING

by

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DEDICATION

To Dr. Emily van Zee for her unwavering support and encouragement over the years. I am especially grateful for her unique inability to accept no as an answer; because of that I am where I am today. Also for the seat at her kitchen table on gray, rainy Oregon days, which provided the environment and focus needed for a lot of work to get done!

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Table of Contents

List of Tables

CHAPTER ONE

Statement of Problem

This study examines ways that newly qualified elementary teachers envision science learning and teaching as they think about beginning to teach science in their own classrooms. In this study, the term *newly qualified teacher* refers to graduates of a teacher preparation program who have not yet begun to teach. The word *vision* is used in this study because of its dynamic connotation. The study documents newly qualified teachers' visions of how they want science teaching and learning to look in their own classrooms, that is, what they want to make happen as they begin to teach science. The study also provides a detailed account of the newly qualified teachers' preparation in an elementary science teaching methods course.

Recent calls for research on teacher education have identified several issues that this study addresses. In *Studying Teacher Education: The report of the AERA Panel on Research and Teacher Education (*Cochran-Smith & Zeichner, 2005), for example, Clift and Brady (2005) review research on methods courses in four domains: English, mathematics, science and social studies. They note that across these four areas, methods courses "are seen as complex sites in which instructors work simultaneously with prospective teachers on beliefs, teaching practices, and creation of identities – their students' and their own" (p. 325). Among their recommendations is the suggestion that the voices heard in research on methods courses extend beyond those of university-based White male and female researchers. They recommend that others who teach methods courses as well as cooperating teachers and prospective teachers also need to be included in the research. This study documents my perspective as an experienced teacher invited to teach a science methods course. The study also interprets the prospective teachers' evolving visions of science learning and teaching.

In a report prepared for the Knowles Foundation's conference on research in the field of science education, van Zee, Long and Windschitl (2009) identify six areas of needed research on secondary science teaching methods courses. The first area concerns the nature of instruction in methods courses, what is being taught, by whom, where, when, how and why? This research is necessary in order to make improvements to methods course design and to align methods courses with other facets of the teacher education program. The second area involves examining ways in which instructors design methods courses, including their rationale for choosing various activities and assignments. Such documentation could help new instructors in the field and give experienced instructors motivation to try something new. The third area refers to research that investigates ways to help prospective teachers build and maintain reform-based teaching practices that engage their students in inquiry. The fourth area involves developing ways to help college faculty shift their instructional approach from didactic lecturing toward student-centered learning. Even methods course instructors may not yet have implemented reform-based practices. If their students (the prospective teachers) are to use reform-based methods and teach in a student-focused way, the instructors need to model this approach to learning and teaching. The fifth area concerns the connections between the methods course and field experiences. Research is needed on ways to support the prospective teachers, their mentor teachers, and the schools to ensure that the prospective teachers' initial attempts at reform-based practices are nurtured. The sixth area refers to the need to examine different models of teacher preparation, to better understand the role of the methods course in the spectrum of the teacher education program. These authors declared that "Every instructor who teaches a methods course can contribute to the literature by documenting how and what the prospective teachers are learning…Particularly useful would be detailed accounts of instructors' efforts to implement reform-based approaches" (p. 40-41).

Davis, et al. (2006) review research on the challenges that new science teachers face. Because they view the preservice period of teaching as part of the learning continuum, their findings are related to this study. Davis et al. (2006) refer to both prospective teachers and early career teachers as new teachers. They state that there is a need for studies of the academic preparation for new teachers of science. Also needed is research to understand what new teachers understand inquiry to be, how they set up learning environments that foster inquiry-based learning, how they actually teach science as inquiry, and what challenges they perceive as they attempt to do so.

As a fifth grade elementary teacher practicing in the classroom, I was asked to teach an elementary science teaching methods course for a local university. In this study, I provide a detailed account of how I designed and taught the methods course and why I made decisions to use this particular structure and assignments. This was an intentional approach focused on implementing the reform efforts of inquiry-based learning and teaching that I had learned in my own preparation to teach and had enacted in my own classroom. I also have documented the newly qualified teachers' visions of learning and teaching after they finished the course but before they began teaching.

Framing the Research Problem

This study focuses on the visions of science learning and teaching held by a group of newly qualified teachers who graduated from a science teaching methods course for which I was the instructor. Four aspects have shaped this research process. The first is the methodological tradition of which this study is a part, visions of learning and teaching articulated by instructors reflecting upon their own teaching practices and students' learning. The second involves the instructional setting, visions of science learning and teaching promoted in science teaching methods courses. The third refers to the research focus, visions of science learning and teaching by prospective and new teachers. The fourth concerns the broader context, visions of science learning and teaching set forth in national reform documents. These aspects are introduced below.

Visions of Learning and Teaching Articulated by Instructors Reflecting upon Their Own Teaching Practices

In *Progressive Education and the Science of Education*, John Dewey (1928/1956) recognized the potential of increasing knowledge about learning and teaching through reports authored by teachers reflecting on their own practices:

> The method of the teacher…becomes a matter of finding the conditions which call out self-educative activity, or learning, and of cooperating with the activities of the pupils so that they have learning as their consequence …A series of constantly multiplying careful reports on conditions which experience has shown in actual cases to be favorable or unfavorable to learning would revolutionize the whole subject of method. (p. 125-126).

Dewey recognized that teachers who systematically reflect on their own teaching and on the learning of their students could deepen the base of knowledge and understanding for others. This would apply to methods instructors as well as to classroom teachers. Reflecting on the practice of teaching science as inquiry, and of the students' learning through this approach, can inform others who wish to do the same.

Teacher educators who study their own teaching practices describe this process in a variety of ways. They often undertake such studies from a desire and need to "ensure that their teaching practice is congruent with the expectations they have of their student-teachers' practice" (Loughran & Northfield, 2005, p. 8). In advocating for the experiential knowledge of teachers, Cochran-Smith and Lytle (1993) argue that academia is not the only place knowledge resides. Samaras (2004) describes *self-study* as an on-going process that "can include looking at one's teaching self, looking at issues of teaching and learning in one's classroom, and looking at self-knowing and professional identity from a developmental perspective" (p.23). Bullough and Pinnegar (2001) describe self-study as a new area of research in teacher education. They address issues of quality by stating, "its endurability as a movement is grounded in the trustworthiness and meaningfulness of the findings" (p. 20). In addition, they acknowledge two purposes, "informing practice to improve teacher education and also for moving the research conversation in teacher education forward" (p. 20).

This study provides an example of such research, which also is known as the *scholarship of teaching and learning* (Boyer, 1990; Shulman, 1999, 2004). According to Shulman (1999),

> A scholarship of teaching will entail a public account of some or all of the full act of teaching, vision, design, enactment, outcomes, and analysis in a

> manner susceptible to 'critical review' by the teacher's professional peers, and amenable to productive employment in future work by members of that same community. (p. 6)

The scholarship of teaching and learning takes us beyond reflecting on our own practices to assume responsibility for our own professional development and for improving our own teaching. The scholarship of teaching and learning further moves us toward making that practice visible to others so that it can be critically reviewed by our peers, and possibly have meaning for others in their practices (Shulman, 1999).

Methods course instructors who have engaged in the scholarship of teaching and learning by making their practice visible for others' critical review have deepened my understanding of practice. As a participant in the Carnegie Academy for the Scholarship of Teaching and Learning, I was fortunate to have become part of a community of teacher researchers. This experience affirmed for me the benefit and the importance of this kind of research.

Visions of Science Learning and Teaching Promoted in Methods Courses

There is a wide range of approaches to teaching methods courses, from very traditional to an approach where there are no formal methods courses at all (van Zee, et al., 2009). There are also different approaches to the timing of methods courses, with most occurring the semester before student teaching, to some that are broken down into separate parts and offered during a multi-term sequence. The UTeach program at the University of Texas, for example, has no course officially identified as a science teaching methods course but offers instead courses with titles such as "Classroom Interactions" and "Project Based Instruction" (see https://uteach.utexas.edu).

Methods courses have a questionable history. A president of Harvard University, James Conant, once said "And now I come to a red-hot question: How about those terrible methods courses, which waste a student's time?" (1963, p. 137; quoted in Grossman, Compton, Igra, Ronfeldt, Shahan, & Williamson, 2009). Grossman et al. (2009) studied how people were prepared for professional practice across three disciplines: clergy, teaching and clinical psychology. Even though there were many approaches to preparation, Grossman et al. (2009) noted that across these disciplines there were courses that focused explicitly on practice. Little was known about these courses except for maybe the title. These authors articulated the need for further study of what, how, and why the instructors of these methods courses design instruction and teach as they do.

A leader in practitioner research and self-study for many years, Abell found that studying one's own practice is needed so that improvements and changes can be made (Abell, 2005; Abell & Bryan, 1997; Abell, Bryan, & Anderson, 1998). Abell and Bryan (1997), for example, designed a methods course around the idea of reflection: students reflected on their own teaching of science, on others' teaching of science, on readings, and on themselves as science learners. Abell's interest in reflecting on practice led others at her university to do the same (Newman, Abell, Hubbard, McDonald, Otaala, & Martini, 2004).

Davis et al. (2006) suggest re-conceptualizing the methods course as the beginning of the professional development spectrum and motivating teachers to continue developing and refining reform-based science instruction. Science content courses taught prior to science methods courses need to be considered in this spectrum of professional development as well. Science content courses that are taught specifically in ways that model good science teaching and use reform-based practices can help prospective teachers experience and understand how effective science learning and teaching should look. It is important that teachers have opportunities for learning science through content courses that are taught in ways in which they will be expected to teach (McDermott, 1990). The power of the learning experience may cause the prospective teachers to begin to think about prior experiences, attitudes and beliefs. Then they may begin the process of reshaping those ideas before they reach the methods course, where this change in belief is often documented (Abell & Bryan 1997; Bianchini, Johnston, Oram, & Cavazos, 2003; Bryan, 2003; Davis et al., 2006; Luft & Roehrig, 2007; McGinnis, Roth-McDuffie, & Parker, 1999; Windschitl, 2003). It is important to be able to continue supporting teachers through professional development that is of high quality and will foster continuing enhancement of learning and teaching. Garet, (2001) in a review of research on professional development found there were six key principles for effective professional development. These are: focus on content and pedagogical knowledge; reform-type activities; relevance of activities to teacher needs; opportunities for active learning; extensive duration; and collective participation (p. 1196). These principles could be considered during the methods course, as practices that will support learning.

As reviews of literature on science teaching methods courses suggest, the complexities of science learning and teaching are many (Clift & Brady, 2005; van Zee et al., 2009). Teacher educators face many competing ideas and challenges for the time and activities possible during a methods course. This study contributes to the literature a detailed account of one instructor's decisions and the prospective teachers' responses.

Visions of Science Learning and Teaching by Prospective and New Teachers

Various terms have been used to refer to ways in which teachers think about learning and teaching such as beliefs, attitudes, mental models, views, perceptions, and intentions. Luft (2007), for example, gives a detailed description of science teacher beliefs. As she notes, there are many differing ideas in what the term *beliefs* means to different researchers. McGinnis et al (2002) refer to both *attitudes* and *beliefs* whereas Thomas, Pedersen and Finson (2001) discuss teachers' *mental models* and *beliefs*. Morrison, Raab, and Ingram (2009) use the term *views* to describe the ideas that teachers have about the nature of science. Some refer to teachers' *perceptions* (Lederman, 1999). Others refer to teachers' *intentions* (Haney, Czerniak, & Lumpe, 1996). This study will document newly qualified teachers' *visions* of how they want science teaching and learning to look in their own classrooms, what they look forward to make happen as they begin to teach (and to learn) science.

Many factors seem to influence the ways prospective teachers think about learning and teaching. Abell and Bryan (1997) and Borg (2004), for example, refer to prospective teachers' beliefs being informed by the *apprenticeship of observation*, years of observing teachers from the perspective of students but seeing only a partial picture of the complexities of teaching from their desks. This term is credited to Lortie (1975), who also suggested that these experiences could undermine the influences of education courses on changing teacher beliefs. Bryan and Abell (1999) combined the use of reflection with field experiences to facilitate refinement in beliefs. Cochran-Smith (1991) reported a similar finding, that when field experiences are carefully crafted, pre-service teachers can and do develop a deeper understanding of teaching. However, Windschitl

(2003) found that using guided and open inquiry during student teaching was associated only with having had significant prior undergraduate or professional research experiences.

What happens in schools is complex. Lederman (1999) focused on finding out what influenced teachers' implementation of reform-based practices in the classroom, specifically in regard to the nature of science. McGinnis, Parker and Graeber, (2004) reported that there were institutional and cultural constraints in schools that impacted new teachers' ability to implement reform-based practices. This is similar to the findings of Bianchini et al. (2003) that teachers established curricular and instructional practices that were "responsive to their personal views, their experiences in science and education, their students' needs, and the structures of their schools" (p. 438).

For teacher educators who want to promote a vision of science learning and teaching that is reform-based as well as inclusive of all learners, significant considerations need to be made. Designing methods courses that encourage prospective teachers to challenge and refine their previous visions is a difficult task. Important components include providing meaningful experiences in the field during the methods course, reflecting on their learning throughout the course and on their teaching experiences in the field, engaging in the practices of science such as questioning, investigating and developing explanations based on evidence, explicitly discussing the nature of science, and providing sustained support as they move into classrooms.

Visions of Science Learning and Teaching Set Forth in National Reform Documents

The *National Science Education Standards,* (National Research Council, 1996) along with *Benchmarks for Scientific Literacy* (American Association for the

Advancement of Science, 1993) created frameworks for reform of science learning and teaching. States and local districts used these frameworks to refine their science curricula and develop state assessments. These documents included standards for the continued professional development of teachers as well as for instruction of students. The vision set forth in the National *Science Education Standards* (NRC, 1996) was the following:

> The *National Science Education Standards* are premised on a conviction that all students deserve and must have the opportunity to become scientifically literate. The *Standards* look toward a future in which all Americans, familiar with basic scientific ideas and processes, can have fuller and more productive lives. This is a vision of great hope and optimism for America, one that can act as a powerful unifying force in our society. We are excited and hopeful about the difference that the *Standards* will make in the lives of individuals and the vitality of the nation. (p. ix)

Prominently placed as the first standard was Teaching Standard A: “Teachers of science plan an inquiry-based science program for their students” (NRC, 1996, p. 30). Successful implementation, however, was influenced by many different factors such as teacher preparation, funding, materials and resources, participation in professional development, and inconsistencies in the goals and the assessments of those goals, to name a few (NRC, 2007).

Two current reform documents, *Taking Science to School: Learning and Teaching Science in Grades K-8* (NRC, 2007) and *Learning Science in Informal Environments: People, Places and Pursuits* (NRC, 2009), consider how science is learned in classrooms and informal settings and what research is needed to facilitate understanding of how children learn science. One of the key findings stressed in these documents is that the prior understanding of children as simplistic thinkers was inadequate. Research has shown that children often come to school with considerable understanding of the natural world and more sophisticated thinking than previously believed. Another key idea is that learning to discuss and debate ideas in science, to regard conclusions to an investigation as plausible and possible, but to consider other explanations as well, is an area in which students need support and practice. Additionally, students need to understand science is not just a collection of facts and concepts but that there are connections among these conceptual ideas in science. Finally, that although there are differences among children in terms of race, gender, socioeconomic status, language, and culture, all children come to the classroom with strengths and understandings of the world that can be built on to achieve proficiency in science (NRC, 2007).

In *Taking Science to School: Learning and Teaching Science in Grades K-8* (NRC, 2007), science proficiency is defined as four strands of an intertwined rope, with learning in one strand providing for learning in another. "For, example, learning how to design controlled experiments enables students to discover and verify knowledge about causal factors in the natural world" (NRC, 2007, p.334). The four strands are the following:

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

4. Participate productively in scientific practices and discourse. (p. 2)

Because not all science learning takes place in formal, classroom settings, another document, *Learning Science in Informal Environments: People, Places, Pursuits* (NRC, 2009) describes science learning that takes place outside of the school setting. “Learning science in informal environments is a vast and expanding area of study and practice that supports a broad range of learning experiences” (NRC, 2009, p. 291). According to this document, all of us regardless of age or background experience science learning in the day-to-day activities of daily life. In an informal environment, people can comfortably and confidently learn about science and build on their scientific knowledge and skill. From turning over a stone to see what is under it, going to a new exhibit at a museum, or on a camping trip with the local scout troop, science learning can occur. *Learning Science in Informal Environments* (NRC, 2009) builds on the four strands of science proficiency that were defined by *Taking Science to School* (NRC, 2007). The informal science education NRC committee added two more strands. These additional strands focus on excitement, interest, and motivation to learn science and ways learners develop an identity relating to doing science.

Efforts to Foster Reform-Based Learning and Teaching

The Maryland Collaboration for Teacher Preparation (MCTP) was a program funded by the National Science Foundation (NSF) for undergraduate teacher interns who were interested in becoming math or science teachers in the upper elementary or middle grades (Gardner & Ayers, 1998; Bell & Denniston, 2002). This project came in to being because NSF recognized that teachers were critical in the process to change science and math education. The vision of MCTP was to prepare teachers to teach math and science through the integration of mathematics and science, exposure to standards-based models, authentic use of technology, including the Internet, and to teach effectively in diverse settings, with sustained support during the first years of teaching. This required the university staff to teach the prospective teachers in ways that modeled how they were expected to teach, employing the skill sets emphasized in reform-based documents, such as exploring, speculating, communicating, and questioning. McGinnis, Roth-McDuffie and Graeber (2006) point out that MCTP classes were taught by faculty members from math, science and education, "who strived to diminish faculty lecture, while emphasizing student-based problem-solving in cross-disciplinary mathematical and scientific applications" (p. 16).

The National Science Foundation program that was the funding source for MCTP, had as its goal to "significantly change teacher preparation programs within a state or region and serve as national models of comprehensive change" (Gardner & Ayers, 1998, p.6). The basic premise of the programs was:

> The content and presentation of science, mathematics engineering, and technology that prospective teachers learn as part of their undergraduate and pre-certification experience will determine the quality of their own teaching efforts; their interest in integrating science, mathematics and technology in their classroom activities; and their ability to adopt and adapt creative effective teaching methods validated by recent research on teaching and learning.
>
> (Straley, 1996, p.vii, as quoted in Gardner & Ayers, 1998, p.6).

As an undergraduate participant in this program, I was profoundly influenced by the models of learning and teaching that were implemented and hold these ideas as goals I still strive to achieve in my own practice.

Position and Epistemological Stance

My position is one of collaborative researcher, taking a stance that embraces the ideas of the scholarship of teaching and learning (Hutchings & Shulman, 2004; Shulman, 2004). My understandings about science learning and teaching were profoundly affected by enrollment in an undergraduate physics course for prospective elementary school teachers (Layman, 1999; Ukens, Hein, Johnson & Layman, 2004). My science teaching methods course instructor also nurtured inquiry approaches to learning and teaching (van Zee, 1998b). As a first year teacher beginning to learn the value of reflective research through the Science Inquiry Group (van Zee, 1998a), I learned to formulate questions, collect data around those questions, and analyze the data, both independently and with colleagues in the Science Inquiry Group. As new teacher researchers, we were encouraged to write up our findings and present them at local and national conferences (see Appendix A) and to submit writings for publication (Roberts, 1999, 2000, 2004). I also participated in collaborative research (Roberts, Bove, & van Zee, 2007; van Zee, Cole, Hogan, Oropeza, & Roberts, 2000; van Zee, Lay, & Roberts, 2003; van Zee & Roberts, 2001, 2006). As a Carnegie scholar I learned about the scholarship of teaching and learning in more depth (Shulman, 2004). The Carnegie Academy for the Scholarship of Teaching and Learning (CASTL) K-12 Program had as a goal to support teacher efforts to construct a scholarship of teaching that would have a positive impact on student learning, enhance the profession of teaching, and honor teaching through recognition and reward as other research is honored (http://www.carnegiefoundation.org/scholarship-teaching-learning).

I understand that as a researcher, I am a tool in the research process (Janesick, 2000; LeCompte & Schensul, 1999). Bogdan and Biklen (1998) suggest that researchers consider their effect on the research study. I recognize that my interpretations reflect my strong beliefs that all children can learn and are sources of knowledge. Ethnic or economic diversity should not be used as an excuse for a student's academic status. As a teacher, I have a responsibility to provide learning experiences that are respectful and equitable for all students. Even at the elementary level, students should have frequent opportunities to do science and science should not be left out of a rounded curriculum. I believe that a teacher needs to be a life long learner, always seeking to improve practice.

As a qualitative researcher, I realize that my epistemological assumptions need to be considered in this study and believe that my assumptions inform my study. As an ethnographer, I attempt to view experiences through the eyes of the participants. Each of the prospective teachers is a source of knowledge. I believe that knowledge is socially constructed, not something discovered or found (Schwandt, 2000). Fetterman (1998) noted that ethnography is a "slice of life" (p. 124). This requires understanding that what is learned is not the complete or whole picture, but that there is always more, beyond the social interaction and discussion that will take place.

Importance of This Research

This study provides information about newly qualified teachers' visions as they get ready to move from student teaching placements into their own classrooms.

The study contributes to understandings of new science teachers and their ideas about science learning and teaching. Today's world requires an increasing literate science citizenry and the path to that end is through our science teachers. Although elementary and middle science teachers, according to the literature, are not often well versed in science content, or pedagogical content knowledge, it is these teachers who can lay the foundation for and instill in children a love of science, of questioning and wonderment about the world.

According to *Taking Science to School* (NRC, 2007)*,* there is agreement that:

> Well-designed opportunities for teacher learning can produce desirable changes in instructional practice and improved science learning for students. Furthermore, research has identified features of quality teacher learning opportunities that can be realized through a diverse array of organizational structures...Well-designed opportunities for teacher learning can benefit diverse student groups, including those that have been underserved. (pp. 322-323)

If this is indeed true, then it seems that the methods course should provide these well-designed opportunities. This study contributes detailed information about one version of such a course.

Definitions of Terms

Inquiry-based science instruction: I use this term interchangeably with reform-based science instruction; see definition below. The textbook for the course, *Teaching Science* *as Inquiry* (Bass, Constant & Carin, 2009) provided the following definition of inquiry instruction:

> Inquiry instruction is a method of teaching that parallels what scientists do when they do science. *What do scientists do when they do science?* No single "scientific method" invariably works for scientists. Rather, there are many methods. But scientists typically ask questions, find ways to investigate the questions through observations and experiments, collect and organize data, and construct models, theories, and explanations based on observational evidence, existing knowledge, and clear arguments. Scientists' imagination also plays a critical role in this process. Through participating in inquiry like scientists, students learn to raise questions, gather data through observation and investigation, acquire scientific knowledge, and use the knowledge in making sense of and explaining observational data. (p. 4)

Methods course: A course that focuses upon the study of recommended teaching practices. According to Collins & Gillespie (2009):

> Perhaps the most common element of all preparation programs is a course (or courses) focused on providing instructional principles and assessment strategies, which despite the variation in course names across institutions, can be classified as science teaching methods. (p. xi)

Newly qualified teacher: In this study, this refers to graduates of a teacher preparation program who have not yet begun to teach.

Reform-based science instruction: Student-centered science teaching and learning with the following characteristics as described in *Taking Science to School: Learning and Teaching Science in Grades K-8* (NRC, 2007):

> Students develop questions, discuss ways to operationalize their questions in observations, collect data, interpret data, and debate conclusions. The students also consider and critique different interpretations of data, and consider how factors like measurement or experimental procedures could affect the data. (p. 256)

Vision: A future orientation that may contain aspects of direction or goal, what is wished to be attained and the means by which it will be accomplished. A vision is an idea that bridges the present to the future.

Research Questions

This study examines ways in which newly qualified teachers envision how science teaching and learning will happen in their own classrooms. The participants were graduates of a science teaching methods course for which I was the instructor. In an effort to give a detailed account of our shared experiences I have organized the study around the following research questions:

- What educational and professional experiences influenced the instructor's visions of science learning and teaching?
- What visions of science learning and teaching were promoted in the participants' science teaching methods course?
- What visions of science learning and teaching did newly qualified teachers bring with them as they graduated from a teacher preparation program?

• How did these visions compare with those advocated by reform documents?

Overview

This study considers visions of science learning and teaching of newly qualified elementary teachers after they had finished their coursework but before they had begun to teach. The study also documents ways in which an elementary science methods course prepared the participants to teach. In Chapter 2, I review literature relevant to the four research questions: visions of learning and teaching articulated by course instructors reflecting upon their own practices, visions of learning and teaching promoted in science teaching methods courses, visions of science learning and teaching among prospective and beginning teachers, and visions of science teaching and learning as encouraged in science education reform documents. Chapter 3 presents the research design and methods chosen for the study. Chapter 4 discusses my interpretations of the participants' responses on assignments, during activities, and in interviews after graduation. In Chapter 5, I discuss the ways in which the assignments, activities and interviews reflect the framework of the four strands of science proficiencies as outlined by *Taking Science to School: Learning and Teaching Science Grades K-8* (NRC, 2007). In Chapter 6, I summarize the findings, discuss these findings in relation to the research literature, note limitations, consider implications, and articulate directions for future research.

CHAPTER TWO

Introduction

This study focuses on the visions of science learning and teaching held by a group of newly qualified teachers who graduated from a science teaching methods course for which I was the instructor. Use of the term *vision* is discussed below. Also reviewed is research related to four aspects that have shaped this research process: studies authored by instructors articulating visions of learning and teaching they have implemented in their own courses; studies reporting visions of science learning and teaching promoted in science teaching methods courses; studies documenting visions of science learning and teaching by prospective and beginning teachers; and visions of science learning and teaching set forth in national reform documents.

Use of the Term "Vision"

The following section discusses different uses of the word *vision* that relate to this study. The first is *vision* as it is used in self-studies. The second is *vision* in relationship to an identity as a science teacher. The third is *vision* as used in studies on teacher beliefs. The fourth is *vision* as it applies to reflection on practice. The fifth is *vision* in reference to instructing science and science methods courses. The sixth is the *vision* of science teaching and learning in reform documents.

***Vision* Used in Self-Studies**

Samaras (2004) used the term *vision* in describing the process of self-study. Authors of self-studies look for "alternative interpretations and visions of their teaching realities" (p.13). Visions generated by self-studies are an on-going process that draw attention to "mistakes, understandings, tensions and insights" (p.13) for a specific context. This use of the word *vision* describes a building of the present to the future. Similarly, in describing a group of university science teachers reflecting on their own practice, Abell (2005) noted that studying one's own teaching with colleagues "can help build a shared vision of teaching across a program or department, that leads to further study and change" (p.294).

***Vision* Used in Reference to Identities as Science Teachers**

The term *vision* also appears in discussions of teacher identities. Abell (2005), for example, found that during a science teaching methods course, prospective teachers were "building their views of inquiry and their visions of themselves as future teachers" (p.287). In a study about implementing a reflective orientation toward the teaching and learning of science, Abell & Bryan (1997) asked prospective teachers to reflect on their science experiences so they could look at their histories (past) and then to the future to envision themselves as science teachers.

In a review of the science teacher education literature, Davis, Petish and Smithey (2006) found that teachers who were better able to envision themselves as science teachers gained more from their education program and became better inquiry-based science teachers. According to the authors, "envisioning oneself as a science teacher is critical in becoming a professional" (p.31). Davis (2006) stated that expert teachers demonstrate a more complex view of teaching than prospective teachers. She found that they make more connections and are more analytical in the classroom. She described this as *professional vision* and stated that developing professional vision is important to enacting effective instruction.

Vision Used in Studies of Teacher Beliefs

In a longitudinal research program based on the Maryland Collaborative Teacher Preparation project, McGinnis, Parker and Graeber (2004) investigated how the beginning teachers' visions of science teaching and learning evolved in the different cultures of the schools in which they were employed. Using data from interviews conducted over two school years, these authors documented the advantages and constraints that beginning teachers identified in implementing their visions of reform-based practices in classrooms. In this example, the term *vision* refers to views of learning and teaching; the study traces if and how the new vision compares to the original.

In a study of prospective teachers' beliefs about science teaching and learning, Bryan & Abell (1998) described a participant who was struggling with the tensions of the differences between her science teaching in a field placement and her vision of science teaching. The participant was able to change both her instruction and her thinking as she confronted the differences between her vision and her actions in teaching. In a study regarding learning to teach by inquiry, Crawford (2007) found that a participant was frustrated by the constraints she felt prevented her from implementing her own vision of an inquiry-based approach to science. In all of these instances, and there are many more, the term *vision* is used to describe what is wished or wanted to be attained and in some cases the means by which it may or may not be accomplished.

Vision Used in Reference to Reflection on Practice

Gomez, Strage, Knutson-Miller and Garcia-Nevarez, (2009) envisioned that the prospective teachers with whom they worked would use reflection on their field experiences to help them better understand the culturally and linguistically diverse children who populated their field placement classrooms. Having teacher candidates draw pictures of their teaching and learning experiences led Armstrong (2007) to understand that "Pre-service teachers are constructing their own vision of teaching while negotiating their way through their apprenticeship of observation" (p.2). As the course progressed, their drawings showed that "the students were able to envision ideals that were far different from their own school experiences" (p.22).

Vision Used in Reference to Instructing Science and Science Methods Courses

In a case study of inquiry-based instruction in undergraduate science education, Rogers and Abell (2008) found that college science instructors need to learn about successful improvements and innovations in undergraduate science instruction so that they can envision inquiry-based teaching and learning. Zembal-Saul, Blumenfeld, and Krajcik (2000) discussed how the understanding of pedagogical content knowledge is critical for teacher educators in order to provide novice teachers with a vision of reform-based teaching.

Vision Used in Reference to Reform

Crawford (2007) referred to a vision from the *National Science Education Standards* (NRC, 1996) "that students in K-12 science classrooms develop abilities to do scientific inquiry, gain understandings about scientific inquiry, and that teachers facilitate students in acquiring deep understanding of science concepts through inquiry approaches" (p.614). A recent reform document, *Taking Science to School: Learning and Teaching Science in Grades K-8,* (NRC, 2007) provided a framework for what it means to be proficient in science. This study referred to a new vision for science teaching and learning that was defined through four strands of science proficiency.

Smith, Cowan & Culp (2009) referred to this 'new vision' for K-8 science as they prepared and planned a new unit of science for young children. They read and discussed the National Research Council's report, *Ready, Set, Science!* (NRC, 2008). This report followed the 2007 NRC document with the intent of providing "how" one might envision implementing the framework provided by *Taking Science to School* (NRC, 2007).

In all of these examples, the term *vision* has a dynamic and active connotation. Vision is what we hope to achieve, what we think might be possible, a goal, something to reach for. It acknowledges that we are here now in the present, but looking toward the future, in this case, the future of science teaching and learning. A desirable vision to have then is the vision of looking back, ten years from now, to realize that this vision has been fulfilled, and a new one is waiting to be created.

Visions of Teaching and Learning Articulated by Instructors Reflecting upon Their Own Practices

Research by teachers on their own teaching practices typically is referred to as *teacher research*. *Practitioner research* is a broader term used to include research by individuals in other roles such as principal, specialist, or instructional assistant. After reviewing literature in these general contexts, I discuss reports of studies by instructors on their teaching and students' learning in methods courses.

Teacher Research

By the end of the 20th century, proponents of teacher research echoed Dewey's early articulation (1928/1956) of the value of teachers producing "careful reports on conditions which experience has shown in actual cases to be favorable or unfavorable to learning" (p. 126). Eleanor Duckworth (1987), for example, envisioned the act of understanding teaching by engaging learners as a quintessential aspect of reflective research; she recognized that researchers who engage in this kind of teaching would want to make their understandings available to others:

> He or she would be fascinated by the questions of how to engage people in it [understanding some part of the world] and how people make sense of it; would have time and resources to pursue these questions to the depth of his or her interest, to write what he or she learned, and to contribute to the theoretical and pedagogical discussions on the nature and development of human learning. (p. 168).

In *The Having of Wonderful Ideas and Other Essays on Teaching and Learning*, Duckworth (1987) exemplified the role of a teacher of inquiry. She provided examples of helping learners struggle through a problem by encouraging them to share their ideas and thinking, without judgment, listening carefully to what they say in order to facilitate deeper learning. This, too, is the role I believe a methods instructor must take, trying to listen for ideas, not giving answers; responding without judgment, and encouraging the students to take their own thinking and learning to a deeper level. An important aspect of this is then to make those encounters public so that others may become engaged with making sense of learning and teaching as well, so that all can benefit.

In *The Teacher Research Movement: A Decade Later*, Cochran-Smith and Lytle (1999) reflected on the value of this practice. They described teacher research as becoming part of reform in professional education that emphasized inquiry:

> posing, not just answering, questions, interrogating one's own and others' practices and assumptions, and making classrooms sites for inquiry—that is, learning how to teach and improve one's teaching by collecting and analyzing the "data" of daily life in schools (p.17).

This again echoes what Dewey and Duckworth have said, reflective practice is active, persistent, systematic and holistic. It is an inquiry into one's own beliefs and actions. It is the continual striving to understand learning and teaching in a way that will most benefit the learner. And it is in the sharing of our collective struggles to understand our teaching, or the struggles of our students as they learn that will improve teaching and learning.

In a chapter entitled *Teachers as Researchers* in the *Handbook of Research on Science Education*, Roth (2007) explained the role of teacher research as important in two ways. First, teacher research can add to the knowledge base in science education and second, help connect the areas of practice and research. Roth claimed that such research has gained respect and is often practiced by teacher educators at the university level. Such research has value in supporting the continuing professional growth of the science teacher and of the science teacher educator. This has been true in my own experience.

Practitioner Research

Research by curriculum specialists, administrators, staff members of various kinds, and college faculty as well as by teachers has been called *practitioner research*. In the fourth edition of the *Handbook of Research on Teaching*, Zeichner and Noffke (2001) noted that theirs was the first chapter on practitioner research to be included in this handbook. Published two years after Cochran-Smith and Lytle's 1999 reflection, this chapter underscored the challenges that teacher research and practitioner research have faced as respected forms of research. Zeichner and Noffke (2001) described an outcome of practitioner research as "changing practice as a result of study and changing practice to better understand it" (p. 306). They discussed the traditions, methodologies, and issues of quality of such research. In considering different reasons people engage in practitioner research, they noted that these range:

> from an interest in better understanding of one's own students and improving one's teaching, to generating knowledge about teaching and schooling that can be shared with others, to improving the various social and institutional contexts in which their educational practice is embedded (p. 323).

This expresses again the idea of sharing one's practice with others to generate knowledge about learning and teaching in ways that may provide insight to a larger audience.

One indication of the growing interest in practitioner research was the availability of funding. The Spencer Foundation, for example, offered Practitioner Research Communication and Mentoring Program grants to those who were interested in strengthening the effectiveness of teacher researchers and to clarify the uses of teacher research. In addition to supporting local teacher researcher groups, the Foundation convened grantees to discuss the who, what, why, where, when and how of teacher research. As a member of a group funded by this program, I experienced many opportunities that were instrumental in my development as a teacher researcher. I believe that my sphere of understanding of learning and teaching, as well as of conducting and participating in this kind of research, was greatly increased by learning about what others were doing in their classrooms as well as by sharing my research and getting feedback from others. These experiences I believe profoundly impacted my personal beliefs and understandings of learning and teaching, and served as a continuing basis for questioning my own practice.

Research by Methods Instructors

Methods instructors have benefited from opportunities to reflect on their own learning and teaching in many ways. Samaras (2004), for example, described her studies of her methods courses as an approach to self-knowing and "to push the boundaries of teaching" (p. 51). She viewed self-study as a "necessary and vital part of who we are as teachers" (p.51). She reflected on her own practice as a way to "see herself and her students more clearly" (1998, p.55).

Sandra Abell has been a leader in such reflective research in science contexts (Abell & Bryan, 1997; Abell, Bryan, & Anderson, 1998; Abell, 2005). She encouraged other methods instructors to do the same, including a team of instructors at her institution (Newman, Abell, Hubbard, McDonald, Otaala, & Martini, 2004). As these university instructors were discussing informally how they were teaching the course, they noticed that they had similar concerns. They developed a set of questions and then undertook a much more formal study of their own teaching practices. Their questions were: "How are we currently teaching inquiry? What aspects of inquiry instruction seem to be working well and what aspects are not working well? What factors influence inquiry instruction in our course? How can we address any identified problems?" (p.260).

Newman et al. (2004) explain that like most teachers, university instructors are interested in how effective they are. By studying one's own practice, information can be provided about what “needs to be changed” (p.294). They state that there is not enough research about what happens in K-20 classrooms. If university instructors share rich information about their own contexts, the data shared can inform others. The practice of university researchers collaborating and discussing ideas also was documented in a study by McGinnis (2003b). This study compared discourse about science and mathematics in which science, math, and methods faculty engaged, and its impact on their collaboration.

The foci of such self-studies have varied. McGinnis, Roth-McDuffie and Graeber (2006), for example, examined the pedagogical strategy of integrating mathematics and science in a course for prospective teachers. van Zee (1998b) considered how she was implementing the professional development standards articulated in the *National Science Education Standards* (NRC, 1996). Windschitl (2003) studied how prospective teachers’ previous investigative experiences had an impact on their understandings of inquiry. Davis (2006) conducted a study of prospective teachers’ integrated ideas about teaching that included learners, subject matter knowledge, assessment and instruction. The very nature of the fact that these foci are varied illustrates the value of this kind of research. Instructors can choose aspects of learning and teaching that are of particular interest to their circumstances. Others, who may not ever have considered this aspect of their own teaching, are made curious just by the sharing of ideas. McGinnis and Pearsall (1998), for example, collaborated on a study of his female students’ experiences as he attempted to implement a female-friendly climate in his elementary science teaching methods course. Just reading this study made me wonder about the experiences of the male students (who are typically a minority in the methods courses I have taught or been a student in).

Some methods instructors have created websites to communicate their practices to others. See *Making a New Song About Science* by Deborah Smith, for example (http://gallery.carnegiefoundation.org/collections/castl_he/dsmith/index2.html). Through a multi-media look at her own practice and concerns, Smith reflected on ways to help her science methods students feel competent and confident about teaching science. Indeed these multimedia websites, known as "snapshots of practice," provide examples of teachers' self studies on issues in their own teaching practices (see: http://gallery.carnegiefoundation.org/). In addition to piquing one's curiosity by reading or hearing about such studies, such websites provide an advantage in having others' experiences as background information for a new study one may be considering, or a re-examination of ideas one may have. In essence, I believe the stance of being a practitioner researcher includes the idea of being open-minded, curious, and questioning while exploring such resources.

As a participant in the Maryland Collaborative for Teacher Preparation (MCTP), I was not surprised to learn that engaging in self-studies was an aspect of the planning and the development of this program. For example, as some university instructors worked to change their practices to meet the challenges of reform-based teaching in MCTP, they kept journals of their thoughts and observations on teaching. These journals not only contributed to the instructors' better understanding of their own teaching and the learning of their students but also led to further refinements in the courses in the program (Gardner & Ayres, 1998), which in turn may have led to the enhanced learning of future students.

Luft (2007) suggests that new teachers be encouraged to share their reflections on their own teaching of science, as a means of supporting them as they begin to teach and as a way to gain understanding of this critical time in their teaching careers. There are many constraints on a new teacher, so she suggests that the research be carried out in tandem with a researcher, who would be careful to allow the teacher voice to be in the forefront. For example, in a study by Bianchini and Colburn (1999), Bianchini was particularly sensitive to the voice of the researcher not overtaking the voice of the instructor. In a collaborative study on teaching the nature of science to prospective elementary teachers, they found "that the teacher as researcher was able to provide greater insight into the contexts of teacher–student exchanges and to critique his own words and actions more constructively. . . . while the researcher drew from different areas of scholarship than the teacher as researcher to provide a broader description of the nature of science enacted (as it was and could be) in the classroom" (p. 206). By sharing both sets of findings, they eliminated the privileging of one researcher's voice over that of another and did not try to hide the challenges that occurred in this collaboration.

What is apparent in these examples is that practitioner research is not static, limited, or limiting. The topics and interests that can contribute to the field are many and have the potential to enrich the practices of others. Such research is not exclusive to any one group, university faculty, classroom teachers, and prospective teachers, and students in those classrooms can all contribute to the knowledge base for science teaching and learning, if care is exercised in how all voices can be heard.

Visions of Science Learning and Teaching

Promoted in Science Methods Courses.

Davis et al. (2006) examine the challenges that new teachers face. Their view of education is that "education is about promoting learning and that teacher education is about promoting learning among teachers" (p. 607). They also state that in order for teachers to become effective science teachers they must receive a sufficient preparation. Clearly an adequate preparation must include experiences before and after the methods course but the methods course is a critical component. In the following section I have organized research on science teaching methods courses around five issues that seems to play a central part in this vision. First is the concept of reflection as integral to a science teaching methods course. Second is the importance and necessity of field experiences. Third is the urgent need for a focus on learning for all students. Fourth is the authentic and intentional use of technology in both science and methods courses. Fifth is that discussion of the learning and teaching of science must be purposely integrated into learning and teaching experiences. This is not meant to be an exhaustive list but includes ideas that were related to my study. Many of the authors are conducting self-studies but this section includes research on methods courses by others as well.

Reflection Orientation

Abell and Bryan (1997) identified a variety of orientations toward teaching science teachers. Some science teaching methods courses are designed with the content to be addressed as the focus, with a different topic discussed each class. Another orientation focuses on science process skills, with the prospective teachers participating in activities that exemplify each skill. Another may be an activities orientation with prospective teachers experiencing one activity after another as if they are elementary students. The last orientation they describe is the reflection orientation.

Instructors with the reflection orientation ask prospective teachers to "describe their ideas, beliefs, and values about science teaching and learning and by offering experiences that help them clarify, confront, and possibly change their personal theories" (Abell & Bryan, 1997, p. 154). This idea is based on the notion that future teachers of science "learn about teaching science in a number of different contexts, each one of which can provide an opportunity of reflection and learning" (p. 154). Abell and Bryan (1997) provide opportunities for the methods students to reflect on video examples of teaching, on their own teaching in field placements, on themselves as learners, and on expert opinions through course readings. Some of this reflection is done collaboratively in the methods course.

Gardiner and Shipley-Robinson (2009) were interested in establishing a collaborative community by pairing students in placement classrooms. This provided both individuals a chance to reflect on their practice and make meaning from their experiences with someone in a non-evaluatory status. As the students grappled with applying theory to practice, they could collaborate by sharing reflections, ideas and resources.

Harford and MacRuairc (2008) also emphasized that reflective practice is a critical aspect of learning and teaching. Like Abell and Bryan (1997), they used video as an element of reflection in a methods course. They stated that using peer-based video sharing was an important scaffolding of the reflection-on-practice community they tried to establish in their methods course. Their students chose a ten-minute segment of a video, shared with their classmates why it was chosen and then the class watched the video and discussed it. The instructor acted as facilitator in guiding the discussion and asking pertinent questions. This sharing time deepened the students' understanding of reflection and the sense of community the learners experienced. In these studies, Dewey's ideas about reflective practice are a foundation on which ideas about reflection are being implemented; reflection is a meaning-making process and needs to happen in community, and in interaction with others (Dewey, 1933).

The implementation of reflection in these methods courses is intentional. Having prospective teachers develop a disposition for reflection is a characteristic of what Davis (2006) describes as *professional vision* and *productive reflection* (p. 283). The difference between productive and unproductive reflection, according to Davis, is that unproductive reflection is a description without analysis or making connections, and probably the kind of reflection student teachers would engage in without the kind of support or practice they had in Abell and Bryan's (1997) or Harford and MacRuairc's (2008) approaches. Without support, prospective teachers have difficulty in perceiving alternatives to their decisions, being able to support their claims with evidence, or question their assumptions (Zembal-Saul et al, 2000). Productive reflection would involve analyzing and integrating ideas, questioning assumptions, and considering multiple views (Davis, 2006). Davis' findings suggest that Abell and Bryan (1997) and Harford and MacRuairc (2008) are providing the supports necessary for the prospective teachers to reflect productively.

Davis (2006) found that when supported, prospective teachers can move beyond description and into analysis, think about their learners, learning and content, and integrate ideas about learning and instruction so that they can "conceptualize teacher learning as knowledge integration" (p.295). These studies support the concept that helping prospective teachers develop an ability to enact reflection-on-action, (Schon, 1983) can give the prospective teachers a view into their own learning and researchers insight into how new teachers can learn from their own teaching (Anderson et al., 2000).

Reflecting on their own practice is important because prospective teachers learn about science in many different contexts, and reflection in each context can deepen understanding. Providing a safe classroom environment so that collaboration and reflection with peers can take place is a way to enhance learning. If supported by their instructor, reflection can help students reflect productively, make connections between theory and practice, and integrate ideas about learning and instruction. Reflection was emphasized in my own undergraduate science and methods courses and has continued to be an important aspect of my teaching practices, with children as well as with adults.

Field Experiences

According to Abell (2006), there has been an emphasis on field experiences in science in many education reform documents. She pointed out that frequently prospective and practicing teachers complain that they did not learn very much in their teacher preparation programs except for the brief field experiences they had. Field experiences seem to vary amongst teacher education programs. In a study of four different teacher preparation programs, Roehrig and Luft (2006) found that teachers from a pre-service program with "an extended student-teaching experience and two science methods courses held beliefs aligned with student-centered practices and implemented more reform-based lessons than did other teachers during the year" (p.963).

Davis, et al. (2006) found that field experiences can influence the beliefs of prospective and beginning teachers. They state that field experiences also impact self-efficacy in a positive way. Forbes and Davis (2010) claimed that the opportunities for prospective teachers to actually try out inquiry-based science lessons in the classroom are insufficient as currently provided and that field experiences with appropriate mentor teachers should be a significant part of teacher education programs. Windschitl (2003) noted that the pedagogical stance of the cooperating teacher should be considered in arranging for field experiences. Field experiences can provide prospective teachers opportunities to develop a basis of understanding of reform-based instruction upon which future teaching and learning can be expanded. More attention may be needed in the planning and implementation of those experiences. There is a need for connections to the field to take place during the methods course, for prospective teachers to try out some of their changing skills and beliefs.

Diversity.

Just as knowledge in science and in understanding scientific theories seem to deepen over time and experience, the same is true for understanding what is possible in science learning and teaching. Today we are faced with many challenges that require all of us to be able to make informed decisions about the world in which we live. The challenges to educators are great as well. In many instances, science has all but been eliminated from curriculum as schools and teachers struggle to meet requirements for achievement in mathematics and reading education, and this is especially true for students learning English as well as students in Title 1 schools (Lee & Buxton, 2008;

Smolleck, 2007). These students should not be denied the opportunities or advantages of learning science.

Prospective teachers are often assigned to field placements in urban settings, with highly diverse populations. Not all prospective teachers have had prior experience in these types of settings. They often encounter situations in which science (and often social studies) are not included in the curriculum. Prospective teachers may not be aware of the influences of linguistic and cultural influences on learning, or how to address those influences. As Lee et al. (2009) report, prospective teachers may not consider "teaching for diversity as their responsibility, overlook racial/cultural differences among students, accept inequities as a given condition, or resist multicultural views of learning" (p. 265).

Methods courses then need to facilitate prospective teachers' *instructional congruence* (Lee & Luykx, 2005, p.412). Instructional congruence is a pedagogical approach to teaching that joins "subject-specific and diversity oriented strategies" (p. 412) to further academic achievement for diverse students. Both teachers' knowledge of science content and teaching practices and strategies for diverse learners are important to teach science in urban and highly diverse settings (Lee et al, 2009). Additionally there is a need for student teachers to "know" their learners. Geneva Gay (2002) described this as *culturally responsive teaching*, which she defined as "using the cultural characteristics, experiences, and perspectives of ethnically diverse students as conduits for teaching more effectively" (p.106). Nieto (1999) explained it simply: "teachers need to learn what can help their students learn, and change their teaching accordingly" (p.143).

The field experience is an opportunity for methods instructors to facilitate this thinking and understanding, to emphasize the pedagogical approaches that are effective in furthering the academic achievement of diverse learners, and to make explicit the inclusion of these strategies (Lee & Luykx, 2005, p. 412). Diversity needs to include not only issues of race, religion, socio-economic status, language, culture, or giftedness, but also issues of developmental disabilities. Teacher beliefs about diverse populations need to be understood as well. McGinnis (2003) attempted to facilitate prospective teachers' ability to collaborate with school faculty to effectively teach science to students with disabilities in an inquiry-based way. The field experiences provided the prospective teachers opportunities to deepen their understanding about inclusion and exclusion, and about inquiry teaching with students with special needs. He found that most prospective teachers' "moral considerations predominated in their professional decision making concerning the cultural and societal inclusion initiative" (p. 211).

Of tantamount importance is for science to be presented as an endeavor open to **all** students. Lee and Luykx (2005) explained most teachers are ill equipped to meet the needs of linguistically and/or culturally diverse students. As with Loucks-Horsley et al. (1998), Lee and Luykx emphasized that teachers are not prepared to teach science content or process in a meaningful way for children of diverse backgrounds. Often, teachers are focused more on content and/or instruction and do not understand the experiences, needs, and resources of non-mainstream students. Unfortunately these institutional constraints create significant problems for teachers like myself, with strong beliefs in equity, in inquiry-based learning, and in the importance of teaching science to all elementary students to encourage and entice female and minority students to think about science as a future career.

Making students aware of the cultural, linguistic, socio-economic, gender, ethnicity, academic and other differences that might exist in their future classrooms is critical. The teachers need to find ways to use culturally responsive teaching to meet the needs of all learners. Without making these ideas explicit, it may be hard for teachers to recognize the strengths that their students bring to their classrooms. Prospective teachers need to learn to capitalize on the resources by being sensitive to differences that may be present amongst their students. Every student deserves an opportunity to learn science and to be successful in science.

Use of Technology

An additional but important component in methods courses is the inclusion of technology. In the 21st century, many of the students from elementary school to the university have had experiences with technology. For our digitally literate students, technology is a must. In science and mathematics courses designed for prospective teachers in the MCTP program, for example, authentic uses of technology were incorporated (Gardner & Ayers, 1998). Technology was an important element of that program for me. In this time when technological advances are occurring at a fast pace, being open to and adapting methods curricula to include technology is imperative.

Many methods course instructors have incorporated the use of technology into their classrooms. Bryan and Abell (1999), for example, used video to facilitate reflection by prospective teachers on their own practice and the practice of other educators. van Zee and Roberts (2006) documented the use of web-based "snapshots of practice" in methods classes. As part of an effort to reform science teacher education, Glasson and McKenzie (1999) had preservice teachers create multi-media portfolios as an assessment of their field experiences. These authors found that the preservice teachers' ability to assess their own learning was greatly enhanced and helped them to tell the story of their teaching and learning experiences in their own voices. The preservice teachers expressed that they appreciated the opportunity to create this electronic portfolio and believed that they would use it for their students. The types of technology and the ways in which they can be incorporated seems to be limited only by funds needed to procure the equipment and software, the time needed to understand and implement its use. Karen Cator, director of the Office of Educational Technology at the United States Department of Education stated that learning no longer has to be restricted to the classroom, or be a one-size-fits-all situation. She noted that "the opportunities afforded by technology should be used to re-imagine 21st-century education, focusing on preparing students to be learners for life" (quoted in Allington & Berry, 2010, p. 10).

Integration of Disciplines

From my experience at the local and state levels, integration of the disciplines has gained momentum because of the reduction, even elimination, of time for science in this era of high stakes testing. The current movement to integrate other content areas into science is not new, however. The MCTP program listed as a goal: "provide courses and field experiences that integrate mathematics and science" Gardner and Ayers, (1998, p. 9). Integration of the use of computers and other technology, including the Internet, was a goal of the project as well. The integration of science and mathematics has been documented through studies of methods courses that include the teacher interns of MCTP program, and non-MCTP teacher interns by McGinnis, Roth- McDuffie and Graeber

(2006). Findings show that the teacher interns in the MCTP program were able to make connections between mathematics and science and to explain their thinking in more complex ways than the non-MCTP teacher interns.

Saul began the Elementary Science Integration Project (ESIP) because she was interested in "helping create reading and writing activities that inform and are informed by science" (quote taken from http://www.esiponline.org/about/who/people.html). As a part of ESIP, elementary students were involved in a science inquiry conference. In this conference, students presented to their peers their own science investigations that integrated reading, writing and mathematics. Adults served only as timekeepers and facilitators of questioning - adults were ready to ask questions or encourage the students in the audience to ask. Saul and Dieckman (2005) found "since the passage of the No Child Left Behind legislation (2002), which ties adequate yearly progress to reading test performance, literacy instruction in the United States has received significantly more school time and money compared with science, social studies, art, music, and physical education" (p. 503). Science advocates were concerned that reading about science would take the place of "doing science," while at the same time literacy scholars were asking that students be given more time and experience in reading informational text (Anderson & Guthrie, 1999). Partly in response to the reducing of, or in some cases elimination of, science in the elementary school experience (Smolleck, 2007), science teachers and curriculum specialists sought to incorporate reading and writing into science. Science methods instructors began employing facets of literacy instruction into their methods courses, as Bryan and Abell (2007) have, with a reading reaction sheet that asks methods students to use before-, during-, and after-reading strategies with the course readings.

Becoming a reflective teacher is a life-long journey. Providing prospective teachers with the opportunities to practice and refine their skills through experiences in a methods course is good place to make progress. The vision of what kinds of science learning and teaching might be promoted in science teaching methods courses is complex, multi-faceted, interconnected, full of challenges and responsibilities. The goal is to best prepare teachers to provide the most effective science instruction possible for all students. Once these newly qualified individuals are prepared, then they also need support in bringing about change in and/or surviving the environments they encounter. Some of these environments, as Smolleck (2007) points out, may not include time for science, or as others describe, may or may not have cultures that are welcoming of reform-based teaching and learning (McGinnis, Parker & Graeber, 2004; Marbach-Ad & McGinnis, 2008).

Visions of Science Learning and Teaching Among Prospective and Beginning Teachers.

The beliefs, attitudes and dispositions of prospective and beginning teachers have been well documented. Tosun (2000), for example, recorded many negative words spoken by prospective teachers when they were interviewed about their science learning experiences. Roehrig and Luft (2006) examined what happened when graduates of various teacher education programs began teaching. They found that the type of training prospective teachers receive influences how they teach. Roehrig and Luft studied graduates from a pre-service program with an extended student teaching experience and two science teaching methods courses. These teachers held beliefs that were aligned with reform-based teaching and student- centered practices. In this section, I discuss the role of such methods courses in helping prospective teachers envision themselves teaching in reform-based ways. Also reviewed are studies of understandings about the nature of science and studies documenting visions of inquiry approaches to learning and teaching.

Role of Methods Courses

I believe science teaching methods courses are important because they may be the only model, or one of a very few models, where a prospective teacher might experience reform-based practices and form new visions about what it means to learn and/or teach science. The *National Science Education Standards* recommends that teachers enact an inquiry-based program in their own classrooms (NRC, 1996, p. 30). If teachers have not experienced what that looks and feels like to be part of an inquiry-based program, through an experience in their education program, they will have a difficult time implementing such a practice. It is more likely that they will simply reproduce the kinds of experiences that they had as students. Abell and Bryan (1997) quote Lortie who describes the phenomena of students who have spent years in classrooms observing and evaluating teachers in action as the *apprenticeship of observation* (p. 274). Abell and Bryan (1997) explain:

> the undergraduate methods course is a powerful experience in this process [of becoming a teacher of science]. In the context of the methods course science educators are responsible for modeling beliefs, values and assumptions about science teaching and learning. Our actions must be consistent with our philosophical framework if we are to be accountable to future teachers. (p. 153)

It is usually through the methods course that students begin to confront and refine their beliefs about science. Many of these beliefs may come from their own experiences as science students. Prospective teachers may not understand that some of the aspects of teaching that they observed as students do not depict the whole experience of being a teacher (Abell & Bryan, 1997; Borg; 2004). As students, prospective teachers have seen only the actions of teaching without any of the complex background work of making those actions possible.

Roehrig and Luft (2006) claim that to have an impact on new science teachers, understanding their beliefs is essential. They state this step is key in designing and developing optimal pre-service or professional development opportunities. By understanding and discovering what prospective and beginning teachers believe, and how their beliefs are connected to their practice, instructors can design the kinds of experiences needed to impact those beliefs, with the goal of improving practice. A good place for this to occur is in the methods course.

If the goal of teacher educations is to have new teachers employ reform-based science teaching strategies in classrooms, what is needed is a better understanding of teachers' beliefs and of their understandings about inquiry (Windschitl, 2003). Methods instructors should make explicit the knowledge and beliefs of the prospective teachers and their assumptions about the practices of science in order to make the connections among these beliefs, their interpretations, and the design of learning experiences for their future students (Bryan & Abell, 1999; Roehrig & Luft, 2006; Windschitl, 2004). Keys and Bryan (2000) add that if success in inquiry based instruction is important, then instructors of methods courses must model reform approaches to learning and teaching.

Understandings and Beliefs about the Nature of Science.

One aspect of reform-based teaching practices is to discuss explicitly the nature of science. Lederman (1999) sought to understand whether or not a teacher's understanding of the nature of science was an influence on classroom practice, and what factors facilitate or impede this understanding of the nature of science being enacted. He found that teachers had ideas about the nature of science that reflect reform-based thinking; especially in regard to understanding that science knowledge is tentative. Teachers with more than ten years experience often taught in ways that were more consistent with the tenets of the nature of science than teachers with less than five years experience. However, these experienced teachers had not chosen the nature of science as an objective or goal for their students to learn. Lederman found that, in general, understanding of the nature of science by teachers did not necessarily translate into classroom practice.

Bianchini, Johnston, Oram, and Cavazos (2002) combined investigating teachers' implementation of the nature of science ideas in their classrooms with teaching science in equitable ways. They described the methods course they taught as explicit in instruction in the nature of science. Their findings suggest that the teachers who participated in their methods course believed they were adequately prepared to teach science in reform-based ways that were inclusive of all students, although they struggled to implement some aspects of the nature of science that were not included in the state content standards. One teacher had participated in scientific research prior to teaching and thought "students should learn both who scientists are and how scientists work" (p. 429). This teacher's perspective that science process is important was similar to that of one of the participants in the McGinnis, Parker and Graeber (2004) study. She thought that the process of doing science was constant while the theories of science can change. She developed inquiry-based labs so that her students could experience and practice the processes of science. This teacher also believed it was important to show connections of science to everyday life. Another participant, who had been a science major prior to teaching, agreed that it is important for students to know more about who scientists are and the nature of their work. Both believed that every student needed to experience success in the classroom and wanted to provide alternative assessments. Both women thought that classrooms should be "safe community environments" where students could be challenged but feel comfortable taking risks.

Visions of Inquiry Approaches to Learning and Teaching

In a study of prospective teachers learning to teach science as inquiry, Crawford (2007) found that there were a variety of approaches taken to teach science, from traditional didactic instruction to open inquiry, even though the prospective teachers in the study were supported in their professional development school setting. She suggested that prospective teachers' intentions and abilities to implement reform-based science teaching depend upon their complex set of personal beliefs about pedagogy, schools, student learning, and the nature of scientific inquiry. She described how difficult it is for a prospective teacher to implement an inquiry-based approach, when the mentor teacher does not teach that way. Windschitl (2003) explained that the pedagogical beliefs of the cooperating or the mentor teacher might directly impact what the prospective teacher can do in the placement classroom. My experience as an instructor of methods courses is that often the placement of student teachers is based on where teachers are who are available and willing to mentor with little information about the mentor teacher known.

When the prospective teachers become beginning teachers, they are not always able or willing to include inquiry based teaching strategies without putting in extra effort, especially if they have to defend this way of teaching to their peers, and/or administrators. McGinnis, Parker and Graeber (2004) documented the experiences of five new teachers who graduated from a reform-based science and mathematics education program. There were differences in school cultures that created challenges to the implementation of reform-based instruction. McGinnis, Roth-MacDuffie, and Graeber (2006) studied several beginning elementary teachers who mentioned their intent to make connections between the mathematics and science disciplines. One expressed a preference to having her students actively engaged. Another advocated cooperative grouping and referred to an emphasis on process as "superior pedagogically" (p. 729) to a content emphasis. Another described teaching as conceptual change and considered that teaching less, in more depth, was important. While articulating these views, the participants acknowledged courses and instructors in their reform-based preparation program as influential in their development. However, not all of the graduates of the program felt successful.

Crawford quoted Bybee (2000) who claimed "most evidence indicates that science teaching is not now, and never has been, in any significant way, centered in inquiry whether as content or technique" (p. 42). Perhaps this is partially because of pre-service preparation, because not all science teaching methods teaching courses use reform-based approaches to prepare their prospective teachers (Crawford, 2007). Perhaps it is due to the many struggles that new teachers face, which include the cultural environment of the school, and the ability of the new teacher to implement reform-based practices without support and/or to defend implementation of reform-based practices in school cultures that do not value those practices.

There were commonalities in the findings across these studies involving prospective and beginning teachers. Novice teachers' efforts to implement science as inquiry were sometimes constrained by the culture of the school setting (Crawford, 2007; McGinnis, Roth-MacDuffie, & Graeber, 2006; McGinnis, Parker & Graeber, 2004). Crawford's findings (2007) also were similar to those of Bryan (2003) showing that there were tensions that exist for teachers due to opposing views they held about schools, the role of the teacher, and the role of the student. Crawford's research (2007) also affirmed findings from a study by Luft, Roehrig, and Patterson (2003) that novice teachers' beliefs and practice are changeable.

Visions of Science Teaching and Learning as Encouraged in National Reform Documents

The framework for examining this methods course will be drawn from the visions set forth by the National Research Council in the *National Science Education Standards* (1996) and in *Taking Science to School: Learning and Teaching Science in Grades K-8* (2007). Both of these documents suggest the importance of students posing questions, teachers guiding and facilitating investigations, discussions, and questioning; the use of models; scientific discussion, with debate, and use of evidence and reasoning to demonstrate understanding.

The *National Science Education Standards* (1996) recommended that teachers implement an inquiry-based program. There is a wide range of interpretations of what inquiry-based instruction is (Flick & Lederman, 2006; Minstrell & van Zee, 2000; National Research Council, 2000; Windschitl, 2003). One description offered by the standards was engaging students in:

> asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. (p. 105)

The recent document by the National Research Council (2007), *Taking Science to School: Learning and Teaching Science in Grades K-8*, suggests that content and process skills not be taught separately, although the authors claim that is what currently is often done. They describe a learning experience in the context of animal behavior as having the following characteristics: students develop questions, discuss ways to operationalize their questions in observations, collect data, interpret data, and debate conclusions. The students are exhibiting proficiency in coordinating theory and evidence as they consider and critique different interpretations of data and consider how factors like measurement or experimental procedures could affect the data.

Taking Science to School (NRC, 2007) recognized that science learning is multifaceted and interrelated. This document described science proficiency in terms of four strands, intertwined as a rope:

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. 2)

This publication stresses that the strands are separated only for the purpose of better understanding the whole and that "students use them in concert when engaging in scientific tasks" (p. 41). The text also emphasizes that there is a "complex interplay among development, learning and instruction" and that:

> a student's instructional history plays a critical role in her scientific knowledge, scientific reasoning and readiness to do and learn more science. Components of the cognitive system . . .certainly are factors that contribute to a student's learning history, but so do other mechanisms that are manipulable by educators and constitute the 'design tools' that a teacher can deploy to most directly affect learning (p.41).

Taking Science to School (NRC, 2007) explains that the view of young children as simplistic thinkers is not what we currently understand. Children are capable of doing and understanding more than previously thought. The studies examined for this publication show that children's science learning should be centered around core concepts that are age appropriate which could then be addressed at each grade level in increasing complexity. This may mean decreasing the number of topics presented, (not going a mile wide and an inch deep) and implementing a learning progressions approach. Learning progressions are described as having four key characteristics that are not evident in earlier standards documents. Those four characteristics are: "use of the current research base on children's learning, interconnected strands of scientific proficiency to build understanding, organization of core knowledge around core ideas, and recognizing multiple sequences and web-like growth" (p. 221).

Learning progressions would impact the way current curriculum and standards are written. Prioritizing the curriculum to identify core ideas in ways that are age appropriate would ensure students are presented with the conceptual tools and practices that are needed at that time, rather than "addressing them in current haphazard ways" (p.247). Using learning progressions would introduce core concepts at appropriate ages. Atomic-molecular theory is given as an example. Some states introduce this idea as early as third or fourth grade and others wait for high school. The research suggests middle school might be the best time to introduce this concept. The learning progressions model also would affect assessment. Because the key conceptual ideas, tools, practices, questions and tasks would be identified, the creation of common assessments (classroom or large scale) would be facilitated. Learning progressions also would guide classroom instruction by providing key questions for the core concepts as well as the tools and practices to introduce concepts that are appropriate for students at a given grade level.

Because this literature is recent, there has not been much research that uses the strands of scientific proficiency as a focus. Smith, Cowan, and Culp (2009) developed a unit for kindergartners that used the four strands as a framework for the study of seeds. After researching district standards, they looked back to other science units the students had studied and identified ways in which to build on that prior knowledge. Next, they read the research on what children think about plants and growth. Then as a team they read *Ready, Set, Science!* (NRC, 2008), which is the educators' version of *Taking Science to School*. *Ready, Set, Science*! has been described as the "how" for educators, using case studies and classroom vignettes to illustrate the implementation of the strands into science lessons. Smith et al. (2009) found that over an 18-week-long unit, the students “were, indeed, capable of engaging in the four strands from *Ready, Set, Science!* when we designed opportunities for them to do so and scaffolded their thinking and talk” (p. 51). Smith Cowan, and Culp expect to continue planning other units of science study in this way. These examples will be helpful to the field as the recommendations from this literature are put into action.

Minogue et al. (2010) also examined classroom implementation of the strands. In reaction to national assessments showing that K- 8 students are only at the basic level in science, Minogue et al. (2010) used the strands of scientific proficiencies to begin to address these issues during the K-8 years. They used the strands as an “analytic lens with which they looked at science teachers’ practices and students actions” (p. 560). Their study focused on the use of science journals as a tool to record the chronological progressions of student thinking as the students work through an investigation. The journals provided the teachers a vehicle for ongoing formative assessment, with “the potential to inform prescriptive approaches for improving inquiry-based science instruction through professional development” (p. 563).

Minogue et al. (2010) created a list of “observables” for each strand, and used this list to identify the use of the strands. Minogue et al. (2010) found that the teachers engaged their students in science tasks that factor in the development of the four strands of science proficiencies but that “the nature, duration, and distribution (across the four strands) of these activities varied” (p.579). These authors were surprised that there were no clear developmental trends and that there was no apparent connection between the teachers’ years of experience and/or educational background and their engagement with the strands or notebook use. Their analysis of ways the strands were evident in the data provides useful information to the field and to educators as this work progresses. However, this table has methodological implications that are discussed further in Chapter Three.

Clark, Nelson, Sengupta and D'Angelo (2009) looked for evidence of the strands in computer games and simulations developed to teach science. They found that Strands 1 and 2 were evident in many games with goals to develop conceptual understanding and generate and evaluate scientific evidence in unison. Strand 3, which focuses on the nature and development of scientific knowledge, was evident in many digital games with virtual contexts because students are enabled to "learn and practice authentic inquiry skills collaboratively" (p.45). Strand 4 was evident in the highly motivational aspect of computer games, especially as an alternative to classroom-based instruction. The authors also claim "multi-player virtual environments can support and promote authentic scientific practices and use of science-centered discourse" (p.45).

Roth et al. (2009) noted that there is a "new and novel nuance established in the strands" (p. 24). This nuance is that the strands are interrelated. They stated that this interrelatedness puts forth the idea that aspects of both practice and content should be simultaneously present in the minds of the learners as they learn science. "Not only should a particular classroom activity be linked to a particular science content idea, but that in addition the relationships among particular aspects of science practice should be explored" (p. 24). These authors also present arguments for developing core concepts of curriculum over the years of instruction. Learning progressions are a way to provide rationality and consistency in the instructional sequence over the K-8 experience. The authors provide this example:

> If ultimately children in the middle grades will be expected to explain phase changes, the kindergarten curriculum can begin to develop the tools that will allow children to explore, analyze, and explain phase changes in later years. For example, in kindergarten children might work on developing a sense of measurement – building on their sense of "felt weight" measurement to a technical measurement of mass. The kindergarten curriculum might also expose students to a host of observable phase changes, and to exploring characteristic properties, such as density, boiling point, and melting point. And while children may struggle to develop microscopic explanations in the early years there is still very good reason to support their efforts to explain what they see – not to merely "observe and describe" as is often the goal in early grades . . . But given the opportunity to develop a repertoire of skills, ideas, and interest and to pursue questions within a longer-term framework they can arrive in the middle grades with more powerful resources for learning. (p. 25).

There has been a subsequent publication dealing with the strands of scientific proficiencies in informal science settings. *Learning Science in Informal Environments: People, Places, and Pursuits* (NRC, 2009) builds on the four strand framework from *Taking Science to School* (NRC, 2007). Two strands were added to the framework for informal science learning. *Learning Science in Informal Environments* (NRC, 2009) takes the idea of excitement, interest, and motivation from Strand 4 of *Taking Science to School* (NRC, 2007) and gives it its own focus and identity as a new Strand 1. Also from Strand 4 of *Taking Science to School,* the informal science version takes the idea of identifying oneself as someone who "knows about, uses, and sometimes contributes to science" (p. 4) and emphasizes it in Strand 6.

The strands of scientific proficiency for *Learning Science in Informal Environments: People, Places, and Pursuits* (NRC, 2009) are listed below:

> Strand 1: Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.
>
> Strand 2: Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science.
>
> Strand 3: Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.
>
> Strand 4: Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.
>
> Strand 5: Participate in scientific activities and learning practices with others, using scientific language and tools.
>
> Strand 6: Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science (pp.4-5).

Strands 2-5 overlap with the strands 1-4 that were developed for science learning in school settings. Kisiel and Anderson (2010) suggest that this document provides a synthesis of research about informal science learning that is much needed. They claim, however, the limited scope of the volume does not allow for attention to assumptions about the cultural and historical contexts of informal science that need consideration.

Learning Science in Informal Environments (NRC, 2009) is even more recent than *Taking Science to School* (NRC, 2007) and there is limited related research based on this modified strand framework. Incorporating ideas and aspects from informal science education in an undergraduate science methods course, Reidinger, Marbach-Ad, McGinnis, Hestness, and Pease (2010) found that prospective teachers were able to articulate ways in which they could use informal science in their classrooms. Katz, McGinnis, Hestness, Reidinger, Marbach-Ad, Dai and Pease (2010a, b) investigated how teacher candidates in an informal science internship program during their formal science teacher preparation program developed professional identity. Their findings include learning that the teacher candidates' participation in the informal science program encouraged their implementing reform-based science strategies and had a positive influence on the teacher candidates' development of professional identity.

Summary

The word *vision* has been used in many different contexts. I chose it to use in this study because of its dynamic connotation. Vision is what we hope to achieve, what we think might be possible, a goal, something to reach for. The word *vision* acknowledges that we are here now in the present, but looking toward the future, in this case, the future of science teaching and learning.

In studies by instructors reflecting upon their own practices, the visions generated are part of an on-going process that researchers participate in to better understand their own teaching with the intention of improving practice. When shared with others who are also studying their own practice, there is potential to build a shared vision that may be beneficial to all.

Visions of science learning and teaching promoted in science teaching methods courses have emphasized the importance of reflection, in thinking about how and why one is learning, or teaching, as well as what. Field experiences provide settings within which prospective teachers can try out their evolving visions, particularly ideas they may have for engaging diverse learners, using technology, and/or integrating teaching science with mathematics and literacy learning.

Methods courses may be the only place where prospective teachers experience reform-based practices and therefore begin to refine their visions of science learning and teaching. The culture of schools where they are placed and/or later employed can either constrain or facilitate development of deep understandings about the nature of science and about inquiry approaches to learning and teaching.

Recent reform documents such as *Taking Science to School* (NRC, 2007), *Ready, Set, Science* (NRC, 2008), and *Learning Science in Informal Environments,* (NRC, 2009), share a vision of how science learning and teaching might occur. These documents articulate this vision in terms intertwined strands of science proficiencies.

The following research questions articulate an investigation of four aspects of visions of science learning and teaching:

- What educational and professional experiences influenced my visions of science learning and teaching as the instructor?
- What visions of science learning and teaching were promoted in the participants' science methods course?
- What visions of science learning and teaching do newly qualified teachers bring with them after they graduate from a teacher preparation program?
- How do these visions compare with those advocated by reform documents?

In the next chapter, I describe the methods of interpretation that were employed in an effort to understand each of these questions.

CHAPTER THREE

Overview of Practitioner Research

This is a practitioner research study (Zeichner & Noffke, 2001) in which I reflected upon the personal, educational, and professional experiences that influenced my own visions of learning and teaching science. I also examined the visions of science promoted during a science teaching methods course for which I was the instructor. In addition, I interpreted the visions of science learning that the newly qualified teachers expressed and ways those visions aligned with current reform efforts.

Practitioner research, self-study and teacher research in science contexts are considered to be in their infancy in terms of research recognized by the academic world (Bullough & Pinnegar, 2001; Roth, 2007; Zeichner & Noffke, 2001). University research values knowledge because it is knowledge but teacher research is usually conducted to improve practice, and unlike university research, which traditionally values objective knowledge, teacher research is always subjective (Abell 2005). There is some skepticism that still exists in the field about considering teacher research as real research, research with the capital R (Abell, 1995; Cochran-Smith and Lytle, 1999; Huberman, 1996).

Abell (2005) describes the need for science teacher research because it is important for "the science education research community. We have too little evidence about what works in classrooms, K-20. However, I do not agree with those who claim that randomized controlled trials are the answer" (p. 294). Teacher research then is a way to provide that evidence. This study of the methods course provides one such view, to be taken into consideration with the views of others. One example, in a very specific context, over the course of one semester, is not large scale or generalizable, but documents reform-based practices implemented in a version of a science teaching methods course.

The aim of self-study research as described by Bullough & Pinnegar (2001) is to "provoke, challenge, and illuminate rather than confirm and settle" (p.20). Cochran-Smith & Lytle, (1999) have a similar idea, "teacher research is associated more with uncertainty than with certainty, more with posing problems and dilemmas than with solving them, and with the recognition that inquiry both stems from and generates questions" (p.20). I would agree with both these statements; the more I think about the course, and the data, the more questions are raised. Also, the more desire I have to teach another course, possibly improving upon this one, and making note of the differences. I have questioned a lot of the decisions I made in that course since the writing of this study began.

Many have pondered ways to conduct teacher research that are considered rigorous and can contribute to the field. Cochran-Smith and Lytle (1999) describe teacher research as needing to be a "systematic and intentional inquiry" (p. 7). Abell (2005) adds to this by asking teacher researchers to study their teaching with the "same passion and vigor as a scientist" (p.293). She continues by stressing the importance of attention to evidence, and to historical perspective, and states that only through this rigorous approach can teacher researchers show how they are "building their scholarship of teaching" (p.294). Bullough and Pinnegar (2001) describe self-study as inviting the reader into the research process to ask questions and to carefully examine the work.

There are risks involved in this kind of research. Samaras (1998) describes self-study as "a disrobing…where one is immediately exposed to public view" (p.55). This is a description of the risk accepted by teacher researchers who take the necessary step of making their findings public and open to others' critique. This is a necessary risk, I might add, if the goal of the research is to improve teaching and improve the learning not only of those in a teaching methods course but in school classrooms throughout the country.

Teacher research has many uses. Roth (2007) finds that teacher research/and teacher educator research studies can give clear perceptions of how science education research and reform is making its way into classrooms, how teachers view these efforts, and what difficulties may be found in the implementation of the findings or if these are being implemented. Abell & Rogers (2008) suggest that college science instructors need to learn about successful improvements and innovations in undergraduate science instruction so that they can envision inquiry-based teaching and learning. Teacher research is one way to provide those examples to share. As Roth (2007) explains teacher research is not typically useful for making quantitative assertions or for generalizing about issues related to student learning or teaching strategies; rather teacher research gives opportunities to discover possibilities and difficulties in many areas of teaching and learning. Teacher research provides an insider view that is often not seen or obvious to those on the outside looking in. As Zeichner and Noffke (2001) state, "Teachers offer special insights into the knowledge-production process that those studying someone else's teaching are unable to provide" (2001, p. 299).

Teacher research is often questioned in regard to its quality. It is often not regarded as equal to academic research because of issues related to validity, reliability, evidence, claims or generalizability. Zeichner and Noffke (2001) nominate the term *trustworthiness* as a replacement for *validity*, as *trustworthiness* "better captures the need for practitioner research to justify its claims to know in terms of the relationships among knowers and knowledges" (pp. 314-315).

Abell discusses the idea of replicable knowledge in relation to teacher research. Teacher research is highly contextual. She explains that "the studies take place in particular settings with particular players. The instruction and learning that occurs is a one-time only event. Replicability in the strictest sense is impossible" (p. 25). She asks a question that is important and should be considered when thinking about the purposes of teacher research, "if a university teacher researcher's main goal is improving teaching, does the study have to be replicated or published to be legitimate?" (p. 25). If the research is conducted in a systematic way, with a scientific passion and vigor, attention to the complexities and the possibilities of multiple meanings of data, collaboration with others to provide more than one perspective, with the goal of transforming the teacher researcher's understanding of teaching, of theory, or of student learning, and is open to the critique of the reader, asking the "so what" questions, then that research should be considered to have quality, trustworthiness, and to be legitimate (Abell, 2005; Bullough & Pinnegar, 2001; Cochran-Smith & Lytle, 1999; Roth, 2007).

Roth (2007) calls for evidence-based reasoning to justify claims and asks for teacher researchers to consider questions that are worthwhile and link to the work of others. I believe the questions asked in this study were worthwhile, as these related to issues of reform in science teaching and learning in a course for prospective teachers. As Abell (2005) has suggested is necessary, the study included my historical perspective, how I arrived at this particular merging of theory and practice, with attention to evidence.

Many have recommended that teacher researchers should look at data in a variety of ways in the same situation and also from multiple perspectives, collaborating with others in trying to understand the complexities of a particular situation (Bullough & Pinnegar, 2001; Cochran-Smith & Lytle, 1999; Roth, 2007). For this purpose, I interviewed participants from the course and included and interpreted a variety of work samples from many participants as well. Once the data were interpreted, the interpretations were shared with the participants to verify the accuracy of data and interpretations. The data were presented in great detail and using a variety of approaches in order to share with others a detailed view of the evidence. In the next section, I discuss the methodology that evolved as I developed interpretations of the data.

Methodology

In conducting a study of my own teaching practices and students' learning I had to make choices about ways to collect and interpret data. This section discusses the settings, participants, data sources, and interpretative approach utilized in this study. I also comment upon reflexive considerations inherent in this study.

Settings

The course that was the focus of the study took place in a southwestern university in an urban area. The class met once a week from 4:50 – 8:20 pm. The classroom was a large computer lab equipped with individual computers, a smart board, dvd/vcr player, projector and multiple screens. The tables were in three sections, each section having five rows of tables with five seats/computers at each table. The prospective teachers usually sat two or three to a table spread out throughout the classroom. When we needed to use materials such as water, or other liquids during class, there was a wide cement area outside the door where we could conduct experiments.

The interviews were held at a variety of coffee shops in the area around the university that were convenient to the participants.

Participants

In descriptions of activities in the course, the term *participants* refers to all twenty of the prospective teachers in the methods course. They were enrolled in the science methods course in a teacher education program for graduate students from other careers to earn certification and a Master's degree in two years. All had prior college degrees and all but two had degrees in areas other than education. Two had degrees in a science field. The prospective teachers ranged from their mid-twenties to early thirties. There were four males and sixteen females. As the instructor, I never asked for specific ethnic identity but visually fifteen students were white, two were Hispanic, one was Middle Eastern, one was Asian, and one was African-American.

Seven of the prospective teachers participated in interviews after they had graduated. These seven, who comprised a purposive sample, are described below. All had completed their Master's degree before participating in the interview. None had started to teach in their own classroom after graduation. Individuals are referred to as Participant #.

Participant 1 is a white male student who is currently teaching in a school district in a suburban area.

Participant 2 is a white female who had completed her undergraduate degree in education, taught one year, then went back to school to enroll in this teacher licensure and Master's program.

Participant 3 is a white female who is currently working in ministry at the university where this course was taught.

Participant 4 is a white female who has enrolled in a doctoral program in another university and is teaching at a small local college.

Participant 5 is a Mexican female who is now teaching at an urban charter school.

Participant 6 is a Mexican-American female who is currently teaching in an American school in a Central American country.

Participant 7 is a white male who is currently the math specialist in a local school district.

Sixteen agreed to let me use their four assignments, weekly reflections, and finals as data sources for this study. In the context of interpretations of these data, the term *participants* refers to these sixteen. These included Participants 1-7 and also:

Participant 8 is a white female whose status is unknown.

Participant 9 is an Asian female who had a prior degree in education.

Participant 10 is a white female who has moved to a state in the Midwest, and has not yet found employment.

Participant 11 is a white male and I have no other information about him.

Participant 12 is a Muslim female who is currently seeking a job in education.

Participant 13 is a white female, who has had a baby and is not yet teaching.

Participant 14 is a white female who is pursuing other interests.

Participant 15 is a white female who is teaching fifth grade in a local school district.

Participant 16 is a white female who moved to a southeastern state and has been teaching.

I was unable to contact the four remaining prospective teachers, one male and three female, who were similar to those who participated in the study.

In addition, participants include myself as a practitioner researcher studying my own teaching practices and students' learning. Reflections on my role as a researcher are included below in the section on *Interpretative Approach* (see page 69).

Data Sources

Data sources included my personal writings, artifacts from the course, and interviews with participants.

Personal Writings. The data sources relevant to the first research question are artifacts such as my responses as a student to assignments in my college science and education courses and writings from my presentations and publications that reflect upon my teaching practices. Publications include McGinnis and Roberts (2009), Roberts (1999, 2000, 2007); Roberts, Bove, and van Zee (2007); van Zee and Roberts (2001,2006,); and van Zee, Lay and Roberts (2003).

Course Artifacts. Data sources relevant to the second, third, and fourth research questions include the participants' responses to the assignments, reflections, multi-media final, for the course and my notes as the instructor.

Course assignments. There were four major assignments: *What is Science?, Status of Science, Interpreting Curriculum, Inquiring about Inquiry*. Each of these is described in detail in the sections where the participants' responses are interpreted.

Course reflections. The weekly reflections were often free-choice so that participants could chose to reflect on something we did in class, something they read, or something that happened in their placement. Assigned topics included: *Your own experience of learning science and how it's different in elementary classrooms today*; *What reading so far was the most meaningful or thought provoking*? *Eye openers from schools*; *your understanding of the current status/politics of science at elementary levels*; and *envisioning yourself as a science teacher.*

Multi-media final. The final involved creating a multi-media website that represented the participants' own learning in the course. This is described in detail in the section interpreting one of the participant's responses.

Instructor notes. Data sources also include my course syllabus, choices of articles to read, notes about changes I made as I went along, and my reflections. Also included are artifacts from an elementary science methods courses I had taught previously at another institution.

Semi-structured interviews. The data sources relevant to the third and fourth research question were the responses during the interviews with the participating newly qualified teachers after they had graduated and before they had begun to teach. The interview questions were designed prior to conducting the interviews; however, the conversation was very open and not confined to the planned questions. The protocol included the following questions about the participants' visions of science teaching, visions of science learning, visions of science investigations, lesson plan reflection and reflection on the methods course.

Questions about visions of science teaching:

- What are the characteristics of a good science teacher?
- Imagine that you now have a job teaching in an elementary school, and you will be responsible for teaching science, what does your classroom look like and what evidence will there be that you are a teacher of science?
- If I walked into your classroom during science instruction, what would I see?

Questions about visions of science learning:

- If you had a classroom and you were teaching science, how would you maximize student learning for your students?
- How are you going to know that your students understand, when they get it?
- How do kids learn best?
- Explain the phrase "science is a social process"

Questions about visions of science investigations:

- So let's say you are going to have kids do science investigations. How would you start?
- Imagine you have just had kids do an investigation; how do you get them to support their conclusions with evidence?
- What about discussion in science – what do you think the role of discussion is in science?
- So how do you go about making sure everyone is participating equally?

Questions about reflections on the lesson plan:

- I have a question about your lesson plan. I don't know what you remember, but I am going to let you look over your lesson plan for a minute. Thinking back to that lesson is there anything that you would change about it now?

Questions about the participants' reflections on the methods course:

- During the methods course, what attempts at best practices did you see your methods instructor modeling for science? Give examples.
- So how was the science methods course different or similar to other methods courses?
- If there was anything that I could have changed about the methods course to better prepare you for actual classroom teaching, what would it have been?

Interpretative Approach

Because interpretation of these data seemed to require multiple methods and reflect multiple perspectives, I chose to use crystallization as a methodology. Richardson (2000) describes crystallization as seeking to produce knowledge about a particular phenomenon through generating a deep and complex interpretation. She rejects the notion of triangulation, stating that this assumes there is a stationary location or object around which triangulation can occur. Rather, she argues that validity in postmodern text involves crystallization "that combines symmetry and substance with an infinite variety of shapes, substances, transmutations, multi-dimensionalities, and angles of approach" (p. 934). Janesick (2000) elaborates, "Crystallization recognizes the many facets of any given approach to the social world" and explains, "What we see when we view a crystal, for example, depends upon how we view it, how we hold it up to the light or not" (p. 392). Goodnough (2001) provides an example of crystallization in her interpretation of ways in which an elementary teacher enhanced her professional knowledge about science.

In this study I employ the concept of crystallization through using a variety of approaches to interpret many different data sources. As discussed below, assignments were evaluated for common themes with participants' comments selected to illustrate particular themes as well as for evidence of the four strands of scientific proficiency articulated in *Taking Science to School*: *Taking science to school: Learning and teaching science in grades K-8* (NRC, 2007). Activities were described in vignettes and also characterized in terms of the four strands of scientific proficiency. The reflections and final portfolio of a representative student were interpreted as a case study. Member check was used to increase the trustworthiness of the interpretations. The participant interviews were interpreted in terms of common themes and also by the strands of scientific proficiency (NRC, 2007). In my endeavor to achieve a deep and complex interpretation, I included the perspectives of the prospective teachers both throughout the course and after they had finished the coursework and student teaching, and my own as instructor, as learner and reflective practitioner. Specific ways in which the data were interpreted are described below.

Description of the historical context. I began the discussion of data with a description of my journey from an undergraduate student in an education program that promoted reform-based teaching (Gardner & Ayers, 1998; McGinnis, 2002) to an elementary and middle school teacher, trying to implement those reform practices and then to instructor of a science methods course encouraging graduate students to employ the same reform based practices.

Vignettes. The activities that I used to begin each class are presented in vignettes, briefly described events to illustrate aspects of the activities in the course (Stake, 1995). The first activity is described in Chapter 4 in some detail (pages 102-105) followed by Table 4.1 that lists each of the activities, a brief description, and the focus. This provides a brief idea of the kind of activities that took place with brief commentary on the aspects of the nature of science modeled. Vignettes for the rest of the activities are presented near the end of Chapter Five (375-390 where they are interpreted in terms of the four strands of science proficiency (NRC, 2007).

Assertions. Responses to each assignment have been interpreted in terms of common themes that are expressed as assertions, formulated by articulating patterns in the data (Stake, 2005) in Chapter 4 (pages 113-213). Student comments supporting these assertions are presented in tables. Comments illustrating the themes are drawn from these tables.

Case study. I have chosen to interpret the data from the reflections and multi-media final project by one student whom I believed was "typical" (Stake, 1995) of the students in the class. I decided to develop a case study because I wanted to describe and interpret my personal understandings as the instructor of the course (Stake, 2000). I chose this as a representative case of a broader set of cases. This case, in my interpretation, is an example of a "typical" set of reflections and final portfolio assessment. As Gerring, (2007) points out where the "selection criteria are multi-dimensional" (p. 92) as in the final portfolios, and there are multiple cases possible as there would be with examining every reflection or portfolio, it may be "useful to identify a typical case" (p. 92). To choose this case, I examined the final portfolios and ranked them according to a rubric designed for the course. I eliminated the top score and the bottom score and chose from those that were left. The majority of the finals I evaluated had the same scores. I believe that in addition to the thorough interpretation of data from assignments, activities and interviews that this case provides an authentic glimpse into the methods course from the perspective of a typical student. As a follow-up to the interpretation of this study, a copy was sent to this participant and she affirmed that the interpretation accurately represented her perspective. This case study is presented in Chapter Four (pages 221-244).

Common themes. The interviews were interpreted first by topic. I grouped the questions into five sections. These are: visions of science teaching, visions of science learning, visions of science practice, lesson plan reflections, and reflections on the methods course. I read the interviews repeatedly and looked for comments around the same topics. I took all the answers to one question, assembled them in a Word document, read through them multiple times looking for multiple comments around the same idea. An idea became a theme that I discussed with examples drawn from the comments of the participants that seemed to best exemplify the idea. Although these themes could have been reported as assertions with accompanying tables as in the interpretation of the assignments, I chose use to a more narrative approach here. I was attempting to document the experiences and perceptions of the newly qualified teachers with an 'emic' perspective (Erickson, 1986), representing the voice of the participants more directly than just listing their comments in a table.

Strand framework. After completing the above interpretations of the participants' responses in class and in the interviews, I turned to using the framework of the four science proficiencies recently presented to the science education community by the National Research Council (2007) as goals for the teaching and learning of science. For the assignments and activities, I provided a brief description of each and then gave examples of aspects that seemed to show an alignment to a particular strand. I also interpreted the interviews in terms of the participants' comments that seemed to be in alignment with the strands as well. Comments that seemed to illustrate a particular strand were gathered and described by participant. It should be noted that the strands are not exclusive and there is not only overlap in their descriptions but complexities of interpretation as well.

I chose not to make a checklist of criteria as related to each strand, because I am concerned that this reform document might be reduced to a checklist, instead of being seen in its entirety, which includes not only the strands but attention to how young children learn, and the importance of building science teaching and learning around core concepts. In contrast, Minogue et al. (2010) created a table to identify ways in which the strands could be observed. Clearly, much consideration was given to creation of the table, perhaps as a way to make qualitative data, quantitative. The entries in a notebook where instances of the strands were observed, according to the table, were termed *meaningful events* and then these were counted. While I greatly appreciate the focus on validity through the use of a mixed methods analysis of data, as a former curriculum specialist I have found that often in the application of research and standards in education settings, the thick, rich, complex ideas that have been put forth tend to get reduced into checklists. The checklists then get used to tell administrators or school districts that said research has been incorporated into curriculum and instruction but the complex understanding that might be nurtured through consideration of the original document is often lost. Therefore, I have modeled in this dissertation the more holistic way in which I would invite science educators to use the strands of science proficiency (NRC, 2007) in professional development settings.

Reflexive Considerations

I believe there is a significant degree of reflexive consideration in this research project. Gergen & Gergen (2003) describe those who engage in reflexive practice as researchers who seek “ways of demonstrating to their audiences their historical and geographic situatedness, their personal investments in the research and the various biases they bring to their work” (p. 579). In my role as researcher, there are no assumptions made to a singular discoverable truth, recognizing the bias of my own understandings and interpretations. I am aware that the knowledge generated from this project is situated in a specific situation, is constructed through my lens and the lens’ of the participants, and that there are multiple ways of understanding the data. I also understand that as instructor of the course, although the course was completed, there are still issues of power relations. My age, and my status as one who could be asked to write recommendations for the participants, complicate the interactions and the relationships.

CHAPTER FOUR

Interpretation of Course Artifacts

This chapter presents and interprets data that provide evidence of the visions of the instructor and prospective teachers based upon my own reflections and the participants' course assignments, reflections, and final.

Research Question 1:

What educational and professional experiences influenced the instructor's visions of science learning and teaching?

Influence of Prior Experiences

Many experiences influenced how I view science learning and teaching. These include learning through inquiry in an undergraduate physics course, participating in the Maryland Collaborative for Teacher Preparation, reflecting on learning and teaching during undergraduate and graduate science teaching methods courses, becoming a teacher researcher as a member of the Science Inquiry Group, maintaining my connections to the university as a beginning teacher, teaching in diverse Title 1 schools, serving as the county elementary science specialist, participating in the Carnegie Academy for the Scholarship of Teaching and Learning, serving as the state elementary science specialist, teaching science methods courses at the University of Maryland, and participating as a member of a National Research Council committee.

Undergraduate physics course. In *Learning to Teach Science Through Inquiry: A New Teacher's Story* (Roberts, 2000), I wrote about experiences in an undergraduate physics course that had been designed to engage prospective teachers in developing powerful ideas in physical science (Ukens, Hein, Johnson, & Layman, 2004).

> My first experience in learning through inquiry was in an undergraduate physics course for future elementary and middle school teachers...In this class, I learned a lot about physics, but I also learned that it can be exciting to learn! I vowed during this class that this was the method of teaching I would try to model in my future classroom (p. 121).

In *Learning About Motion: Fun for All!* (Roberts, 2007), I elaborated on this experience

> (The professor) knew just how much information to give, which questions to ask, and when to let us struggle. He modeled what he taught…
>
> (The professor) designed the physics course around microcomputer-based laboratories (MBL)…the student uses a computer with some sort of probe attached to it so the computer draws a graph as the student uses the probe…
>
> On the first day of class, (the professor) had the computers ready to go. He told us all we needed to do was for one person to click on start and for the other person to stand about one meter away from the little box (a motion detector) and see what happened. We were afraid to be very creative. We did not already know what was expected. (The professor) walked around the room observing what we were doing, asking us to tell him about what we were observing and doing and why. We were

> watching the graph, which was a real tool in trying to understand what we were doing.
>
> When we came to a stopping point in the activity, (the professor) told us that our best resource in the room was our lab partner first, and then other members of the class. He asked for one comment from each of us. This was a very unnerving experience. We had to make a statement about what we were doing, and others were encouraged to comment on what we had said. As the class progressed, we all became very accustomed to doing this, and the questioning and arguing that ensued was very valuable in our continued learning. (p. 125-126)

The teaching and learning that occurred in that physics class became my ideal for how science should be taught and learned. The professor in that course challenged each of us, pushed each of us and motivated students to think and act like scientists. The questioning, hands-on experiences, critical thinking, and then more questioning was the most rigorous and the most exhilarating work and learning I had done in science. My goal for the methods course (and my struggle today) was to re-create the same kind of experience for the prospective teachers.

The factors from that classroom experience that had the greatest impact on me, were:

- The professor made the students in that class feel capable. This was not done through insincere praise, or inflated grades, but through the ways in which he interacted with the students.

- He first asked us if we believed that we were scientists, and when no one really gave a firm response, he said, " I'll answer that question for you. You are scientists. You are carrying out scientific investigations and employing scientific practices. You are all scientists." That was followed again with actions and behaviors that clearly showed he believed we were scientists.
- Not only were the classroom expectations for our learning high, but also they were clearly expressed. We were going to be successful, and we were. We were pushed and challenged, and we were always successful. Sometimes it may have taken a little longer to achieve that success than others, but we were always successful. The professor demonstrated that he valued us as individuals, as learners, and as future fellow teachers of science.
- He engaged us in reflecting on our learning, usually after a class discussion, by recording on the board what we believed we understood at the end of the class, as well as any questions we had. At the beginning of each class, this list was reviewed for changes in understanding and discussion. He also often asked us in class, "Is this something you might do in an elementary classroom? How might that look?" There was a way to connect what we were doing with what and how we might teach a particular concept.

None of these factors were written on the board or listed in the syllabus, but through the demeanor and encouragement and the dedication of this professor to the success of each student, it may well have been engraved on the wall. I would be remiss if I did not add that the teaching methodology of the course contributed to the factors listed above as well. This was a course designed around reform-based principles, and was taught in an inquiry – based way. Some of these very tenets, student – focused learning, creating a community of learners who are engaged in doing science in ways that are authentic, are inherent in teaching by inquiry; however, they do not always come across as clearly as they did with this instructor.

Maryland Collaborative for Teacher Preparation. The physics course was part of a new program, the Maryland Collaborative for Teacher Preparation. This program was designed to encourage students to prepare to become elementary science and mathematics specialists (Gardner & Ayres, 1998; Bell & Denniston, 2002). The professors involved made fundamental changes in mathematics, science, and methods courses in which they shifted to a more hands-on interactive, student-centered approach to teaching. In contrast to the traditional lecture format, these faculty members employed cooperative learning strategies and created environments in which students explored mathematics and science questions and discovered the answers themselves with guidance from the faculty (p. 10). There was a seminar class where students and professors got together and talked about ways of teaching and learning in science and math. There were also field experiences where the professors led us through a nature trail as if we were students. As in the physics course, these experiences confirmed my belief that children would learn best with a teacher who implemented these reform strategies.

Undergraduate science methods course. There were others who were influential in this journey. My undergraduate science methods professor also modeled an inquiry-based stance in teaching. For those students in the class who had not experienced inquiry-based learning as I had, this methodology was somewhat of a surprise. For me, it was affirming my prior experiences. She also had an emphasis on reflection. Each week we had to reflect on a particular science topic or activity, usually related to our placement classrooms. This emphasis on reflection has been a part of my teaching since that course.

In thinking through my personal experiences as a methods student, I identified several experiences that were profound in my personal learning. The first was reflection. In both science teaching methods courses that I had experienced as a student, reflection was an expectation and part of the class work. Taking the time to think about science learning and teaching, both my own learning and teaching and my students' learning was powerful to me. Sometimes the understanding became much clearer when the thought was committed to paper. More often than not, many questions emerged, which required further thinking or observing in the classroom. My undergraduate methods course introduced a further way to use reflection, which was called teacher research (van Zee, 1998; van Zee & Roberts, 2001; van Zee, Lay & Roberts, 2003). The role of teacher as researcher was one I assumed wholeheartedly, and one that I believe has kept me in the education field (Roberts, 1999, 2000, 2007).

I remembered quite vividly the challenges of the methods course semester, the challenges to juggle all assignments, the hours of internship, and the requirements of the school and the classroom, and was determined to try to make my assignments meaningful AND reasonable.

Graduate science teaching methods course. I also had a graduate level method course with a professor who was part of the same program of science teaching reform.

He had similar attitudes and methodologies to my physics instructor as well. He also encouraged inquiry-based teaching and learning. With deep interests in diversity and socio-cultural issues, his research encompassed a broad view of science in relation to society (McGinnis, 2000, 2003; McGinnis & Simmons, 1999) and being reflexive. I remember one of the assignments being to create a syllabus for a science methods course, so of course, I looked for my work. When I found it, I had to chuckle at the comments by the professor, which were something to the effect of - you might want to think about how much is possible for a prospective teacher taking multiple methods courses, and make choices in your requirements.

Science Inquiry Group. These courses at the university were the foundation of my philosophy for teaching and learning, in general, and science specifically. As a new teacher, I was able to maintain my connection to some of the professors from the university program. One of the ways I did that was by participating in the Science Inquiry Group (known as SING). Several recent graduates and one of the professors got together to form a teacher research group (van Zee, 1998a). The first study I did was with first graders and monthly nature walks to show change over time (Roberts, 2000). Another study involved first graders and their parents observing the moon (Roberts, 1999).

Connections to the university as a beginning teacher. Another way I was able to maintain connections to some of the professors at the university, was to ask permission to bring my first graders to the physics class to use the motion detectors and interact with the current group of prospective teachers. This was a valuable experience for all, and one that was continued for the next two years. A series of studies followed that involved first graders, second graders, fourth graders, eighth graders, methods students, and practicing teachers in learning about real-time graphs made with motion detectors connected to computers (Roberts, 2007).

As a student in the MCTP program, my physics class, my science methods class, and the MCTP seminars had all been hands-on, student focused, and facilitated by experts in the field. We were responsible for our learning, but were supported by our professors. The support usually came in the way of well-directed questions to lead us in the right direction. As a beginning classroom teacher I tried to emulate the same methodology.

Teacher in diverse Title 1 schools. My experience includes teaching science at the elementary and middle school levels in Title I schools in Maryland and Arizona. In Maryland, I taught in schools with high African American and Latino populations in areas of high poverty. In Arizona, I taught in diverse settings with high Latino and Native American populations. My ability to speak Spanish fluently has helped me a great deal, especially in working with the parents and the communities in which I taught. In an article published by *Science and Children,* entitled *The Sky's the Limit: Parents and Their First Grade Students Look at the Sky*, I documented one such experience.

As a first year teacher, I looked for innovative and creative ways to engage students in learning science. Because of the excitement I felt in the undergraduate physics course for prospective teachers, I asked the professor if I could bring my first grade students to the university to work with the motion detectors. He agreed, as it would be a good opportunity for his current class to interact with elementary students. We were all amazed at how quickly the first grade students were able to move in front of the detectors to make graphs on the computer screen go up, down or stay straight, however they wanted. In the closing discussion, again they amazed all the adults in the room with the ease with which they were able to talk about what the lines on the graphs meant. As we left the university, the first graders were pointing out the dorms and saying, “When I come to this college, I’m going to stay there!” This excitement for learning is what I have tried to emulate in my elementary science teaching methods course.

County elementary science specialist. When I became a science curriculum specialist for the county and was responsible for professional development for the science liaison teachers from each elementary school, I continued to employ the same methodology, to which most teachers seemed to have a positive response. For each of our half day meetings we would spend the first portion of the meeting time conducting an investigation, and then reflect on that investigation and talk about how that would translate into classroom practice.

One of the responsibilities I had had as the science specialist was to develop and implement a summer institute for elementary teachers with goals similar to those of the program I was a part of as an undergraduate: a more hands-on interactive, student-centered approach to teaching, in contrast to the traditional lecture format. The teachers in the summer institute were given opportunities to experience and then expected to employ inquiry-based learning strategies and create environments in which their students explored science questions and discovered the answers themselves with guidance as needed. The strong foundation that I had received as a college student gave me the resources I needed to prepare and execute such a program for teachers.

An additional piece of this grant program was to assist the teachers in preparing their students to attend and present their own science investigations to their peers from around the county at a “Kids Inquiry Conference.” (http://www.esiponline.org/kic/about.html). This was modeled after the Elementary Science Inquiry Project of Wendy Saul, Charles Pearce and others from that group. This group of teachers had an opportunity to visit the ESIP Inquiry conference first, and see firsthand how powerful the conference was for the students, and how capable the elementary students were in their roles as presenters, and audience members. The teachers who were a part of the summer institute were also guided to document their practices, write up their findings and present their reflections on the experiences in their classrooms at the National Science Teacher Associations annual meeting.

Carnegie Academy for the Scholarship of Teaching and Learning. The opportunity to be a member of the Carnegie Academy for the Scholarship of Teaching and Learning was life-changing. Lee Shulman (2004) has had a profound effect on my practices. His ideas of pedagogical content knowledge affirmed and deepened my understanding of science teaching and learning (Shulman, 1999). The interactions with the other Carnegie scholars and the sharing of our collective practices and research was both a humbling and motivating experience that continues to inform my practice as a teacher, as a teacher researcher, and as someone who facilitates professional development. One thing I took from Carnegie that I frequently use was the KEEP TOOLkit free software for multi-media representation of teacher research on the Internet. I have used that in professional development, in my methods courses, and with elementary students in my classroom (van Zee & Roberts, 2006).

State elementary science specialist. As K-8 science specialist for the state of Maryland, I collaborated with assessment experts and science colleagues to begin development of the Maryland Science Assessment and it's field-testing. In addition to assisting the team that developed the MDK-12 Toolkit for teachers, I organized the Governor's Academy professional development summer program for high school biology teachers and collaborated in development of the materials for that program. These experiences gave me a deeper understanding and broader perspective for what is involved in curriculum design and assessment, which enriched my design of the methods course.

National Research Council committee. Another wonderful opportunity I had was to be part of a committee for the National Research Council that developed the book, *Taking Science to School: Learning and teaching science in grades K-8* (2007). This committee worked for more than a year developing a new framework for understanding science teaching and learning. One of my university professors invited me to collaborate with him in providing examples of the four strands of scientific proficiencies articulated by this committee (McGinnis & Roberts, 2009).

Elementary science methods course instructor. In teaching elementary science methods courses at the University of Maryland (2004, 2005), I emphasized reform-based practices. My courses addressed issues of equity in classrooms and schools through readings and video case studies. The prospective teachers were often placed in schools that had diverse student populations. Discussions about issues they observed in their field placements were frequent. My assignments included exploring the status of science in their schools and planning and teaching a science lesson there.

Vision guiding design of the course. These experiences were the inspiration for my decisions as I designed the methods course that is the focus of this study. My vision of a science classroom is a classroom where the students' are encouraged, challenged, and supported as they engage in authentic and relevant science activities. The expectation for a community of learners, (of which the instructor is one) that is risk free – students have the responsibility to share their ideas, and to hear others without being criticized or humiliated - is essential. The students need to be engaged, to be held accountable, and to feel capable. The instructor needs to be a person who is perceptive and takes the time to know his/her students as individuals, not just by percentages in the grade book. The instructor should plan assignments and activities with the ultimate goal of teaching these students in ways in which they will teach others, but not in a way that makes them feel as if they are elementary students yet again. Instead my goal is to teach in a way that provides the opportunity for them to experience, reflect upon, and practice implementing the practices and investigations of scientists, the pedagogy that should shape their classroom instruction, and ideas gleaned from course readings that will hopefully lead to their future students' success in science.

Research Question 2:

What visions of science learning and teaching were promoted in the participants' science teaching methods course?

Initial Design of a Science Teaching Methods Course

I taught an elementary science teaching methods course twice at a mid-Atlantic state university before being asked to teach a similar course at a southwestern university.

Below I discuss the initial questions and prior experiences that influenced development of my syllabus for the methods course that is the focus of this study.

Initial Questions

When I was first asked to teach an elementary science teaching methods class for graduate students at a mid-Atlantic state university, my initial questions were many, the first of which being, where do I start? So I asked several trusted professors for a copy of their syllabi, and looked at my own work from an undergraduate and a graduate methods course in science. What parts of the course work I went through made sense to me as a teacher and as a student?

In thinking about myself as a teacher, there were questions about my own practice. What was the content knowledge necessary to be a good teacher of science at the elementary level, and what was the pedagogical content knowledge that was necessary? How do I help prospective teachers connect to the elementary students' curiosities and enhance their science learning? How do I connect and explore the curiosities of my methods students? How do I raise the awareness for prospective teachers of the current state of science in elementary schools today? I wanted them to be able to encourage their students to create, question, explore, analyze and find answers to science questions - but how? This was a one-semester course, and one of five methods courses the students were involved in. Selecting activities and assignments that would best facilitate their learning but not overwhelm them was a challenge.

The first methods course I taught was in 2003, shortly after the impact of No Child Left Behind was beginning to hit school systems hard. The initial reaction in the county in which I worked, and in many other school districts across the nation, was to stop teaching science and social studies in order to focus upon what was being tested, math and reading. This was similar to what was reported by Smolleck, (2007). Another question I had to face was how to help my methods students see the value and importance of teaching science, despite resistance from schools or outright removal of the subject from the academic day. In other words, there was a need for them to become agents of change as new teachers in order for their students to get any science experience in the classroom. At this time, I was working at the county office as the K-5 science specialist, so this was part of my daily problem as well. Fortunately, through conferences and other venues, I had become familiar with the work of Charlie Pearce (1999), and a group that he worked with under the direction of Wendy Saul, called the Elementary Science Integration Project (Saul, Reardon, & Pearce, 2002). Charlie and I had developed some professional development opportunities for teachers in the district that gave me some experiences of teacher learning to reflect on, as well as some strong classroom teachers to have as teacher leaders. As a graduate student at the university, I interacted with some wonderful professors who listened to my questions, made suggestions and shared resources and experiences as well.

Creation of the Syllabus for My First Science Teaching Methods Course

With all of these thoughts, and syllabi and experiences, I went to work creating my first official science teaching methods course syllabus. I started by thinking about all of these outcomes, and about the specific district science curriculum for the teachers with whom I would be working. I began to review books that I felt the methods students would benefit from as course texts, possibly even keep to use as resources in their classrooms, and not immediately sell back to the bookstore once the semester was over.

The books I chose were: *Doing What Scientists Do: Children Learn to Investigate Their World* by Ellen Doris (1991), *Teaching Science in Elementary and Middle School Classrooms; A Project-Based Approach* by Joseph Krajcik, Charlene Czerniak, and Carl Berger (2003), *Nurturing Inquiry, Real Science for the Elementary Classroom* by Charles Pearce (1999) and *Science Workshop: Reading, Writing, and Thinking Like a Scientist* by Wendy Saul (2002).

I chose the Doris book because it showed real life examples from a classroom in a way that could made the readers feel they were was capable of implementing science in a similar way. The Krajcik et al. book had a wonderful way of looking at science learning through a "driving question." Driving questions were used to focus science instruction on a given topic. This book had many wonderful science examples and scenarios from classrooms, with many thought provoking questions in each section. The Pearce book was a thoughtful collection of vignettes, examples and resources for the inquiry classroom with a focus on the integration of literacy in the science classroom. It was a window into Mr. Pearce's classroom, and included copies of documents he used to motivate, organize, inspire and assess his students. Wendy Saul's book was chosen for it's authentic take on literacy in a science classroom. She had collaborated with teachers who gave classroom examples of both reading and writing used to enhance science learning, and many assessment resources.

My next question to ponder was how to incorporate authentic science teaching and learning into the methods class. How would I facilitate the kinds of experiences I had had as a prospective teacher in my physics class? My decision was to begin each class with a science investigation and to teach it as I would for students. One anticipated issue was that the students would try to act the ages of elementary students as they did the activity, but fortunately, they were so engaged that never happened.

Reflection was a weekly requirement through journaling. There also were four major assignments. The final involved using free software (KeepTOOLkit) by the Carnegie Foundation for the Advancement of Teaching) to build a website representing what they had learned in the course. These are discussed below as they formed the basis for the assignments and final in the science teaching methods course that is the focus of this study.

Implementation of the Science Teaching Methods Course in the Southwest

The following sections present constraints and challenges I encountered in teaching the methods course at the southwestern university. After providing an overview of the course, I then describe the components of the course: activities, assignments, reflections and final. In each section I also interpret student responses.

Constraints

I kept the same basic ideas when I was invited to teach a graduate science teaching methods course at the southwestern university. However, I was somewhat confined by the structures I was required to follow. One of those structures was a required textbook, not of my choosing, that was to be the only textbook. Another structure was the use of some case study videos. Neither the book, nor the videos were bad, and the need to adjust, gave me an opportunity to think about the course and the needs of the methods students in this state. I decided to keep my same assignments, as they correlated to the professional teaching standards that were required by the state.

Because I was hired shortly before the course started, I had no input into the selection of the textbook. I also asked a colleague who was teaching the same course but on a different night to share her syllabus with me. When I looked at her syllabus, however, I chose not to use it. I perceived her assignments in general to be more restrictive and less useful to the students in the future. Some of the activities seemed to me more like busy work rather than an intellectually useful undertaking.

Science education today, on many fronts, is struggling to maintain its existence in elementary schools around the country as a result of high stakes testing (Smolleck, 2007). It seems the situation is exacerbated in this state because of the current focus on language and literacy instruction for English Language Learner (ELL) students as a result of litigation (Flores vs. Arizona) claiming that the state is failing to adequately fund programs for English Language Learners. I knew that many of the partner schools were Title l schools and have a high ELL population. The state, as a result of that lawsuit, chose to incorporate the Sheltered Instruction Observation Protocol (SIOP) model for English language learners (ELL). (The SIOP Model was developed by researchers at California State University, Long Beach (Jana Echevarria and Mary Ellen Vogt), and the Center for Applied Linguistics (Deborah J. Short) under the auspices of the Center for Research on Education, Diversity & Excellence (CREDE), a national research center funded by the U.S. Department of Education from 1996 through 2003). For students in our state, this translated to all ELL learners mandated to receive four hours of literacy instruction in English every day. That is a huge chunk of a six-hour day, and again science is not the most emphasized content area. The need to engage and convince the prospective teachers to create opportunities for their students to learn science and to become agents of change was going to be even more important in this course.

The principles as listed by the university for this course were: Awareness of Self and Students, Active Learning and Inquiry, and Practical Application of Theory. The Essential Question listed by the university for the course was: What factors are involved in an inquiry-based science education in the elementary classroom? The following clarifying questions and statements further refined this question:

- Experiences and attitudes toward K-8 science education, how can a teacher's beliefs and perceptions affect their science instruction?
- Teaching and learning science with inquiry-based methods
- What is, and isn't, science and the nature of science?
- Relevant science instruction, how do we provide meaningful science experiences for students?
- How educational standards, learning principles and content knowledge affect instructional planning?

These focus questions provided a reasonable framework for the course and fit well with what I had previously designed.

Challenges

There were many challenges to teaching this course. As a new instructor, even after attending an orientation and meeting the other instructor for this course, I was still left without some important basic information, such as how to get into the room and what technology and science equipment was available. In addition to complexities with the physical setting, I encountered some resistance from students who did not understand my approach to instruction nor initially appreciate my requirement that they actually teach a science lesson in their placement classrooms, when this was not required by other instructors. Facilitating discussions was also a challenge with participants accustomed to listening to lectures and reciting ‘right’ answers.

As a full time teacher, I had to rush from the end of my school day to begin the weekly university course session. When I arrived 30 minutes early for my first class, the door of the room the class was to be in was locked. I ran back to the teaching program office and no one was there. I went back to the building and room – still locked. I rushed into an open office one floor up, and the secretary there directed me to another office two floors up. I ran up there only to find the door locked. I saw someone inside, so I knocked and she came to the door. She gave me a master key and instructed me to go down, unlock the door and come back immediately. After running around for twenty minutes, I finally got the door open. There was a student sitting outside the class waiting for the door to be open, so I asked her if she would into the classroom while I brought the key back. She agreed and off I went. Now I felt totally anxious because I had not had the time I needed to prepare.

The physical classroom was not the best either. There were some tables, some beanbag chairs, and several floor-to-ceiling bookshelves creating a little hallway near the entrance of the room. When I spoke to the other instructor, she laughed and said, “Welcome to science methods course teaching! She also told me that there was some equipment in a locked closet in that room that I could use if I asked in advance, including a projector and DVD player if I planned to show students any video, or other presentations. Then she told me she would not use that room because of its condition, and that I should email a certain person and ask for a room change. I did not want to do that, but wanted to use the equipment, so I emailed the faculty member in charge of that issue. She told me I was not to touch that equipment as it was for graduate students who were TA's to use and only for them. So I emailed the other person about a room change.

Before the second class, our room was changed. We were put into a computer lab. The room was beautiful with state of the art equipment, smart boards, projectors, VCR player, DVD player, multiple screens and both Mac and PC computers to use in the front. The students sat at tables that were complete with computers as well. The computers were folded down into the table, so that the table could actually be used as a writing surface.

There were several problems with this, however. The first thing the students did when they got to the room was open up the laptops that were folded away and start checking email, surfing the web, looking at their Facebook accounts, etc. I told them they could keep the computers up until class started, and then the computers needed to go back down. This rarely worked without my having to remind people that the computers had to go back down. And there were two students who sat at the back of the room who seemed to always get their computers back up during class, often commenting that they were verifying or researching something we were talking about.

Another issue with this was that doing science experiments on top of tables that had computers in them was a little scary! I was worried that some liquid or other material would go down the openings into the computers. So, sometimes, we worked on the floor (which was carpeted and not much better), and sometimes we went right outside of the classroom to do our activities on the sidewalk.

Yet another challenge for me initially was the way in which I taught. I did not lecture and relied on the students to dialogue with me and with each other. They told me they were so used to be in classes they called “sit and get” that the idea of an interactive class where they were expected to participate, and the instructor asked more questions than giving answers, was frustrating. One young man asked me after the second class when we were going to get to the content of the course. His impression was that I had not really started “teaching” yet.

Two of the students had undergraduate degrees in education and were not required to intern during this course. Two or three other students had placements where they were not permitted to “teach a science lesson,” so for these students I had to find places where they could complete the activities required by the assignments. The students told me that none of their other methods classes required or even suggested that they teach in their placement classrooms. Some of them reported in their assignments or reflections that during my course was the first time they had been required to teach. I invited several of them to my own fifth grade classroom, but my school was about 40 minutes from the campus. Some of the students felt this was too far, and so I had to find other places for them to go to complete their assignments. These were assignments that I was requiring because I felt it was important for the prospective teachers to go through planning, implementing and reflecting on a real science learning and teaching experience with children. The other science instructor and the teaching assistants who taught the undergraduate classes did not require this.

Always a challenge in teaching at any level is developing a relationship with the students, and creating a classroom environment where they feel comfortable, but

challenged, can take risks without fear of humiliation, and are motivated to participate. There was one student in particular in the class who I felt was not enjoying the class. She always had other work out (or the computer up) and frequently was doing other work during the class. When we got in groups to do experiments, she was always the one who somehow managed to stay in her seat. Her answers, and her class work and reflections were of pretty high quality, so I was uncomfortable about calling her out on it. I often wondered if the course was not rigorous enough for her; perhaps, I needed to find a way to challenge her more. One evening, I was there very early, and she came in five minutes after me. The first comment out of her mouth was, "You know this is our favorite class, don't you? Even though there is a lot of work, you actually treat us as if we are breathing, thinking adults. I love this class, I actually am learning things in here."
After picking my jaw up off the floor, I asked her if she were challenged enough in the class because I noticed that she was always doing other things during the class. She explained, "Oh, I am unofficially ADHD, and I have to keep busy." I would have never guessed any of that!

One young man, who was very dismissive during the first class about our first experiment with UV beads, was also sometimes dismissive during class discussions. It seemed, at times, that he was not willing to listen to others' points of view, because he was right, or because his opinion was different. This is also hard for a teacher to orchestrate especially if the goal is to make everyone feel valued. It is also necessary for students to be open to change and to challenges to their ideas in an inquiry-based classroom. By the end of the course, his demeanor had changed. I believe that he may have been uncomfortable with the methodology of the instruction, maybe challenged by the idea that there may be more than one “right” answer. None of these issues ever surfaced in his assignments; however, he seemed to “get it,” at least when he reflected on the class in his assignments and reflections.

As most teachers, I care deeply about the learning that takes place in my classrooms. Creating some level of challenge and cognitive dissonance can be beneficial, but there is a fine line between challenge and frustration. Creating that environment that promotes risk taking, and motivates students to stay engaged is a tenuous balance and sometimes changes from week to week. Knowing the students well enough to individualize instruction at times, to consent to let someone to step back, in order to move forward, and at the same time maintain high but achievable expectations is a constant mental struggle.

There were two students who came to this class with a background in a science. One had a degree in kinesthesiology, and the second with a degree in clinical pharmacology. Having them engage in some science activities that did not always start and end in the same way that they had been trained, was initially very difficult. Reading some of the articles we read, in particular the Harwood (2004) article about the activity model for science as a way to expand thinking about “the” scientific method, was not comfortable for them at first, and difficult for me to explain well, except by continual modeling. The teacher research idea was initially difficult for these students as well because the research they were familiar with was quantitative and highly precise.

My class requirements were different from the other instructor’s. The students had to plan and teach a lesson in their placement schools. The other instructor required her students to teach a lesson in class to their peers. An additional challenge I had with this requirement was that two of the students had undergraduate degrees in education and had taught previously for a year. So they were not required to student teach, or work in a placement setting. I had to help them find classrooms where they could carry out this assignment, and another assignment as well. Another student had a problem with her placement, the school to which she was assigned decided not to participate, and so I helped her by inviting her into my own classroom. But even that was problematic, because I felt the additional pressure of having to have a "model classroom," and had to rearrange my classroom schedule (and hope I did not get caught by my principal for not sticking to my team's schedule) to meet the needs of this student's schedule.

A constant struggle I faced was the participants' frustration with the lack of science being taught in schools. This was a personal struggle for me as a teacher as well. Each week they would come with criticism and were visibly disturbed by the situations in their placements. I remember distinctly similar issues when I was student teaching. However, the lack of science was not nearly as profound in 1996 as now. Maintaining a positive attitude, encouraging the teachers to become agents of change and work against what is currently permitted or prescribed in their settings and remaining professional in my interactions was difficult at best for me and for them. Learning to teach and having to go against the grain of the classroom you are a guest in is not an ideal situation.

Another challenge was helping students recognize and refine the bits and pieces of didactic instruction that kept popping up in their assignments and reflections (Abell & Bryan, 1997). One of the most commonly recurring ideas was the idea of modeling. Modeling, in our state means for the teacher to stand in front of the class and do whatever it is the students are going to be required to do. In other words, in the case of science, the teacher would lead the students through each and every piece of an investigation *before* inviting them to do it. These comments are noted in the interpretation of interviews, which are interpreted in Chapter Five. Additionally their lack of attention to curricular assumptions about the knowing their learners, and attention to issues of physical ability, special needs, giftedness, race/ethnicity/culture, gender or socio-economic status was a concern, as noted in their comments in Table 4 – 17.

Overview of Class

Our classes met 4:50 – 8:20 p.m. each week. The class structure was not rigid, but generally followed a sequence of activities. The sequence was the following:

- We spent the first hour to hour and a half in doing a science investigation that had a particular focus, but usually multiple foci (see Table 4.1). Then we would take time to debrief and answer questions about both the <u>process</u> and the <u>content</u> of the investigation.
- The next half an hour or so involved reflecting on the investigation through discussion, questioning, etc. We always included how and what the literacy and or math connections were for that lesson.
- There was a 15 - 20 minute break for snacks and informal visiting
- During the next hour, individual students facilitated discussion of the readings. Usually, the students had to read a chapter from the book, and a research article. The required textbook was *Teaching Science as Inquiry* by Bass, Contant & Carin (2008). For each of these readings a student prepared summary (hard copy) and shared it with the class. The student

who had written the summary was also expected to have several questions prepared to facilitate a classroom discussion. Often the topics of the readings overlapped, so the two discussions were often one big discussion.

- At times, these activities were shifted or shortened to allow for watching video case studies and debriefing them.
- The last few minutes was reserved for summary, (what is it that we did this evening?) lingering questions, and explanation or clarification of upcoming assignments.
- Several of the last classes included time for the students to learn to use the web-based portfolio for their finals. Those who learned quickly were able to begin working on their final; those who did not, received individual attention.

There were four major assignments in the class and they grew in complexity as the semester progressed. The first assignment was just for the students to think about science from their personal perspective, and provide me some background information on their perceptions of science. The second assignment asked the students to explore the perspective of science of their school district and school. The third assignment asked them to evaluate a science lesson of their choice and to rewrite it using the 5 E format. In the fourth assignment they were to plan and implement a lesson using a peer observer and video tape recording of their lesson, and then reflect on their experience, and the information from the peer observer and the videotape. Each week the students wrote a reflection. Four of the reflections had prompts I created, the rest were free choice. Their final was to create a “snapshot” of their learning in this course by using the Carnegie

KEEP TOOLkit software. This was a multimedia synthesis of what they thought they had learned.

The students in this class were also in internships, but they had more than one placement during their internship. For some it was just switching grade levels at the same school; for many it was also a change in schools. During my time with this group of students they worked with two different grade levels, and in one case, a change from a self contained elementary class to middle school math. The students' placements in elementary schools in the area provided a rich source of discussion topics.

Course Activities

Every week we started with an experiment and each experiment had a particular focus. I wanted the students to learn that each of them was a scientist, could be a scientist, just as a physics professor had convinced me, I too could be a scientist. Unfortunately I did not have the same resources available to me here as I did in the two prior versions of the course (actually I had no resources so I had to get creative). The experiments for the sessions are listed in Table 4.1. Each experiment is identified with a brief explanation and the foci for the particular investigation is noted. Each focus listed was the main topic of discourse during and after the activity. A more detailed description of these activities is provided on pages 376-387 of Chapter Five.

Table 4.1

Course Activities

Experiment	Description	Focus
UV beads	Students receive beads without knowing what is "special" about them,	Skill of observation and testing

	Keep an observation journal, to use observations to determine what causes color change.	hypotheses.
Paper folding	Students make predictions about how many times they can fold a piece of paper, fold it and several other types of paper to see if folding capacity is the same.	Variables
Apples	Some groups of students are given a sheet of paper and a pencil. They sit in groups and brainstorm everything they know about apples. Other groups are given apples, a knife, a magnifying glass, colored pencils, and paper and asked to write down everything they know about apples.	Demonstrating the richness of hands on experiences in contrast to non hands-on experiences.
Film canisters sound activity	Students see a variety of objects that may be in film canister, try to determine which items are in theirs. Then create new assortments and share with other students to guess.	Testing hypothesis
What happens when M & M's get wet?	M&M's are put onto a paper plate, a small amount of water is added, and	How to collect data/compare data to

	students time how long it takes the "color" from the candy to reach pre-designated points. Data is collected and shared.	draw conclusions, supporting conclusion by using evidence (data)
Fake snow	Students use their senses and background knowledge to figure out what this white powder is. The powder is actually a polymer used to make fake snow.	Using prior knowledge, multiple interpretations of what powder is using senses, and developing a plan to test substance to determine what it is.
Oobleck	Students mix ingredients to make a non-Newtonian substance	Following procedures with accuracy/chemical change
ADHD's (Aerodynamic heli-devices) Paper helicopters	Students make an ADHD and observe how it spins when dropped. They find ways to change the speed, and time from drop to floor.	Variables, recording accurate data, necessity to do multiple trials and to use benchmarks.
Pen and paper sports	Students use paper and pencil for several activities trying to improve	Variables

	their achievement each time.	
Boat Building	Students try to see how many pennies they can float on tap water and then on salt water, next on water with more/less salt added.	Variables/multiple trials

For two of the weeks, the students took turns bringing in their own experiments that they had found and tried out on their own. They shared them with each other in class in a gallery walk. Half the class presented one week and half the class the next week. This was after most of the semester had gone by, so they were pretty critical of the experiments they had chosen to share.

For several weeks, we watched case study videos relating to issues of special needs students such as English Language Learners and special education students.

Example course activity. The first science activity was one I had heard Charlie Pearce discuss at a conference in which he used beads that changed color in ultra-violet light. He also describes this in his book (Pearce, 1999, p. 20). This was my fourth version as I had done this with teachers in a professional development program during the summer and during the two courses for prospective teachers in the mid-Atlantic state. I describe all four versions below as the differences among them were instructive to my development as a teacher of teachers.

Professional development program version. I began the activity by having the teachers in the summer science professional development program create a small paper journal. I then gave each of them 10 beads, and asked them to cut themselves an eight-inch piece of string. They were to thread the beads onto the string and wear it as a bracelet, or just tie it together and keep it with them. When I did this activity with these experienced teachers, they tried out many different experiments. This was a two-week professional development experience and we were together for 6 hours a day. On the second day of having the beads these teachers were given time to find out if light or heat made the beads change colors. One of the teachers put her beads under different colors of paper, and laid them out in the sun. Another put some beads in sunscreen, and others in sun tanning oil. Another teacher brought in her blow dryer from home. One teacher, convinced that the beads change because of the sun, glued his bead to a pillar inside the library where we were working, and went outside with a small mirror and reflected sunlight from about 50 feet away onto the bead and we watched it change color inside. (There were still those questioning the heat idea because they believed that maybe the reflected light was somehow more intense, and perhaps was radiating heat as well!)

First science teaching methods course version. During my first science teaching methods course at the mid-Atlantic university, I began the activity as before by having the students create a small paper journal, cut an eight-inch piece of string, thread the beads onto the string and wear it as a bracelet, or just tie it together and keep it with them. The instructions were for them to make at least daily observations of the beads until the next class, which was in one week. We discussed how the activity would have gone (at this point) for elementary students. I shared with them that several had not been very accurate in their measuring and cutting of string. I asked if they thought their elementary students would struggle with this. I asked about my modeling of instruction for creating the journal. I had asked them all to put their names on the front cover. Several of them had not yet completed this step. We related that to the elementary students. I asked them how they were thinking about recording their observations. What information would they put in their books? How often? How would they organize it? The students were very uncomfortable with the openness of the activity.

They wanted me to tell them exactly how to do it, and to explain why I was using these beads, and what this was all about anyway. I explained that they would soon have some answers, and then asked if they thought their elementary students would feel the same way. One student said, “Why didn’t you wait to give us this at the end of class? Now I can’t stop thinking about this. I am sooooo curious.” And of course the most important question – “Is this for a grade? How will you grade our journals? Do we get a bad grade if we don’t figure it out?” This ended up being a great way to share to what the “engage” step of the 5E’s refers. It also helped in the discussion of the components of a scientific investigation the following week. The beads were UV beads, and looked white in the absence of UV rays, but once exposed to the sun, changed to bright colors. I was able to observe some of the students as they left from the classroom window. “Cool – look at this – they change colors! Let me see yours! Aww, you got more purple beads than I did – not fair!”

Obviously this activity carried over into the next week. The methods students were eager to share their journals and stories. At one school site they had agreed to not bring them to school because they didn’t want the elementary students to see them, and they had a plan for trying to obtain some extra beads from me. Their observations ranged from very scientific to very basic. Some of the descriptions were much like those of elementary students. "I noticed my beads changed color when I went outside and I like the orange ones the best." They all had done some extended experimentation on their own. They were trying to answer the question - "Do the beads change because of light, or because of heat?" A huge debate ensued, and they discussed how they knew for sure it was light and not just any light, it was the sun. One student had conducted several experiments to confirm that thesis. He had placed his beads under a heat lamp, under a regular light bulb, outside at night, and in the sun. He had also put them on the hood of his car for several minutes and then moved them into the car, onto the dashboard, underneath a tinted windshield. Another student had used a blow dryer on the beads, and still another had taken them off the string and placed them across from her in an area outside, from underneath a tree, to out in the full sun. She discussed the range of intensity of the colors.

At this point, I asked for the students to work in pairs and come up with some questions for further experimentation with the beads. Many students were not as convinced that heat was not a viable consideration. I introduced the idea of a question board, and had the students post their questions. Having done this activity with teachers and with students before, I had some idea of what the questions might be and had brought some materials for them to use to test out their ideas. I had sunscreen with varying SPFs, tanning lotion, colored paper, mirrors, sunglasses, different weights and colors of fabric, a blow dryer and a black light. They got together in groups and hypothesized about a particular question they chose. They tried out their experiments, recorded data, and had conclusions. They shared their results and received questions and scrutiny from their classmates.

The discussion that followed was about how this related to elementary students. Some of the groups had not recorded their data; they simply shared what had happened. One student asked a team presenting, “If you have no evidence, how can you convince me of your conclusion?” We watched a video clip from Charlie Pearce that showed a young girl explaining that she had made a piece of mica magnetic. The piece of mica she had was wet, and was sticking to the dry erase board. Mr. Pearce (who was the teacher at the time) asked the student if she could confirm it. She went back to her table and tried the piece of mica on several different pieces of metal, only to come back later disappointedly and tell him it wasn’t magnetic, it was just that it had been wet. Over the next few weeks as we did other investigations, we addressed different components of scientific investigation. We talked about developing a testable question, what was a hypothesis, how to help students develop a procedure for carrying out their experiments, data collection, conclusions, and repeated trials, and discussion and debate. The investigations also helped with an understanding of the 5E lesson format. We discussed how to evaluate student investigations, and how to assess and extend student thinking from the questions that arise at the end of an investigation.

The first reading was from the Pearce book. Since I had a set of these to use with teachers, students could borrow one of my books for the semester. The first two chapters provided the reading basis for the class. Chapter one is Pearce’s descriptions of inquiry, and the second chapter talks about some inquiry activities and the UV bead activity was there as well. The students really seemed to understand and like the descriptions they were reading about inquiry-based science, but with some skepticism. One student who summarized the first chapter said, "This is like science la-la land, the Disney version of science class. I am not sure we'll ever get there, or be allowed to go there." In some respects, that was an accurate comment, especially given the number of science kits that were coming back to our district warehouse unopened. However, they all seemed able to envision the UV bead activity taking place in their classrooms, and each had ideas on how they might make it happen. They discussed how doing the bead journal and writing conclusions could be part of a literacy block activity, and that they could even incorporate some reading about the sun and sun safety for the students. They felt older students might be interested in doing research on how the beads were made, or maybe this was really their own question.

Second science teaching methods course version. The second time I taught the course at the mid-Atlantic university, the individuals in the class were not as open or willing to just jump in and do the science. Many of them came around, but some of them did not. This group of students had a different personality than the first group of students. It took more time and more effort to get them to buy into inquiry science and integrating science into other content areas. Some of these students felt that science was a waste of time at the elementary school level, and felt as if the focus on only math and reading was a good decision because if kids were good readers and good math students they could always catch up in science later. There were fewer students in this group with science backgrounds; however, many of them shared that they were graduates of the same district in which I was working as science specialist. This district had been doing inquiry science for about 15 years, so I was both surprised and challenged by their thinking.

***Version that is the focus of this study*.** On the first class of the science teaching methods course at the southwestern university, I began with the UV bead activity. We made journals, cut string, made bracelets, but this time there was a little more pushback. Why do we have to do this? What are we looking for? What do you mean make observations? What does this have to do with anything? How will this be graded? So I stepped back, and relied on an activity that I had done as a methods student (van Zee & Roberts, 2001) and asked each student to draw a picture of a science learning experience they had enjoyed as students. For the next step, they were asked to list all of the factors they felt contributed to their personal learning in that situation. Then they shared that with one partner, then as a table group. Each table group listed on a piece of poster paper the factors that members of that group had in common. As each table group shared, other groups put a check by the ones that were common to their group. By the end of the sharing we had a list of about ten or so factors that fostered positive learning in science.

Fortunately for me, one of the factors listed was "being given the opportunity to try to figure things out for ourselves." The bead activity was one of those opportunities I explained – and we moved on. The next week when they brought in their beads and journals there was a great deal more excitement and openness than the week before. Many of the students had already done some experimenting. Still there were a few who were confused about the cause of the color change – was it heat or was it light? Again we did some experiments right in class. Soon the students were convinced that the color change was due to the sun. Several students took the beads home and froze them in ice cubes in different liquids to measure the rate of change. The students were full of ways to use these with students to help them understand about sun and UV rays. UV beads and their application to the real world is much more apparent in the southwest in August than on the east coast.

About two weeks later, I was looking through their bead journals, and found that one of the students actually never got it at all – he said he thought the beads were dumb, and he lost them at a party at his brother's house. In the free choice reflections however, one student said that she had wondered why in the world I had given them beads and bead journals. But after finding out that the beads changed color, finding out through experimentation that it was the sun's rays that made them change, and doing the readings on inquiry-based science, she realized that I had taken them through an entire inquiry cycle, and it was the best way to learn she had ever experienced. She even had a diagram that I had given them and she had filled in the UV experiment components in exactly the right places on the cycle.

Because of my collective experiences, starting every class with an inquiry investigation was important to me. My impression from the other instructor was that they did not actually do many experiments. Her focus, as she explained it to me, was to get through the book, and share the videos that the publisher provided. However, I feel strongly that dedicating one third of our class time to actually carrying out science investigations and experiencing science the way that the elementary students would experience needed the time and attention I chose to dedicate to it. My hope was that in the years to come, the participants of my class would find ways not only to implement this kind of science teaching and learning, but would facilitate a change in their schools, among their colleagues and possibly their districts.

Assignments

The following sections discuss the four assignments for the course. An interpretation of responses follows each description.

Assignment 1. The first assignment was used as a pre-assessment. The assignment was called *What is Science?*

> *Assignment I: What is science? For this assignment, first think about yourself, and your experiences. What is science to you? Then do the assigned readings for class, and look back at what you have written about what science means to you. Describe how the readings are similar to or different from your ideas.*

This was a pre-assessment because it gave me a basic understanding of how these prospective teachers thought about "science." Learning about who was science-phobic, or how globally they thought about science helped me understand them as individuals and as future teachers of science.

Assertion 1: Participants had many different attitudes and beliefs about science.

The following table presents common themes identified in the participants' responses to the question, *What is Science?* in Assignment 1. They referred to their personal understandings and experiences with science. This information helped me understand their personal perspectives about science. The responses range from those who feel science is for the curious, and that our need to satisfy our curiosity is what drives scientists. Some see it as mostly research. Others see science as representing the world around them and their relationship with it. Science is described as ongoing procedural and occurring whenever one investigates the unknown. Science is also described as systematic, procedural and investigative. Science is seen as a field that makes new and worthy contributions to the world. Science continues to evolve and is a never-ending process was expressed as well as an idea that science in this country is in "big trouble because we lean toward tradition instead of truth" (Participant 11). Many facets of science and many ideas and understandings of what science is co-exist.

Table 4.2

Participants' Descriptions of Science

Descriptions	Participant Responses
Curiosity	Science is for the curious and the intuitive. (Participant 11). The key to science is curiosity; it is what drives us to first engage in science as children. We pick up a stone to see what is underneath of it. We have to satiate our curiosity. The same curiosity that drove us to pick up that stone in our backyard is the same curiosity that drives adult scientists to continue their path of inquiry throughout their lives and careers. (Participant 7)
Research	Science consists of large amounts of research, (Participant 4) I think of experiments, research and the scientific method (Participant 10)
World around us	Science represents my relationship and understanding of the world around me and my observations and questions relating to my surroundings. (Participant 2) Impacts our world: can achieve noble and wonderful things

	such as saving people by curing deadly diseases or it can simply, but extraordinarily, make our watermelons seedless. (Participant 4) Explains the natural phenomena that happen on earth. (Participant 8) Science has the ability to give the human race insight into the way the universe works. (Participant 11).
Definitions	Science is the practical activity encompassing the systematic study of the structure and behavior of the natural world through observation and experiment. (Participant 2) Study of life, the earth and the universe. (Participant 4) To me, science is following a process that allows you to investigate, hypothesize, research, ask questions, and then do experiments to see if what you thought is true or not. (Participant 8) Science is any kind of investigation or exploration of the unknown. Any time a person encounters something that is different or unusual to them and they attempt to understand it, they are performing science. (Participant 7)
Observations	When I think of science I think about observations about something that will benefit us in the present or future. (Participant 4)
New Contributions	Science is a field of study that comes up with new medicines,

	new inventions, and new ways of combating diseases, and resources that better the quality of life. (Participant 10) This includes scientists attempting to find cures for deadly diseases. (Participant 4) Scientists come in many different forms. Inventors creating new forms of renewable fuels, (Participant 7)
Ongoing	Although there are certain areas of science that have continued to be proven and supported, there still is ample opportunity for established laws of science to be modified or disproved. This is the beauty of being scientific. Science continues to evolve and progress. (Participant 11) I think of science as an ongoing, never ending process, (Participant 8)
Science and society	I see a real decay in our society's ways of processing information. We seem to be a nation of believers in what we are being told, but do not demand proof and scientific support to base our beliefs. There is a good portion of society that finds validity in such pseudoscience as faith-healing, channeling UFO's, and other areas that have no scientific support. Science is in big trouble in this country and perhaps the world because we lean towards tradition instead of truth. (Participant 11)

Assertion 2: The participants also described science as they had experienced it at school, usually in the context of "traditional" instruction.

The following table presents common themes identified in the participants' descriptions of their experiences with science at school in Assignment 1. They referred to their science learning experiences in school as teacher directed, for example, using the lecture method. Having to memorize facts, charts and tables was another example given. Using the textbook as the main source of science learning, just following procedures without in depth understanding and doing experiments with pre-determined results, were common experiences shared. Students expressed wondering why science at school seemed to have no connection to life. Science for some was not exciting, while others describe having positive experiences with it. These themes represent what I consider to be characteristics of a traditional classroom.

Table 4.3

Participants' Perceptions of Science as Experienced at School

Experiences	Participant Responses
Teacher-directed	Science experiences were often ones in which I didn't have a choice and was told to do something and follow a specific procedure with no room for flexibility or creativity. Anyone can follow procedures. . . (Participant 2) Focus was to learn concepts and memorize them, The teacher dictated concepts (Participant 5) . . . listening to the teacher lecture, and then watching

	demonstrations (Participant 8) Science was indistinguishable from the mess of general information we learned from boring textbooks and strict teachers who never gave us a chance to do any hands-on learning. (Participant 12)
Memorization	Science was memorization of words and terms as well as scientific method. (Participant 4) Tests were often the result of memorizing key terms and concepts. (Participant 10)
Textbook Driven	Science was reading the book and passing the test (Participant 16) Reading from textbook and then answering questions at the end of the chapter. (Participant 16) When I was in school I remember learning science using textbooks, answering a lot of questions from the textbook, listening to the teacher lecture, and then watching demonstrations (Participant 8)
Procedural	Science was following procedures (Participant 4) I was told to follow a specific procedure. (Participant 2)
Experiments had pre-determined results	Science experiments with worksheets to reach a predetermined result (Participant 6) I remember doing experiments knowing that there was a specific right answer to each of the questions and I had to find the

	right one. (Participant 13)
Teaching science with no connection to life	No connection to our own lives (Participant 14) Not about what we were interested in (Participant 2)
Not exciting	When I think back to science classes I don't get excited (Participant 1) The way science was presented to us in school was the biggest problem. Science was no longer something exciting and all about discovery. (Participant 16)
Positive experiences	My experiences in science have always been extremely positive. . science is not just lab experiments and periodic tables. (Participant 11) I have two fun memories from my 7th grade science class, dissecting cows eyes and frogs, and the rest were boring (Participant 4) Infrequently there were experiences in which I was able to have some freedom to explore my thinking and conduct my own experiment. (Participant 2) I enjoyed when we worked in teams (Participant 5)

Assertion 3. Participants sometimes expressed negative attitudes towards their ability to do science, or their experiences with science.

The following table presents common themes related to negative attitudes evident in participants' descriptions of their experiences in school science classes from Assignment 1. Although they each had described a positive science learning experience previously during our first class, there were still those who felt science was out of their range; either because it was elitist, it was too difficult, they were not good at it, or they felt their science knowledge to be limited. This is the exact opposite of what I wanted for my students.

Table 4.4

Participants' Negative Expressions Toward Science

Attitude	Participant Responses
Difficult	My personal view of science is in one word, complicated. (Participant 12) I thought science was a subject "better left to someone who's willing to really understand and conquer the knowledge." (Participant 1) I did find them (science courses) difficult (Participant 1) I also think science is very confusing. (Participant 8) I love science but it can become very complicated (Participant 8)

Not good at it	I was never any good at science and I do not have any memories that truly stick out (Participant 13). I never had a clear understanding of key concepts. (Participant 10) I remember being frustrated because the last step in the scientific method required the data to "make sense" which I often struggled with, since the findings were already pre-determined by the teacher. (Participant 10)
Limited	I do not have many memories of learning science at all. (Participant 4) My experience and knowledge about what science is were very limited (before reading (Participant 4) I do not feel that science in elementary school prepared me in the least to understand the world around me. (Participant 4) I was never any good at science and I do not have any memories that truly stick out (Participant 13)

Assertion 4. Participants' visions of science and science teaching sometimes reflected current views of the nature of science.

The following table presents common themes related to the participants' visions of science and science teaching evident in descriptions of their experiences in school science classes from Assignment 1. Some of the students had very beautiful and poetic ideas about science, which seem to exemplify their understandings of the nature of science. The ideas of becoming a life long scientist, being curious, exploring, reasoning, and the idea that science is evolving, were among the themes they mentioned.

Table 4.5

Participants' Visions of Science and Science Teaching

Visions	Participant Responses
Become a life-long scientist	Any time that a person encounters something that is different or unusual to them and they attempt to understand it, they are performing science. Our goal as teachers should be to take that love of discovery that is so fervent in children and cement it so that it never fades and they can become life long scientists….(Participant 7) Today teachers need to treat students as scientist (Participant 5)
Curiosity	The key to science is curiosity; it is what drives us to first engage in science as children. We see a stone lying on the ground and we wonder what is under it. We may have some idea from previous experiences, but we wont really know until we look, so we pick up the stone to discover what kind of bugs are underneath. We have to satiate our curiosity. That same curiosity that drove us to pick up that stone in our backyard is the same curiosity that drives adult scientists to continue their path of inquiry through out their lives and careers. (Participant 7)

	allowing them to be curious (Participant 5) Science is for the curious and intuitive. If you are someone that makes up their mind about things before evidence has been displayed, then science tends to not be of much concern. (Participant 11) Science is not the problem, it is the solution. There is so much beauty in being curious and wanting answers. (Participant 7) Kids are naturally curious (Participant 7)
Exploring	For me, I appreciated the experiences in which I was able to have some freedom to explore my own thinking and design and conduct my own experiment. (Participant 2) Real scientists explore things, and usually have more questions after their answer. (Participant 11)
Reasoning	These students are learning by reasoning and verifying concepts themselves. They are learning skills that they will use as true professionals. (Participant 5)
Evolving	Science has the ability to give the human race insight into the way the universe works. There is not a "perfect" science known to man. Although, there are certain areas of science that have continued to be proven and supported, there still is ample opportunity for established laws of science to be modified or disproved. This is the beauty of being scientific. Science continues to evolve and progress. (Participant 11)

	We can show our students what a never - ending source of amazement science holds. (Participant 6)

Assertion 5. Readings seemed to have influenced some participants to see science in a different way.

The readings for the week for this assignment were chapters 3 & 4 in the textbook, which included the 5E model (Engage, Explore, Explain, Extend, Evaluate) (Bybee, 2009), and an article by William Harwood 2004), “A New Model for Inquiry: Is the Scientific Method Dead?” There were several participants who were surprised by Harwood’s ideas that the current model of the scientific method can be limiting. “There has been renewed discussion of the scientific method, with many voices arguing that it presents a very limited or even wholly incorrect image of the way science is really done. At the same time, the idea of a scientific method is pervasive” Harwood, 2004, p. 29). Others had not yet heard of the 5E model. These readings led to a rich discussion and caused some cognitive dissonance for some.

The following table presents common themes in the participants’ comments relevant to the readings in their descriptions of experiences in school science classes from Assignment 1. They really struggled with the idea that there was another model other than the scientific method, so new perspectives were being formed. Several had experienced some reformed-based science instruction in high school, so there were affirmations from that group. Still others pointed out the differences between the approach their teachers had used and the current approach; others noted the differences between what the readings espoused and what they experienced.

Table 4.6

Participants' Reflections On the Readings

Reflections on readings	Participant Responses
Surprises/New perspectives	One thing that was new to me was the idea in the handout that the scientific method is outdated and not very accurate in describing the actual work scientists do. I'd never really questioned the scientific method. It's something that was ingrained into your mind as a student (Participant 7) The 5-E model is probably the most impressive thing I have read in our textbook thus far. In my future science instruction I would like to implement this model because I believe it functions as an incredible tool to engage students in science inquiry. I feel like this model promotes the pursuit of knowledge in an effective way. The students are not only asked to do the science, but also evaluate their findings, as well as pose their own science questions and theories (Bass 91-92). (Participant 11) After the readings I see that the focus today is on allowing students the chance to think more critically and *guide* their learning rather than just providing them with the information. By giving students hands-on opportunities we "create opportunities

	for them to gain a much deeper understanding of the concepts. (Participant 14) This class and these readings are opening up my eyes. The skills that we build now will be relevant to our students as they move into adulthood. Science allows us to build up critical thinking skills, which will be something we will all need as we make decisions about our world. (Participant 14) I feel that it is important from a teacher's point of view we need to remember that though using a text book day in and day out is easy, we need to also go into unknown territory sometimes and try lessons and experiments that we've never done before, and perhaps don't have any lesson plans from prior years. Science is really about the unknown and making it a little more known. (Participant 1) The text states that science is more than a noun it is also a verb; I love this definition (Participant 4)
Affirmations	This coincides with my opinion that curiosity is the key to science, because, after all, all questions arise from curiosity. Everything that follows is interchangeable and can follow any order. I like this because it shows that science is a fluid process that is constantly evolving and growing. (Participant 7) In the first chapter it is suggested that science should be

	taught as inquiry. This means that we teach science in a way that actively supports curiosity and promotes hands-on learning. The children explore and construct ideas and explanations of the natural world with the help of instructors. This really coexists with my beliefs on how science should be taught in schools. In order to keep the students engaged in the material, we need to let them perform science, and not just show them science (Bass 3-4). (Participant 11)
Differences in approach	What I don't remember is the elaborate phase. My teacher would never really extend our knowledge. I remember times when we would have questions or be really interested in some experiment and want to investigate something similar or go farther with the current investigation but the teacher never let us, we just moved on to the next lesson.(Participant 15) The major difference I see (between my experience and the readings) is that I was never encouraged to talk with other students and ask questions about the procedures evidence or explanations. (Participant 8) I consider the inquiry method to be a set of tools for the students, that help the students better make sense of the world around them. These tools also create a problem-solving situation that will strengthen their skills for every day life. Today's science seems to put more control and learning in the hands of the

	students. (Participant13) Giving priority to evidence to generate explanations and engage in "critical discourse" instead of not requiring any response at all. (Participant 8)
Differences in classroom experiences	Another difference that I saw was in the features of inquiry instruction in Chapter 4. These include engaging the learners in scientific questions; giving priority to evidence as learners plan and conduct investigations; the learners connect evidence and scientific knowledge in generating explanations; learners apply their knowledge to new scientific problems; and Learners engage in critical discourse with others about procedures, evidence, and explanations (Bass, J. et al, 2009). This last step is where I see the major difference. I was never encouraged to talk with other students and ask questions about the procedures, evidence, or explanations. We would pretty much just do our lab work, write it up and turn it in. There was no debating about the evidence, explaining how we all did it, or if there were other procedures that may have worked. We just finished one lab and went to the next. (Participant 8 Part of the reading talked about how important data collection is whether it's through graphs or tables, and I think this is

	important because I know some science classes I had in high school, it seemed as though we did the experiment and then just sort of wrote about what happened which was tough for me. I feel that if more of the classes had graphs and visual results I would have maybe had a better understanding when we completed the experiment. (Participant 1)

Assignment 2. The second assignment was adapted from an assignment I had as an undergraduate student. For this assignment the participants had a list of questions to think about and analyze to assess the status of science in their particular setting. The questions for them to think about were the following:

- What curriculum is being used in your classroom?
- What is the science addressed by this curriculum?
- How often and for how long is science instruction?
- Using the interview questions we designed in class, interview your mentor teacher, the principal, the science resource teacher, or science liaison teacher, and a teacher from another grade level. Summarize the results of the interview.
- What is the school's perspective on teaching science?
- Review the websites for the county in which you are working. Is there information about the county perspective on teaching science?

- What are your thoughts, ideas, and feelings about science at the elementary level?

This assignment was due after they had been in their placements for about 4 weeks, and in the methods class for about that long. Part of the assignment was for the students to interview key players in their school. During one of our class periods, we broke into groups and brainstormed a list of questions the students would use for their interviews. From this list the participants as a class chose the ones they felt were the most relevant. They were encouraged to interview in pairs if they were in the same schools.

The following is the list of questions they chose from a longer list they had created:

Interview Questions:

1. What is the school's perspective on teaching science?
2. How do you choose your curriculum?
3. What resources / materials are available?
4. How much money does the school spend on science related resources?
5. How much time during the week are teachers expected to perform science?
6. What professional development is available?
7. What is your approach to teaching science?
8. What are the expectations for the students?
9. How is science assessed?
    a. Do you do formative and summative assessments?
    b. Is it formal or informal?
10. Are there opportunities for field trips, extracurricular activities?

11. Do you have a technology, science, robotics club?
12. What is the most challenging part about teaching science?
13. What is the most challenging part about getting teachers to teach science?
14. How do you differentiate subjects in science?
15. What do you do if a student comes from another area that does not have the same base?
16. How important is vocabulary?
17. Does every grade level teach science?
    a. Is the science curriculum built upon the grade level?
18. Do the students enjoy science?
19. How important do you think literacy is in science?
20. Why do children need science?
    a. Do you integrate science into other subjects?
    b. Does science reach beyond the classroom?
    c. How much real life application is brought into the classroom?
        i. Recycling?
        ii. Conserving power?
        iii. Carpooling?
21. What does scientific literacy mean to you?
22. What life skills are learned through science?
23. Do you bring the outside world into the classroom or do you go to the outside world?
24. How much flexibility does the teacher have when planning the curriculum?

25. Is there any outreach to the community around your school?
26. Does the community come to the school?
27. What kinds of guest speakers are available?
28. Does your school departmentalize for the different subjects?
29. What are the group dynamics of your classrooms?

None of the participants used all of the questions but they felt they needed a substantial number of questions, in case they ran out of things to discuss.

The purpose of this assignment was to give the participants a more informed perspective about the importance (or non-importance) of science instruction and resources in their schools. It gave them the opportunity to probe their mentor teacher and principal about science, as well as another individual in the school. It forced them to look at school websites and district information. As an assignment, it provided a vehicle through which the participants could ask candid questions, search for materials and resources on a school and district level and create an awareness of the status of science for their students.

Assertion 1. There were a variety of attitudes about science amongst those interviewed on school staffs.

The following table presents common themes in participants' comments in their evaluations of interviews conducted at their school sites. The interviews prompted rich classroom discussion and thoughtful writing. The data the participants gathered ranged from the view that science is necessary to science is an extra. Some participants found that the teachers they interviewed were not comfortable teaching science, other teachers tried to pull science instruction in through literacy, and others commented on the value of science outside of school, as in field trips, etc. Still others described science as a positive, a benefit to the students.

Table 4.7

Attitudes Toward Science Espoused by School Staff

Attitude	Participant Responses
Science is necessary	The principal believes that the fourth and eighth grade teachers cannot have the sole job of teaching the students science for the test; it must be a cumulative effort that begins in kindergarten and each grade builds upon the grades before. (Participant 4)
Teacher comfort level with science	3rd grade teacher said science had never been her strong suit. (Participant 7) I am wondering how science can be made more accessible to teachers, especially those that are intimidated by the subject matter? As I am spending more time in the classroom, it s becoming evident that there are lots of demands that come with being a teacher; and perhaps doing science regularly creates too big of a demand. (Participant 6) My mentor teacher thinks that some teachers are a little apprehensive about teaching science. They are not comfortable

	teaching it because it is still new to them. He thinks this hinders the students and affects possible field trips because some teachers are not competent in science and teach the minimum. (Participant 11)
Literacy activities and science	All interviewees thought vocabulary is extremely important to science, and literacy is not of utmost importance because the meaning from the (science) project can be gained without the skills of reading and writing. (Participant 6) She (the principal) explained that because other subjects are so highly crucial in testing, that teachers focus on reading and writing. When I asked the two teachers this question, they both let out a chuckle and looked at one another. My placement teacher proceeded to tell me how hard it is when his students (3rd grade) are reading and writing at a kindergarten-first grade level (Participant 15)
Science outside of school	In addition, they all agreed that science is important outside the classroom, and provides the students with "problem-solving skills necessary in life, and that science is . . . applicable to real life. (Participant 6)
Science is extra	When I asked my first question (to the principal) - what is the school's perspective on science? She laughed and asked if I wanted her perspective or the school's perspective. She said that "in general" science is pretty much seen as an extra thing.

	(Participant 15) My placement teacher proceeded to tell me how hard it is (to do science) when his students (3^{rd} grade) are reading and writing at a kindergarten-first grade level (so how can he teach science) (Participant 15)
Science is a positive	A few years ago there was no real science curriculum set, because the school did not test for it. The principal made it clear that most of the teachers at the school rarely taught science in their classrooms and she is ecstatic this is changing. (Participant 11) I believe that the more they (the students) use science and see how much fun it can be the better off they will be going forward. (Participant 11)

Assertion 2. Interviews conducted by the participants included comments related to the influence of standardized testing on Science Instruction.

The following table presents common themes in participants' reporting of comments about standardized testing mentioned in the interviews conducted at their school sites. At some of the school sites the standardized testing increased the focus or time spent on science. Personnel at other school sites felt more pressure to increase test scores in Language Arts and math, and commented that science was not part of their Average Yearly Progress consideration, so science was not a priority. Many of the teachers spoke of the pressure they felt to perform in terms of test results, especially in this new climate of accountability. Because this was the first year that standardized testing scores will be reported for science in fourth and eighth grades, some participants felt their teachers might change their classroom assessment practices, once the results were out.

Table 4.8

Participants' Impressions of School Staffs' Perceptions of the Influence of Standardized Testing on Science Instruction

Influence	Participant Responses
Increased interest/focus in science	Both teachers agree that until recently their school hadn't put much of an emphasis on science. The new school principal has taken a greater interest but they implied it was because science was being including state test. Judging by his apparent lack of interest in discussing science with three graduate students I would assume that this newfound emphasis is based off of standardized testing rather that a genuine interest in science. (Participant 7)
Decreased interest/focus in science	Though many educators value and enjoy teaching science it continually is pushed down on the list of priorities as it can pose many challenges to teachers trying to get their class through the stringent standards (in reading, writing and math) they are held accountable for through testing. Thus science is often absent from the elementary classroom, and students pass from grade to grade with sporadic science lessons interspersed throughout their

	hours of math and reading and writing. (Participant 9) Although this school commits more time to science than some other state schools, the teacher said that he devotes the most time to math and reading for the state standards and state testing because those are the only subjects tested in his grade level. The principal requires 4 hours a week learning about science. (Participant 4) When I asked my first question (to the principal)- what is the school's perspective on science? She laughed and asked if I wanted her perspective or the schools perspective. She said that "in general" science is pretty much seen as an extra thing. She explained that because other subjects are so highly crucial in testing, that teachers focus on reading and writing. (Participant 6)
Classroom assessment and standardized testing	My teacher does not give the class science exams. He believes in informal assessments of the students by strong teacher observation. He said he really has to pay attention to how the students are learning and if they are staying on task otherwise group learning is not effective. I think this style may change depending on how well the students do on the science state test. (Participant 4)
Test results	It is unfortunate, but "science (test results) will not make or break the school." (Participant 9) One of the teachers felt the kits offered her no flexibility, and

	she felt "pressured because the kids get tested in science in 4th grade. Interesting comment to have been made because the vice principal told me that the science section of the test has nothing to do with the state ranking of the school. In regards to NCLB, it doesn't make much of a difference. (Participant 6) The principal and the teachers I interviewed think science is important because it is part of everyday life that can be applied in real situations, and it helps developing higher order thinking skills. The principal asserted that reading and math scores had gone up by consistently teaching science. However, I found inconsistencies on the school's point of view and the reality of the classroom. (Participant 5)
Pressure to perform	There is such a heavy focus on the subjects that are covered by the standardized tests such as reading, writing and math that it leaves no time for science. I was able to tell that all three of these women (interviewees) know how important science is for students but are pressured to have their students perform well on the states standardized tests. I think it is sad that science is ignored in classrooms for this generation of students. (Participant 13) Our school uses a test practice company (Galileo) and they made a science practice test to prepare the students for the state test in April. (Participant 11)

Assertion 3. Participants perceived inconsistencies in the way the role of science is espoused by administrators, and districts and the reality of the classroom.

During the interviews the participants also checked district and school websites as well as interviewing several members of the school staff. In doing so, they found inconsistencies between what the district said and did, what the administrator thought or said about science teaching and learning and the reality of the school, and differences in what the teachers responded and what actually happened in classrooms.

Table 4.9

Participants' Perceptions of Inconsistencies in School and District-Wide Perspectives

Source	Participant Responses
District	The school web page encourages parents to get involved in their children's education: "Our national education goals made becoming literate in science important for all Americans. The President and the Governors have set these challenging goals, and it is up to all of us to do our best to help our children learn what they will need to know in order to live and work in today's world and in the next century." But I did not see this in the classroom. (Participant 5) At another district I was in, the goal is also for the teachers to fit science in twice a week. I know, however, firsthand that this is not the case. (Participant 6) On the school district's website there is clearly no section dedicated to science (and/or math for that matter). After surfing around the page, I found the word "science" mentioned in one place. It states that this

	district's "Signature Schools," among many other things offer "math and science and technology." The only problem is that most of the elementary schools in this district are not "Signature Schools." (Participant 6)
Administrator	It was interesting for me to see the difference in the principal's ideas about science from the teachers. The principal described science as crucial, and a wonderful way to build language through integration. "Kids get so excited about science!" she said. The teachers didn't seem to be on the same page. My teacher seemed to think the principal would rather have him working on reading and writing with his ELD students. (Participant 15) According to the principal, K-3 has 2-3 hrs of science per week, 4th and 5th grades have 3-4 hours per week, and 6-7th grade daily. But according to the teachers since the focus is on reading, writing and math, most of the time they don't have enough time to teach science. (Participant 12)
Teacher	My mentor teacher has yet to pull out her science kit. She blames this on the time it takes to plan science lessons and the time it takes to do them in class. She says it is too much of a crunch to fit in everything so science is sacrificed. The other teacher I interviewed is able to fit science in a couple of times a week. Her biggest complaint is the prep time and the lack of a lab room. (Participant 6)
School	The principal and the teachers I interviewed think science is

	important because it is part of everyday life, that can be applied in real situations, and it helps developing higher order thinking skills. The principal asserted that reading and math scores had gone up by consistently teaching science. However, I found inconsistencies on the school's point of view and the reality of the classroom. Science wasn't taught. (Participant 5)

Assertion 4. Participants reported that school staff perceived a variety of ways science is being integrated, or could be integrated, into the curriculum.

As a response to the increased focus in reading, writing and math accountability, many educators have responded by "integrating" science into other content areas, or other content areas into science. One of the aspects of science instruction we discussed frequently was just this (although scientists have been reading, writing and using math to do science for a long time). Participants asked the faculty members they interviewed about how science was integrated with other subjects, and there were a range of responses to this as well. There were teachers who integrated everything with science, only literacy with science, math with science, and those that found it impossible to integrate, even one teacher who "integrated" by having items from nature in her room even though these items were never discussed.

Table 4.10

Participants' Impressions of School Staffs' Integration of Science into the Curriculum

Integration	Participant Responses
Literacy only	3rd grade teacher tries to integrate science and all other subjects together – students read about science and write reports. (Participant 7)
Literacy and math	Mr. X also does incorporate other subjects into science so that his class can spend the most time possible devoted to the subject. For example, last week he had me read a science book about bugs aloud to the class. So Mr. X was incorporating reading into science and he was also engaging the students by asking questions about what we read and having them make various predictions about the different bugs. The students also completed a worksheet that was about the same bugs but was concentrated on math. The students were asked to count the number of bugs on one leaf, or the number of legs on a bug. (Participant 4) Third grade teacher says that she likes the plant unit because it works to incorporate math skills like measurement, and writing skills like journaling, connecting science to the vital math and writing components present on the state test. (Participant 9)
Integration	If it were up to Principal G, all lesson plans would integrate

throughout the curriculum	all of the subjects and she said this is what the school is working towards. According to her, the last principal had a very traditional teaching style and she is trying to encourage the teachers into the many new interactive teaching techniques. (Participant 4)
Integration of natural materials	I found little science going on in my intern teacher's classroom. However, she has found several ways to incorporate science into her curriculum. She has a real spider along with growing potatoes in water. Throughout the class I have not witnessed any type of teacher directed learning or observing with these items. (Participant 13)
Impossible to integrate	Rotating classes (Participant5th/6th) made it hard if not impossible to integrate science into other disciplines. (Participant 7)

Assertion 5. Participants reported that time for science varied among schools and teachers.

The following table presents common themes in students' reporting of comments about the amount of time allotted for science mentioned in the interviews conducted at their school sites. In these responses there was a range of time devoted to science by various school sites. One principal claims that the amount of time is flexible, teachers say there is no time or little time and that prep takes too long. Science time was reported to be given up, if a math, reading, or writing assignment takes too long. Amount of time actually spent on science in one week as reported by school staffs went from 5 hours a week to 1.5 hours a week.

Table 4.11

Participants' Report of the Time Allotted for Science

Time Allotted	Participant Responses
As much time as needed	3rd grade teacher spends however long it takes to do science, adjusts her schedule based off of the needs of her students. (Participant 7)
5 hours a week	According to the principal, each class has science for one hour each day. (Participant 15)
4 hours a week	The principal requires 4 hours a week learning about science. (Participant 4)
2.5 hours a week	and the third grade teacher for two and a half hours (Participant 5)
1.5 hours a week	The second grade teacher says she instructs science for one and a half hours a week, (Participant 5) Time devoted to science and social studies are the most vulnerable, with science scheduled for three days a week for about thirty minutes a day. (Participant 9)
Not enough time	But according to the teachers since the focus is on reading,

	writing and math, most of the time they don't have enough time to teach science. (Participant 12) After conducting this assignment it is clear that science is not a main focus (or just not) in elementary schools. (Participant 6) After speaking with the vice principal and two teachers it is apparent that the time and effort dedicated to science in the classroom is limited. The vice principal of the first district I was placed in says that the goal for her science teachers is to do science twice a week; however, the reality might be quite different. (Participant 6) At another district I was in the goal is also for the teachers to fit science in twice a week. I know, however, firsthand that this is not the case. My mentor teacher is yet to pull out her science kit. (Participant 6) When I asked the two teachers this question, they both let out a chuckle and looked at one another. My placement teacher proceeded to tell me how hard it is when his students (3rd grade) are reading and writing at a kindergarten-first grade level. (Participant 15)
No prep time/ little science time	She blames this on the time it takes to plan science lessons and the time it takes to do them in class. She says it is too much of a crunch to fit in everything so science is sacrificed (Participant 2)

	The other teacher I interviewed is able to fit science in a couple of times a week. Her biggest complaint is the prep time and the lack of a lab room. (Participant 6)
Flexible time	The principal informed me that the teachers are still given a great deal of flexibility in how and when they choose to teach science in their individual classes. (Participant 9)

Assertion 6. There were some aspects of inquiry-based science reported.

The following table presents common themes in participants' reporting of comments about aspects of inquiry-based science mentioned in the interviews conducted at their school sites. Many of the schools were in a beginning process of incorporating FOSS kits into their classrooms (http://www.fossweb.com/). The participants noted many different ways in which inquiry was being played out in the classrooms. One teacher had students observing seeds, supposedly a hands-on activity, but did not allow them to touch them – only look at them. And the extreme opposite was a teacher who claimed he wanted his students to be doing science hands-on and working in groups, and writing what they see and learn. Questioning, group work and real world connections were also often mentioned during these interviews.

Table 4.12

Participants' Impressions of the Prevalence of Inquiry-Based Science

Aspects	Participant Responses
Hands-on materials	There were two hands-on activities I observed – the first, the

provided but not touched	students in groups of four were given an assortment of seeds. They were told not to touch the seeds. They discussed the similarities and differences, and then were told to get out their science journals and copy down the terms listed on the board for the next 10 – 15 minutes. The next activity the students put plants in foam with the roots dangling in the water. The activity ended with the science journals out and students copying terms from the board. (Participant 15)
Hands-on	Both teachers encouraged hands-on activities and group work. (Participant 7) The school adopted this model (FOSS) after the state redid the science standards which demanded that the lessons have a more hands-on approach. (Participant 4) His approach to teaching science is very hands –on and student directed. He wants his students to investigate and observe in groups and individually without constant formal direction. He has the students keep a science journal to focus on how the students are thinking, not how they write about what they are thinking (Participant 4). The principal informed me that science at their school is very hands-on and almost all inquiry based instruction. (Participant 11) I feel that the hands-on approach to science is the best way to

	engage young students. Perhaps when we are older and have seen some of these experiments first hand it is not necessary to always have a live experiment in front of us. But as young scientists it can be difficult to understand how things work just by reading an experiment and the results. (Participant 11)
Questioning	I also like how the teachers ask students questions to get them thinking. My teacher corrected me when a student asked me a question and I answered. The teacher told me, the next time ask them "well, what do you think will happen?" I also heard him asking, "how do you know that?" to encourage the students to explain their thought process. (Participant 15) He encourages the students to ask many questions and he asks them many questions as well, most of which the students are responsible for finding the answer to. (Participant 4)
Group work	Both teachers encouraged hands-on activities and group work. (Participant 7) I appreciate and support the group seating, which is a common characteristic of inquiry based classrooms. (Participant 15)
Real world connections	Teachers use field trips to augment the instruction they are doing to show their students the real world application of the things they are learning. (Participant 7) In addition, they all agreed that science is important outside the

	classroom, and provides the with "problem-solving skills necessary in life, and that science is . . . applicable to real life. (Participant 6) Both teachers combine their science efforts and make sure they take their students outside to see science at work first hand. Last year they built a hill with their students out in the quad and measured the erosion that took place when affected by rain. Because our downtown area does not experience much rain – the measurement was not very hard, and the hill still stands. (Participant 11)

Assertion 7. Participants perceived many challenges to science teaching and learning in elementary classrooms.

The following table presents common themes in participants' reporting of challenges in teaching science mentioned in the interviews conducted at their school sites. Ask any school faculty member about a challenge and the list will begin. That was the finding of the participants with this question. Challenges ranged from lack of training or quality of training/professional development for teaching science to the perception of teachers that they did not have the content knowledge they felt they needed. Some reported not having enough materials and resources. How to differentiate in science teaching and compartmentalization of science were also concerns. Still other interviewees felt as if they needed to follow the teacher guides from the kits line-by-line, page-by-page, and they were challenged by what they perceived as a lack of flexibility in curriculum. For some, the amount of time needed to prepare for science was a big obstacle. Others mentioned the state mandated block for structured English immersion for ELL students. Controlling student behavior during science (due to excitement) and the level of students' literacy skills for science activities were additional concerns listed.

Table 4.13

Participant and School Staff Impressions of the Challenges of Science Teaching and Learning

Challenge	Participant Response
Lack of Resources	This teacher's most formidable opposition to teaching science is the lack of resources that limit the activities and hands-on experiences she can provide her students. (Participant 9) The teacher said her issue with teaching science is time and resources. (Participant 13)
Differentiation	3rd grade teacher said overcoming her own lack of science knowledge and training was her biggest challenge, and differentiating her instruction for different types of learners was a challenge. (Participant 7)
Compartmentalization	Having fifth and sixth grade students rotate to special classrooms for science instruction is a mistake. It may be necessary in high school, but in elementary school it is an

	unnecessary compartmentalization of subjects. (Participant 7)
Behavior	The biggest challenge the time to prepare for classes, and controlling the students' behavior (students get very excited), and getting them to comprehend readings and respond to experiments in writing. (Participant 5) and controlling the students' behavior (students get very excited), and getting them to comprehend readings and respond to experiments in writing
Students literacy skills	. . . and getting them to comprehend readings and respond to experiments in writing. (Participant 5)
Lack of training/quality or Lack of professional development	It's ironic that the teacher who feels she has ample time to teach science feels like she doesn't have the proper training, while the teacher who feels adequately trained doesn't have enough time. (Participant 7) The teacher said her issue with teaching science is time and resources. The principal said that science doesn't get the attention it deserves. There is no professional development for science, but could be some in the future. She stated the biggest issue with getting teachers to teach science is time. (Participant 13) 3rd grade teacher said she would welcome any kind of

	science training. (Participant 6) The school and the district are taking proactive steps to try and improve their students' science performance on the state test. One way they could help to achieve that goal is to offer more professional development for their teachers. (Participant 9) The only science specific training that is provided by the district is a FOSS class. Neither teacher felt it was worth their time – they could have easily learned by simply reading the instructions that came with the kits. Current FOSS training in the teachers' words is "a joke." (Participant 7) The only science specific training that is provided by the district is a FOSS class. Neither teacher felt it was worth their time – they could have easily learned by simply reading the instructions that came with the kits. Both teachers encouraged hands-on activities and group work. (Participant 7) The school and the district are taking proactive steps to try and improve their students' science performance on the state test. One way they could help to achieve that goal is to offer more professional development for their teachers. Current FOSS training in the teachers' words is "a joke." (Participant 7) 3rd grade teacher said she would welcome any kind of

	science training. Both teachers encouraged hands-on activities and group work. (Participant 4) Principal G believes that the lack of science professional development for the teachers last year has resulted in much of their discontent. (Participant 4)
Lack of content knowledge	3rd grade teacher said overcoming her own lack of science knowledge and training was her biggest challenge, and differentiating her instruction for different types of learners was a challenge. (Participant 7) 3rd grade teacher said science had never been her strong suit. (Participant 6) I am wondering how science can be made more accessible to teachers, especially those that are intimidated by the subject matter? As I am spending more time in the classroom, it s becoming evident that there are lots of demands that come with being a teacher; and perhaps doing science regularly create too big of a demand, especially when you don't have the time or materials. (Participant 6) My mentor teacher thinks that some teachers are a little apprehensive about teaching science. They are not comfortable teaching it because it is still new to them. He thinks this hinders the students and affects possible field trips because some teachers are not competent in science and teach the

	minimum. (Participant 11)
Preparation	The teacher said that the hardest part about teaching science is the preparation. …. and that many teachers are quite reluctant and unenthusiastic about science because it requires so much time outside of the classroom. He also said that the majority of the preparation that the FOSS lessons are expecting the students to complete is actually done by the teachers. He also said that clean-up time is very time consuming which gives the teachers another reason to criticize this model. (Participant 4) Principal says students favorite subject is science but it is a fight to get the teachers even excited about teaching it, because of the prep time it demands. She thinks this attributed to the fact that this is only the second year that the school has had the FOSS kits. (Participant 5) The most challenging part of teaching science is to learn the curriculum and prepare the materials. Teachers confirm that preparing the materials takes longer than the whole lesson and there is just not enough time to have the students do it. (Participant 12) One of the teachers felt the kits offered her no flexibility, and she felt “pressured because the kids get tested in science in 4th grade. (Participant 6)

	The biggest challenge the time to prepare for classes (Participant 5) Science is a harder subject to teach because science requires more prep time. (Participant 9) The preparation for the lessons was very complex – I had the pleasure of putting eight habitats together and it took me multiple tries and actually caused a lot of frustration. I thought it was absolutely ridiculous to expect an eight year old to perform a task that I could barely do. (Participant 4)
Lack of Flexibility	Teachers have no flexibility in planning the curriculum that the district has chosen for them. I think this is a huge barrier for teachers to not have the flexibility on the curriculum, and I also think that this is the reason many elementary teachers although competent and enthusiastic in most of the subjects they teach simply do not enjoy science or feel comfortable teaching it. (Participant 12) One of the teachers felt the kits offered her no flexibility, and she felt "pressured because the kids get tested in science in 4th grade. (Participant 6)
ELL	The reason for the lack of time to teach science is because of the 90 minute reading block required of each teacher, and the newly mandated English Language Development pull out programs. Obstacles for the teachers:

	having adequate time for planning and fitting science into the daily grind include the pressure for improved standardized testing results ad the new ELD pullout programs. The vp says it is unfortunate, but "teachers have to prioritize" and as of recent, science does not make the top of the list. (Participant 6)

Assignment 3. Assignment three was an opportunity for participants to evaluate a science lesson of their choice from the curriculum that was being used in the classroom. Again there were some questions the participants had to consider to guide their analysis. Those questions were:

What is your first impression of the lesson?

If you were to implement this lesson as is, what do you think would happen with the students in the classroom you are in?

What things in the lesson would motivate the students?

What would they like about it?

What parts of this lesson would be challenging for the students? Why?

Is this lesson scientifically accurate?

Does this lesson make any assumptions about students in regard to:

- Math or reading ability?
- Physical ability?
- Special Needs?

- Giftedness?
- Race/Ethnicity/Culture?
- Gender?
- Socio Economic Status?
- Language?

The intention here was for the prospective teachers to think about a lesson in terms of the students they were working with for content and implementation. This is important for many reasons. No two classrooms are identical. Each classroom has it's own "personality" based on the students and the teacher. Often, we do not take the time to consider the strengths, needs or differences in our students as we choose lessons. The next step of this process was for the prospective teachers to re-write the lesson using a 5E format, and then to make changes to the lesson in order to address the challenges they had identified. Analyzing this lesson with the focus on students "forced" the prospective teachers to consider multiple ways of presenting the lesson, ways to group students, and individualizing instruction so that each student would be successful. Once they had done the analysis and rewriting, they were asked to create a valid assessment for this lesson. Because the students were in many different settings, some with more student diversity in terms of language and ethnicity, others with students with more academic diversity, it was important to have them take the time to look at both a lesson and their students and begin to think of ways to reach each one.

Assertion 1: Participants' initial impressions demonstrate some awareness of inquiry-based instruction in evaluating a lesson plan.

The following table presents common themes in participants' initial impressions of inquiry-based instruction in evaluating a lesson plan. So what did they cue in to? A wide range of aspects were noted. The first was whether or not the students will enjoy and be engaged with the lesson as written. They chose to look for appropriateness to grade level, and whether or not the lesson already includes inquiry. They wanted to see if the lesson could be easily modified, what standards the lesson met, and what other content could be integrated. Also important was identifying things the student might not understand and of course, and ease of implementation.

Table 4.14

Participants' Initial Impressions of a Lesson Plan

Initial Impressions	Participant Responses
Students will /will not enjoy	Students will love this activity to observe ants (Participant 4) It seemed very simplistic in scope and I doubt that many students would really be engaged by it (Participant 7)
Grade level appropriate	Ms. Silcox (lesson plan from internet) designed her lesson for grades 3, 4, or 5, but I would use it in a 3rd grade setting. (Participant 6)
Includes/does not include inquiry	My initial reaction was that this lesson uses very little inquiry. It really doesn't follow any of the E's from the 5E Format, at least

	not in any effective form. (Participant 7) The information listed in the lesson plans lacks the intent to engage the students right off the bat. I feel this lesson needs an attention getter for the students. (Participant 14) The lesson seems student centered and interactive. I like that the students work in groups and make predictions through collaboration and discussions. Students are able to share ideas and help one another elaborate on observations. (Participant 15)
Could be easily modified	It's not completely bad, though, and I think that with some modifications it could become a good lesson in 5E. (Participant 7)
Students won't understand	My first impression of the lesson was: "How are the students supposed to understand what a tsunami is without seeing and/or recreating one?" The lesson involves no visual aid for a tsunami. (Participant 6)
Standards	My other first impression was, "What standards does this meet?"(Participant 6)
Integration	Cross-curricular activities, in my opinion, are always a good idea (Participant 6) I have looked at reading, writing, math, social studies, and science lessons. The only thing I am starting to notice is that very few lessons/activities only use skills from one content area. By this I mean that almost all lessons taught in classrooms involve more than one skill. In particular, I think most science lessons

	almost always integrate other subjects. The most commonly integrated subjects are reading and writing. Math can also be included in science but this often depends on the topic of the lesson and the grade level that is completing the activity. (Participant 3) However, I was worried that there was not enough emphasis on Science. Of course the exploration of nature and the discussion of things found in nature are related to science, but during the activity it seemed like the kids would be focused more on the alphabet and making connections between objects in nature and the letter they start with. Although I do not think this is a bad thing, I knew right away that I was going to need to discuss with the children that the observations and discoveries they would be making are science skills that are important when doing experiments and activities. After they understood that part, we would talk about using the alphabet to improve our reading and writing skills. Again, the discussion would be brought back to science when we discussed how we would draw "scientifically accurate" pictures of the objects we found. (Participant 3) This particular lesson is listed as a "Science/Social Studies," lesson. The social studies component comes into play when the students discuss the social effects it would have in a society. "What would happen to the people that live there?" "What would

	the destruction do to a society on a social, economic and political level?" "What precautions could be taken to prepare for future tsunamis?" In addition, this lesson necessarily involves math to make ratios between the actual sizes of buildings versus the replicated sizes of buildings. The students would have to decide on a scale for the sizes. Also, this may be a little bit of stretch, but it could be used for understanding the mathematics behind waves. I say that it would be a stretch, because the math associated with waves involves advanced (high school) levels of math. Without ever being a teacher, I don't know the capabilities of each grade of students. In order to make it incorporate math, it would have to be the basic inner-workings of a wave. (Participant 6)
Easy to implement	When I first started looking at the activity, it seemed very basic. The concept was clear, the instructions were simple, the activity seemed engaging and fun, and the preparation did not seem too difficult. (Participant 3)

Assertion 2: Participant modifications reflect a growing understanding of reform-based instruction.

The following table presents common themes in participants' ideas for modification of lesson plans to increase inquiry-based instruction after evaluating a lesson plan. The modifications the participants suggested for the lesson plan they evaluated demonstrated that they had a fair understanding of what inquiry based instruction looked like. Participants chose to modify materials, procedures, and the way in which the original lesson was assessed. Some participants modified the engagement strategy, others ways to make the lesson more interactive. Classroom management was an often-documented consideration. Technology integration, challenges evident, using prior knowledge and what learning would occur were all changes they noted. Last, but not least were modifications they would make to support the students' learning.

Table 4.15

Participants' Modifications of The Lesson Plans

Modifications	Participant Responses
Materials	Instead of using soup can size glass jars, I have seen much larger glass walls that I think would be more effective (Participant 4)
Procedure	I would use the same questions as the original lesson, but I would not have the students make their drawings yet. (Participant 7) In the Ms. Silcox's lesson plan, she points to the different bones on the skeleton and tells them "what the function of each bone is and/or what it protects." I think there's a better way to do this using the "Explore" part of the 5E Format. It'll be much more interesting to the kids if they get to play with the model. Each table can have the chance to come up and explore the skeleton. For the tables that are waiting for their turn it would be

	good to have smaller models of different parts of a skeleton like a hand or skull, plus diagrams of the human skeleton. This way they'll have something to explore while waiting for their chance to explore the large model. I would move into the "Explain" portion of the lesson. This would have similarities to Ms. Silcox's Activity 1, but instead of simply pointing to parts of the skeleton I would ask the kids what questions they have. I will write many of their questions on the whiteboard. (Participant 7) Ms. Silcox's activity 3 is very similar to what I would do in the "Extend" portion of the lesson. She has the students make individual skeletons from work sheets. I would do something similar. Since I'm very artistic in nature I would probably design my own skeletons. I think making it a bit like a puzzle would be good. After we pass out the work sheets of each skeleton puzzle, this is when I would name the important bones in the body. I would use sticky notes to label the bones on our big class skeleton. The students would label the bones in their puzzles in crayon. Then the students would cut out their bones and put them together into a skeleton. I think I would have the finished puzzle be about 2-3 feet tall. Another way to make this interesting for the students is to do this project sometime in the beginning of October, so that the finished skeletons could hang around the classroom as not only scientific examples, but also Halloween

	decorations. (Participant 7) I would add these steps: They will record attempts in a chart Students will analyze and explain their findings with other students. Students will be required to make a Venn diagram to compare and contrast with one other salad dressing, and utilize their data charts to draw a reasonable conclusion. (Participant 13)
Assessment	I would informally assess the students by listening to the discussion that they had in pairs, and asking questions and then and how active and how good their explanations were to other students in the class discussions. I would assess the students formally by giving them points for completing the three facts that they wrote down from the book. (Participant 4) Ms. Silcox uses informal assessment in her lesson. She uses formative assessment throughout the lesson through questioning and summative assessment at the end through making sure everyone completes a skeleton. Nothing is graded in her lesson plan. I feel that in order to really make sure every student got a good introduction to skeletal systems some formal assessment is needed. In my “Evaluate” stage I would check to make sure everybody’s skeletons are properly built. I would develop a simple scoring tool to evaluate their work. I would, of

	course, also use formative assessment throughout the lesson. (Participant 7) I would not assess the students as the book suggested. I would informally assess the students by listening to the discussion that they had in pairs and how active students were in the class discussions. I would assess the students formally by giving them points for completing the three facts that they wrote down from the book. (Participant 4) Later, the books can be used to determine if the children are able to make connections between letters and objects (Participant 14).
Engagement	I think that there are better ways to grab the students' attention at the beginning of this lesson. For instance, I think having a full-size skeleton model is going to really get their attention and be a memorable part of the lesson. To "Engage" the students I would have the skeleton covered with a blanket so the students wouldn't see exactly what was under it. Then I'd ask the students if any of them have ever broken a bone. In a class full of nine year olds the odds are at least someone has broken a bone. If no one has I can tell them about my broken thumb from earlier this year. After awhile when I feel that their curiosity is growing I would ask them if they want to see what a skeleton looks like.

	By this point their answer is going to be yes. That's when I pull the blanket off of the skeleton. (Participant 7) A few things I would probably try to incorporate into the lesson would maybe be some sort of literature for engagement. I would maybe find a fun story about a plant. (Participant 15) I feel this lesson needs an attention getter for the students. This could be done by having the students do a blind taste test of common salad dressings and ask the students what ingredients compose the dressing. (Participant 13)
Interaction	I may also think of more interactive ways to share the information. For example, making a class list, or doing a jigsaw. I would like to incorporate more interactions and possibly movement among the various groups, so the students are able to see more than the seedlings and ideas of their group alone (Participant 15)
Classroom management	I think having a large glass wall for the entire class to observe would ensure that none of the ants would be subject to any of the students' aggressive behavior. I think this would be helpful in making sure that the students can focus on their other work when they are not working on science. (Participant 4) I think that keeping students on task is always challenging in any subject but especially in science. This is because the students would be so excited about simply watching

	the ants that I can see some of them not wanting to or simply forgetting to do their work. This is why it is so important for the teacher to constantly be observing. I believe that it would be important and educational to allow the students to have time to be engaged with the ants simply by watching them but I would also guide them through the process so that they can gently be reminded of the other tasks they need to accomplish as well. (Participant 4) For the tables that are waiting for their turn it would be good to have smaller models of different parts of a skeleton like a hand or skull, plus diagrams of the human skeleton. This way they'll have something to explore while waiting for their chance to explore the large model. (Participant 7) I foresee with this activity the children becoming overly excited during our nature walk. Because I know that kids are distracted easily and enjoy exploring, I would be sure to discuss the expectations and acceptable behaviors for the walk. The students would need to understand that science is fun, but this is an educational experience that will help us learn. (Participant 14)
Integration	I would add a reading from a book about ants. I would find a book that talked about ants' behaviors, environments, different types of ants, etc. and of course it would have to

	include wonderful vibrant pictures. Ideally I would like to have one large book for me to read at the front of the class and then each student would have their own individual book to read along with. (Participant 4) A few things I would probably try to incorporate into the lesson would maybe be some sort of literature for engagement. (Participant 15) After the students are done observing the ants, as a class we will fill out the I Notice- I Wonder chart on the whiteboard at the front of the class. (drawing from readings – The Sky's the Limit) (Participant 4) As a class we will read a book about skeletons. Ms. Silcox recommended the book *The Skeleton Inside You*, but I was unable to find a copy of it at my library. I would try to find something grade appropriate about the skeleton. It is possible our school science text would have something. After we've read through the text I would ask the students which of their questions were answered in the reading. Any questions that weren't answered could be found on the internet. The goal would be to answer all of their questions about skeletons. (Participant 7) By tweaking the lesson a bit, a teacher could easily add additional content into the lesson. I think their can almost always be room for math in science. The teacher could have the students

	graph the information in various ways. The teacher could also discuss the history of the plants, for example, why do we have corn? This could incorporate some social studies. The teacher could go further to discuss where the plants typically grow and why, which would also fall under social studies, specifically geography. Depending on the grade level standards, there are many opportunities outside of the investigation for the teacher to incorporate additional content areas. (Participant 15) Not only science students will be working on their writing skill as well, they will have to write the details of their discovery and summery of what they have learned from the lesson. (Participant 12) I found an activity called "Make an ABC Nature Book". Although this is not a lesson from a specific curriculum, it can be modified to meet the standards in science, reading, and writing. In particular, I think most science lessons almost always integrate other subjects. The most commonly integrated subjects are reading and writing. Math can also be included in science but this often depends on the topic of the lesson and the grade level that is completing the activity. Because I am planning to teach 1st grade, integration of math will not be as common in science lessons. However, because of the emphasis that is placed on reading and writing, I will try to provide science

	instruction that involves both of these skills in order to "double and triple dip" during activities and assignments. My children will be using and improving their reading and writing skills, but they will be participating in science activities that are not only fun and engaging, but also educational (Participant 14) It would be easy to discuss geographical differences between areas (desert vs. mountains) and even integrate a little bit of social studies. (Participant 14)
Technology	Then show the students a tsunami video from You Tube and have them discuss how what they saw is connected to a tsunami. (Participant 6)
Challenges for students	Lead the students through the experiment *Wipe Out* and have them write down their scientific observations about what they see. Challenge (for students): understanding the characteristics of a wave) Collaboratively, students will choose ratio for the heights of buildings, and the area of the village or city. Challenge (for students: ratio) (Participant 6)
Prior knowledge	The lesson opens with the teacher asking students a series of questions about a house being built. This is supposed to lead them into wanting to learn about skeletons. The problem with this is that I don't think the students are really going to get

	hooked by this line of questioning. If anything I think they might get confused by the home construction talk. Also I don't know if many 3rd graders would have knowledge of building frame supports to make a house. (Participant 7) My first impression of the lesson was: "How are the students supposed to understand what a tsunami is without seeing and/or recreating one?" (Participant 6)
Learning	I would anticipate that after the students worked through the lesson, they would not gain a deep understanding of tsunamis and their causes and/or their consequences on a society. After reviewing the lesson, it seems that they would have a surface-level (no pun intended) understanding of tsunamis. The students would most likely have fun creating a model of a village or city doomed to be hit by a tsunami; however, without further investigation, I don't know how valuable this lesson would be for my students? I think that the students would get greatly involved in the model-making process, which is great for group-skills, but that they may forget why they were building it. (Participant 6)
Support needed	Students would need support with understanding the damage a tsunami would cause and building a village using ratio. (Participant 6) For students to come up with the definition of magnetism on

	their own. (Participant 12) One problem may be that the children are unable to find objects to represent each letter of the alphabet. In this case, we would brainstorm as a class and come up with objects that would still be found in nature but might not be found on our playground or in our neighborhood (EX: Z is for Zebra). (Participant 14)

Assertion 3: The participants identified inquiry-based ways to motivate student learning.

The following table presents common themes in participants' ideas, expressed after evaluating a lesson plan, about motivating students through inquiry-based instruction When the participants thought about the kinds of science instruction that would motivate elementary children, they immediately went to components of inquiry. Using live specimens, making real world connections and taking advantage of the natural curiosity of children were chosen as motivating. Having hands-on activities, working in small groups and even going outside were other ideas for motivating elementary students.

Table 4.16

Participants' Identification of Ways to Motivate Learning

Motivations for students	Participant Responses
Use of live specimens	I think that simply observing the ants would be a huge

	motivation to the students. My second grade class' favorite subject is science and they have already studied larva, mealworms and butterflies and they absolutely love watching these animals change and just simply live. The fact that ants are very mobile creatures makes this lesson even more enjoyable because the students will thrive on the ants' fast pace environment. (Participant 4) I also think students will be very motivated to learn because they will be working on real life objects. (Participant 12)
Real world connection	I would have the skeleton covered with a blanket so the students wouldn't see exactly what was under it. Then I'd ask the students if any of them have ever broken a bone. In a class full of nine year olds the odds are at least someone has broken a bone. If no one has I can tell them about my broken thumb from earlier this year. This would engage them in the activity. I'd ask some open-ended questions to fuel the conversation. These could be things like "What do think you do for a broken bone?" or "How many bones do you think we have?" or "Why do you think we have bones?" I'd base my questions off of the responses I get from my students. This way it would be like a normal conversation. (Participant 7)
Using student curiosity	I would have the skeleton covered with a blanket so the students wouldn't see exactly what was under it. After awhile

	when I feel that their curiosity is growing I would ask them if they want to see what a skeleton looks like. By this point their answer is going to be yes. That's when I pull the blanket off of the skeleton. (Participant 7)
Hands-on	The recreation of a village or city is a hands-on activity, which would motivate the students. It is also up to the students to decide how to recreate the city and to break into groups to be in charge of making all the components of a city. Choice almost always provides motivation. This lesson is like a classroom version of the computer game Sims City. From what I understand, this is a highly popular game. (Participant 6)
Small groups	I think the students would really enjoy the engagement of the lesson, as they would be able to look closely, in groups, at the seedlings. I think they would also really enjoy a break from lecture style in the classroom to work with their small groups. I think working with others in groups would motivate the students. This would also help to keep students on task, as typically the seating arrangement is done in a way that at each group, there is a "leader," and the students keep one another on task (Participant 15)
Outdoors	One of the highlights and eye catchers of the lesson is the fact that it gets children out of the classroom. It is often difficult to bring the outside into the classroom, but it is very easy to take

	the classroom outside. The children will be motivated to find different objects; they will be forced to be creative and use their careful searching skills. I think most 1st graders enjoy getting dirty, searching for bugs, and spotting different types of plants and leaves; this activity will allow them to do just that, but from a teaching perspective, they will be improving their observation skills, reading, writing, text to object correlations, and phonics skills. Understanding this is important because each of these skills is essential for children to develop as they progress through school. (Participant 14)

Assertion 4: In evaluating lesson plans, the participants seemed to focus more on assumptions about content than other areas, such as physical ability, special needs, giftedness, race/ethnicity/culture, gender or socio-economic status.

The following table presents common themes in participants' ideas about assumptions made/ not made in the lesson plan they were evaluating. The participants were asked to think about their lessons to see if they made any assumptions. When they did, they found that there were assumptions made about the prior knowledge of the learners, and also assumption about the math concepts and ability, and reading and writing ability the learners might have. One participant noticed there were some possible cultural and special needs assumptions made, and one participant who found no assumptions at all!

Table 4.17

Participants' Identification of Assumptions Within Lesson Plans

Assumption	Participant Response
Prior knowledge	This lesson makes the assumption that the students have seen and are familiar with ants because the first part of the lesson involves the students drawing the ants and explaining their drawings. (Participant 4) The lesson opens with the teacher asking students a series of questions about a house being built. This is supposed to lead them into wanting to learn about skeletons. The problem with this is that I don't think the students are really going to get hooked by this line of questioning. If anything I think they might get confused by the home construction talk. Also I don't know if many 3rd graders would have knowledge of building frame supports to make a house. (Participant 7) There is a major assumption that after a brief, 3 paragraph explanation (included with the lesson), that the students will be able to visualize a tsunami. Even more, this lesson supposes that children have the previous experience of either being to the ocean and having firsthand experience with the characteristics of a wave or that at some point in their life experiences/education

	have been properly introduced to the characteristics of waves. (Participant 6) As previously mentioned, this lesson assumes that students understand the characteristics of waves. Granted, this is a 6th-8th-grade lesson, therefore, they may well understand waves. We do, however, live in a state without any coastline! (Participant 6) Some assumptions that this lesson makes are that all students have the ability to recognize these ingredients. Without some prior knowledge the students may mix too much of one ingredient or too many of all the ingredients and they may never come to a final edible salad dressing. (Participant 13)
Math concepts and ability	There is also an assumption that students will be able to create ratios with regards to the buildings and land area. The assumption is that they their math skills are at a high enough level to make those ratios. (Participant 6) This lesson also assumes that these students have the ability to use measurements. (Participant 15)

Reading/Writing ability	I don't necessarily think the students need to be at a particular reading level to engage in this activity. The readings could be read individually, as groups, or aloud as a class. That is one of the positive features of this investigation in an ELD classroom, however, some reading may be beneficial to the students, as it is meaningful and content imbedded. But according to the lesson, this investigation does NOT require individual reading. (Participant 15) Depending on how the students are charting the characteristics, this may require some writing skills while charting, which go in part with reading. While working in groups, students could take turns writing, or the more proficient students may step up to write. Students could be required to write sentences, or they may just write words. This would allow the teacher to modify the instruction based on the level of proficiency of the group, or the individual student. (Participant 14) This science lesson may assume that children know each of the 26 letters in the alphabet, but in reality, this is not an absolute necessity. (Participant 14)
Cultural	Depending on the cultural background of the students some of them may not have any knowledge or experience with salad dressing.

Special Needs	Special Needs Adaptation: the lesson assumes there are no special needs. During the demonstration/experiment you could pair a special needs child up with another child who understands the material and the concepts. Working in pairs will help both of the students. It will benefit the special needs student by having someone other than the teacher explain the concepts to him/her. Also, by explaining the concepts to someone else, the other student will reinforce his/her own knowledge of the subject matter. (Participant 12)
No assumptions	Additionally, factors such as physical ability, special needs, giftedness, race, ethnicity, culture, gender, and socioeconomic status do not play a role in the activity; one student will not have an advantage over another and therefore everyone will be able to participate in the activity and explore nature at the same pace. (Participant 14)

Assignment 4. By the time the participants got to the fourth assignment, they were very familiar with "teaching by inquiry" and learning by inquiry because each of our classes began with an inquiry-based science lesson. Assignment 4 was multi-faceted, combining developing a lesson, teaching the lesson, have a peer observation and reflection. There was synthesis of key concepts of the course. Participants needed to use a driving question about teaching and learning that they were exploring in the context of planning and implementing their lesson. They could choose to teach only to a small

group of students to make differentiation a little more manageable. They were required to identify benchmarks and standards for the district they were in, as well as identify the national standards the lesson addressed. They needed to find ways to integrate other content areas and technology if it was possible, and also create an assessment. They needed to have a pre and post observation with the peer observer, but were asked to do some personal reflection before the post observation.

This lesson was video taped so that the participant doing the teaching could review the tape prior to the post discussion. There were very specific steps that the peer observers needed to follow, as well as the observee during the post discussion. The peer observer was given the opportunity to share all of their thoughts from the notes they took during the observation while the "teacher" remained silent. Afterwards the teacher shared a personal reflection of the lesson, and then could address the comments of the observer.

Again, there was a framework of questions provided for the summary the prospective teachers had to write. These were:

- After analyzing your video, what were your successes?
- Your frustrations?
- What were the student successes and frustrations?
- What did you see in the video that you did not notice during the time you were teaching the lesson?
- How would you assess yourself?
- How did the observations of your colleague match your perceptions of the lesson?

- What would your next steps be?
- What questions do you have now?
- What did you learn about yourself, your students, and learning and teaching from this experience?
- Take another copy of the lesson and mark it to show what changes you would make.

The process was involved, but the idea of studying your own teaching, peer observation, driving questions, integration of other content and or technology, and helping students reach their potential were all repeated themes in the course. This assignment built on the previous assignment when the participants had analyzed a lesson.

Assertion 1: The driving questions the participants chose were often about student engagement.

The following table presents common themes in participants' choice of driving questions about their own implementation of inquiry-based lessons they were going to teach. The driving questions were intended to focus observations by a peer. The majority chose a question that involved student engagement. Several participants asked a driving question about the content outcomes. A participant who believed she needed to make sure she was giving equal opportunities to boys and to girls chose gender concerns. Higher order thinking skills, attending to each student and giving appropriate feedback were also chosen.

Table 4.18

Driving Questions to Guide Observation of Teaching

Driving question	Participant Responses
Student engagement	Does my lesson keep students fully engaged in learning? (Participant 1) My driving question for this lesson is “are the students engaged and for how long?” I want to know if the majority of the class is engaged in the activity and for how long this engagement takes place. Are there certain parts of the lesson that the students are more involved in than others? Was there a specific timeframe? (Participant 4) What is level of student engagement? (Participant 3) Are all/most of my students engaged at all phases throughout the lesson? How does my teaching help/hinder student’s engagement? (Participant 6) Are the students engaged at all times? (Participant 14) Are the students involved in the learning while I am teaching? (Participant 12) I wanted to see how well they students that were not engaged in my questions acted and responded. (Participant 2)
Content Outcomes	Would students be able to identify their ridge patterns by themselves? (Participant 5) Will this inquiry experience lead to a solid grasp on the basic

	physical traits of Earth? (Participant 11)
Gender	I want to find out if I was paying any type of special attention or extra attention to female students versus male students. (Participant 13)
Higher order thinking skills	Am I asking questions that inspire higher order thinking? (Participant 15)
Attending to each student	Do I give each student appropriate attention, rather than focusing only on a few students to the exclusion of the others? (Participant 7)
Appropriate feedback	Am I providing students with enough feedback both to encourage and help refine/correct their work? (Participant 9)

Assertion 2: Participants found ways to integrate their science lessons with other content areas.

The following table presents common themes in participants' ideas about integrating other content areas into science lessons. In choosing a lesson, some participants found there was some natural integration that occurred. Others modified their lessons to incorporate more integration. Some participants integrated science and math, others, science math and language arts. Science was also integrated with just reading, with technology and also with art!

Table 4.19

Participants' Integration of Science with Other Content Areas in Revised Lesson Plans

Integration	Participant Responses
Science and Math	I feel that because these two standards of math and science fit together so well, that adding another content area could make the lesson overwhelming if done improperly. I only included two content areas with my lesson, but if I extended the lesson over a couple days, I would possibly be able to include a language arts component of writing a description of the created tessellation or even adding an art content and allowing students to color and decorate their tessellation. (Participant 1) The lesson is also integrated with math standards. (Participant 13)
Science, Math and Language Arts	My lesson integrates science, math, reading and writing. It is an investigation driven lesson that is centered on science but I also added other subjects as well. Originally, the FOSS lesson had only integrated reading into the lesson but I thought there was also an opportunity to include math and writing. Math was easily included by having the students make a graph about how many washers they could pick up; depending on where on the rivet they wound the wire. Writing was easily included at the end of the lesson so that the students could reflect on what they had learned and use the new vocabulary so that they immediately made these

	personal connections. (Participant 4) I only included two content areas with my lesson, but if I extended the lesson over a couple days, I would possibly be able to include a language arts component of writing a description of the created tessellation or even adding an art content and allowing students to color and decorate their tessellation. (Participant 1) Students can use books or the internet to research to incorporate reading, and the multiple writing sections of the lesson require the inclusion of that second language arts area. Measurements and observations that take place pull in mathematics skills the students already possess. (Participant3) Other content areas that can be included I this lesson include writing, if a formal written evaluation is chosen and math, of rulers and recording sheets are used to measure the lengths of the walls and the distance between the dominoes. (Participant 6) This lesson has the potential to be connected with writing standards as well. (Participant 13)
Science and Reading	A content area that would be associated with this lesson is reading. When students are participating in the button BINGO game, they will first need to identify the words on the BINGO chart. (Participant 2)
Science and Technology	I was able to find a technology component (website), which would allow a student who is unable to use scissors to participate

	in the activity. The technology factor was something I originally planned on using in my lesson as an additional step to students making a tessellation, because scientists often use computers/technology but had to get rid of the component the day of the lesson because the student laptops were being used by another class. (Participant 1) Students can use books or the internet to research to incorporate reading on classroom laptops. (Participant 3)
Science and Art	Allow students to not only write, but also draw, and/or chart their findings. This will support students who are more visual in expressing through drawings rather than writing. (Participant 15) I would possibly be able to include a language arts component of writing a description of the created tessellation or even adding art content and allowing students to color and decorate their tessellation. (Participant 1)

Assertion 3: The prospective teachers used different types of assessment in the lessons they taught.

The following table presents common themes in participants' ideas about assessing science lessons. Assessment is a word on every educator's mind. The themes included assessing prior knowledge, products, and discussions. Class participation/on task behavior was an aspect assessed, as well as assessment through teacher observation.

Table 4.20

Participants' Use of Assessments in Lessons Taught

Assessment	Participant Response
Prior Knowledge	I wanted to assess the student's prior knowledge, so I encouraged them to talk about what they knew about fingerprints. I did this by listening to their comments on the shapes they saw on their fingertips and later by reading the journal entry they wrote when identifying their own pattern. (Participant 5)
Products	My main assessment for this lesson was looking at what the students created (completed tessellation). If the students were able to make a full tessellation or even the majority of a tessellation then I knew that they were working diligently. If however students turned in a sheet of paper with only one or two shapes draw or perhaps turned in nothing at all, then I would know that students were either being distracted, or were distracting others. . . . I would also judge some of the success on how well the tessellation was designed, meaning if the tessellation had spaces and gaps, or if the tessellation was clear looking with few flaws. (Participant 1) The formal assessments were if the students made the graph and wrote a reflection using the new vocabulary. I did not grade

	for punctuation or grammar; I was only concerned about them making a graph that showed their findings and writing their thoughts using the new words. This is another good way to assess their learning since every student is required to write something and in even the best classroom discussion not every students gets to share his/her thoughts. Therefore, this will give me further insight as to how well they truly understand the information. (Participant 4) I will evaluate . . . the quality of the product (did they follow directions?) (Oobleck). (Participant 3) Their packet will be turned in and used to evaluate their understanding of states of matter as well as see if they followed the instructions and completed all the activities. (Participant 3) The chart/handout I created served as a concrete method to assess student understanding and complete evaluations if needed. (Participant 9)
Discussions	I assessed the students informally and formally. The main assessment was the discussions; did the students participate and did they understand the concepts? I would know if they had been successful in learning this lesson through these discussions. Unfortunately, it was difficult to have a class discussion with this particular class without having to ask many of the students to please stop talking. It was very loud and somewhat

	overwhelming so after doing the lesson, I think that a more accurate assessment was done when I talked with each group individually. (Participant 3) I felt that the combination of learning to define new terms, record data, and think more critically would be evident through discussion would make this lesson beneficial to all of the students. (Participant 9)
Class participation/on task	I will evaluate class participation, how well each child follows directions, if they are keeping on task (Participant 3)
Through Observation	I am not going to use a formal assessment, asking the students to write out and draw how domino walls work; however, that would also serve as a clear indicator as to whether or not the students were successful. I will observe and assess as the students are working. (Participant 6)

Assertion 4: In general, participants felt they were successful in teaching the lesson.

The following table presents common themes in participants' ideas about successes when teaching their science lessons. There were many different ways the participants described what they felt were their successes. Some based their success on the children's learning, others on how well they engaged the students. Others thought if they and the students had fun they were successful, and some looked for student achievement to judge their success. Student participation, products, and the clarity of the instruction given were components listed as successes. If their students completed the lesson, if they participated in and were correct in an oral assessment-like discussion, the prospective teachers felt successful. If they were able to use teaching techniques, like giving feedback, using good questioning strategies and had a process that went smoothly, they believed they were successful.

Table 4.21

Participants' Perceptions of Success in Teaching the Lessons

Element of Success	Participant Response
Elementary students learning	Students were successful in learning this lesson; they told me fingerprints are used in everyday life to identify people. They believed that maybe animals would have different prints, too. The students knew most of the vocabulary words. (Participant 5)
Engaging the students	My successes were being able to engage the students (Participant 5) The students seemed to have the success of enjoyment, because they were cutting and tracing and doing an activity that was out of their ordinary routine and so they were more engaged then I could have predicted. (Participant1) My colleague's observations were in-line with my observations, because he mentioned that the lesson went smoothly and that all students seemed to be engaged in the activity, and how all students were able to produce something (some more than

	others though). (Participant 1) I immediately engaged the students by showing them the colorful buttons ad asking, “How can you group buttons?” Right away when I asked about groupings of buttons, all students wanted to contribute and they quickly understood what I was asking. (Participant 2) Overall I feel I did a really good job teaching this lesson. The students were engaged throughout the entire lesson and my questions were clear and specific. (Participant 2) The teacher who observed me was very encouraging. He said that I did an excellent job of engaging the students. (Participant 2) I feel that overall I was successful at keeping the kids engaged for the 35-40 minutes we took for the lesson. (Participant 6) I think my “Explore” portion was pretty good. This actually engaged the kids more than the engage did. They students were very excited to use the camera and see what everyone else was talking about. (Participant 7) This lesson was a highly successful experience for me, especially in the areas of (giving) feedback, student engagement, and proximity as I focused extra effort to incorporate them into my teaching. (Participant 9) Students were engaged in the activity from start to finish because I made a point of not lecturing or giving answers and

	giving students the opportunity to explore and find things out for themselves. (Participant 9)
Having fun	My successes were being able to engage the students . . . .have fun. (Participant 5) The success of my lesson was that . . . the students had a blast making the oobleck. (Participant 3)
Student achievement	I was successful in teaching them more about fingerprints. I noticed that the four girls had no problem in identifying their own ridge pattern, even without magnifying glasses. They quickly identified and described them. (Participant 5) By the end of the lesson the students had a really strong foundation on classifying objects according to their physical properties and gave me ideas of new ways that they could do it. (Participant 2) They all refreshed their previous knowledge of states of matter and learned a good deal of new information. (Participant 3) All of the students were very successful in learning and applying the new terms, classifying materials, and discussing their new knowledge. (Participant 9)
Participation	I think that my biggest success in this lesson was having all the students participating in the activity, because part of me thought there might be one or two students who would refuse to do the activity because I wasn't their teacher, or some kind of 6th

	grade reasoning about being cool. (Participant 1) It is apparent that most of them absolutely love to do science experiments. I was pleasantly surprised to see some students that are not usually actively involved be very excited and participatory in this lab. (Participant 4)
Products	and how all students were able to produce something (some more than others though). (Participant 1) The students were successful at being active participants….all the students were on task and they contributed to the discussion. (Participant 2) Also they all completed excellent favorite food descriptive paragraphs, which was a feat because most of them have been told they cannot write well at all. (Participant 13) I will be able to tell if my students are successful if they productively build a domino wall. Also if the students can effectively create various shapes with the dominos that will serve as a clear indication that the students have succeeded. (Participant 6)
Clarity of instruction	The students were engaged throughout the entire lesson and my questions were clear and specific. I did not have to reword my questions to make sure the understood. (Participant 2)
Completed the lesson	The success of my lesson was that I completed it (Participant 3)

Oral Assessment	I will be sure that they are successful if they can correctly explain their findings and defend them, as “real” scientists would. (Participant 6) As far as the class “discussions as assessment” went, I was sure to make the students raise their and, and when I noticed someone had not participated, I directed a question towards them. (Participant 6) All of the students were very successful in learning and applying the new terms, classifying materials, and discussing their new knowledge (Participant 9)
Feedback	This lesson was a highly successful experience for me, especially in the areas of feedback, (student engagement, and proximity) as I focused extra effort to incorporate them into my teaching (Participant 9)
Questioning	My driving question! Am I asking questions that inspire higher order thinking? (Participant 15)
Process	For some reason I ended up giving the students one piece of paper and allowing them to go through the whole process step by step. Then I handed out the next piece and so on. I am really glad it happened the way it did. I feel it would have been too confusing for the students to have several pieces of paper out and to keep their thoughts organized.

Assertion 5: The participants were able to look critically at their experience and reflect on ways to improve.

The following table presents common themes in participants' ideas about improvements to be made when teaching these science lessons. In thinking about how their lessons went, despite their many successes, the participants found ways they could improve. Many of them would like to have extended the learning. Using technology, integrating the other content areas more, more time and better use of time were some suggestions they had. Classroom management was an area identified as needing improvement. One participant felt she needed more eye contact, still others felt their instruction needed more clarity. Safety was an issue for one participant; others felt they would have benefited from knowing their students a little better. Improvements could have been made in discussion and closure. Engagement and maintaining of engagement were improvements that were desired. Better visual aids were on the list too.

Table 4.22

Participants' Ideas for Improving the Lessons

Improvements	Participant Responses
Extend the learning	Observer noted that I could have made a list on the board of how fingerprints are used. At the end she suggested I could have made a graph of the patterns that were found in the group. I agree that I could have integrated these suggestions so the lesson had

	more content. Next time I will think more about how I can incorporate math and other subject areas into it to make the lesson better? (Participant 5) If I were teaching this in my own class, I would say that I would maybe have the students build a 3D model of their tessellation or maybe build a second more complex tessellation. I would have questions though about available materials I would be allowed to order for students to build a 3D model of their tessellation, and perhaps how much time and/or money we would be allowed to work on a project like this. Maybe I could look for some natural (honeycomb) or man-made (chain link fence) as examples. (Participant 1) If I had to teach this lesson again there may be more discussion and closure at the end or a writing component to assess. (Participant 5) I wish I had had the students write their own ideas on the board/charts during discussions. Not only would they have a higher sense of ownership in the project, they also would be providing themselves a resource to consult during the classification process. (Participant 3) The "Extend" portion could have gone smoother. (Participant 7)
Use of technology	I think the lesson could have gone better if we had gotten to

	use the laptops and had some additional time. (Participant 1)
More integration	Next time I will think more about how I can incorporate math and other subject areas into it. (Participant 5)
More time	I think the lesson could have gone better if. . we had some additional time. (Participant 1)
Use of time	During the actual construction of the cameras, sometimes the students were sitting around waiting for me to come by and give them instruction. My observer told me that for times like those when you have to split attention to groups it is important to have something that the others can be doing. She recommended having printed out instructions rather than directly showing each individual group the procedures. (Participant 7)
Classroom Management	After doing the lesson, I think that I need to work on focusing on these students more rather than focus on the misbehaving students. I try to be encouraging but I think that I can do better and make sure that I am constantly being positive and not letting the more unruly students get the best of me. Perhaps this also means I need to practice having more patience! Overall, I think that this has really shown me the importance of having an effective and consistent classroom management technique. (Participant 4) Keep all of the materials in one central location and have the students come up one at a time. Let the students chart their states

	of matter on chart paper or the board. (Participant 3) Looking back I should have had one cereal box per student rather than grouping them. Also, it would have helped to have had printed our instructions for each student to use, that way I could have assisted, but they'd have been the ones figuring it out. I would also want to have one pair of scissors and a roll of tape per student – much of our wasted time was in waiting to share materials. (Participant 7)
Eye contact	I asked my observer to focus on my use of space and interactions with the children. She noted that I needed to be sure I made eye contact during instruction. This is definitely a great critique that I need to improve upon. I felt as though I was interacting with everyone because the group was so small. (Participant 2)
Clarity	My peer observer also revealed that I probably should have explained the rules for BINGO. (Participant 2) Another area of improvement would be to have modeled to the girls how they were supposed to explain on writing the pattern they had. There seemed to be confusion about this because I failed to model it. (Participant 5)
Safety	I did not notice that one of the girls tried to put a button in her mouth. It would have been a good idea to go over proper ways to handle the objects such as not putting buttons in the mouth or

	nose. (Participant 2)
Knowing your students	I also noticed how quick some children were at making groups of buttons and how they seemed to take charge. I could have rotated groups halfway through the lesson to allow students to work with someone different. (Participant 2) Teamwork! (Participant 6)
Discussion/closure	If I had to teach this lesson again there may be more discussion and closure. (Participant 2)
Engage/ Maintain engagement	There were many times when I could have done much better. I definitely could have improved the engagement level during the instruction/discussion parts. (Participant 3) I should have come up with something for the engage that would have grabbed their attention better. I think finding a video on the internet would have been a good opener. (Participant 6) The experiment and discussion took about half an hour. By the time we were done, half the group was losing interest though, which would be something I would try to work on for next time. (Participant 9)
Visual Aids	I would say that their biggest challenge was working with the unfamiliar chart format to record data. After observing some difficulty in filling out the chart, I revised my plan and we went through the chart step by step as a whole group. I think that with a better visual aid much of their frustration would have been

	eased. (Participant 9)

Assertion 6: The prospective teachers were able to identify pertinent challenges they encountered when teaching their lesson.

The following table presents common themes in participants' ideas about challenges they encountered when teaching their science lessons. These challenges are probably familiar to all teachers. The first challenge listed though was one of the research situation – the students were distracted by the camera that was recording their lessons for their own analysis. There were challenges the prospective teachers recognized in the elementary students' frustrations. Classroom management, time and implementation were challenges as well for some participants. Lack of support from the mentor teacher was mentioned. One participant found that the elementary students were quite challenged by the concept of teamwork. One participant felt she had no control over things that happened pertinent to their lesson, and another by the student responses

Table 4.23

Participants' Perceptions of Challenges They Encountered in Teaching

Challenge	Participant Response
Distractions	The students got distracted with the video camera, they wanted to leave their desks and use the blackboard to show me their own fingerprints. (Participant 5)
Elementary student frustrations	Student frustrations were that they could not fully describe in writing the pattern that they had. (Participant 5)

	A couple students were a little bothered when I announced that it was time to clean up and that the activity was over. (Participant 1) The student's frustration not only included the teamwork issue, but also the frustration of creating the wall. The good part is that their frustration was a key part of their learning. (Participant 6)
Classroom management	I thinking that a frustration I had was getting the students attention once I had given them the direction to start the activity. I gave directions on what to do, and a couple students helped me pass out materials, and then once students had started working, I wanted to add some hints and tips, and that's what I found difficult is getting the students to stop working for a minute and just listen to some additional instructions. (Participant 1) Unfortunately, it was difficult to have a class discussion with this particular class without having to ask many of the students to please stop talking. It was very loud and somewhat overwhelming so after doing the lesson, I think that a more accurate assessment was done when I talked with each group individually. I think that this problem is mostly attributed to the lack of classroom management. The students are very energetic which can be wonderful but in this class' case, where there is no discipline, it is horrible. Many students shout out inappropriate and rude comments to be funny or mean and there are no consequences for their actions. Some kids have little respect for their teacher and even less respect for the interns. I had to ask a young man

	so many times to please be respectful that I finally insisted that he leave the room for his behavior. It is such a shame that these students who are so full of life do not have the discipline that they need in order to be in an effective learning environment. By the end of the lesson, I was almost in tears because of how much babysitting I had to do and how little teaching and I interacting I actually did get to do. The problem is that this is not the students' fault and I am really sorry that the many of the students who are sweet and want to learn are hindered due to this atmosphere. (Participant 4) The frustrations I noticed were that a couple of children seemed to dominate the conversation and were probably better at recognizing words during BINGO, so they would help out their neighbors. This took away the opportunity for the children to identify words on their own. Each student had their own BINGO card but some students were quicker at identifying the characteristics and then finding the corresponding words. (Participant 2) My biggest frustration was attempting to deal with two of the more independent and obstinate kids in the class. While I had anticipated some problems they seemed to be extra abrasive the day I did my lesson. (Participant 3) The only major frustration I had was the little boy that had so much energy and would finish everything long before the other students. Though I gave him challenges he kept rushing around the

	room and saying how easy everything was for him, rather than thinking about what I was asking him. (Participant 9) The other small frustration was trying to make the shy little girl open up and participate. . . . I think that some of the more eager students intimidated her from speaking up in whole group discussion. When I worked with her one on one she opened up and talked to me a great deal. (Participant 9)
Time	My frustrations were with myself and not with the students. I felt as though I was rushed for time, because I only wanted to take 20-25 minutes of the teacher's/students time. (Participant 2)
Implementation	I could have been more thorough in explaining why scientists classify things and how they (the children) are scientists themselves. I could have also encourage the students to get up and walk around to see how other students classified their buttons instead of going around the table and explaining (seated). I could have incorporated a writing component by asking the students to list all the ways there are to classify buttons but I do not know if time would have allowed this. (Participant 2) The main problem was that I allowed myself to get upset by little things that were not going as planned and other distractions. (Participant 3) I then jumped right into the lesson plan by explaining that we were going to make and record observations, predictions and outcomes,

	instead of explaining how to read the chart and fill it in. This minor hurdle did not prevent further development in the lesson. (Participant 13)
Lack of support	Also the fact that my teacher simply sat in the corner and watched was not encouraging. I had hoped he would walk through the class to observe how engaged they were, or at least take notes on what he liked and thought I could improve. (Participant 3)
Teamwork	One of the failures of the science experience was rooted in an over-looked detail: teamwork. I did not anticipate the skill of teamwork to play such a major role in the effectiveness of this experience. I am not exaggerating, though, when I say that this was the first science activity of the year for the students. At first when the students broke off into their groups, there was a lot of arguing about who was going to set up the domino wall. I had already explained that "working as teams, meaning everyone participates," the groups were to set up the domino walls, but they didn't seem to pay much attention to that detail. It was very surprising how large teamwork's role was in this science experience. (Participant 6)
Lack of control	My original experiment was changed at the last minute. I was frustrated by not knowing who I was going to be working with. Something with the way the teacher chose the students I worked with also frustrated me. (Participant 15)
Student	I was also surprised by how some of the student's responses were

responses	incredibly off topic. I mean nothing to do with dominos, nothing to do with knocking things down! (Participant 6)

Assertion 7: The prospective teachers' reflections were thoughtful and meaningful regarding themselves, their peer observations and students.

The following table presents common themes in participants' reflections and learnings, after talking with their peer observer and viewing the video of their lessons. Some of the participants focused on specific issues about themselves and their teaching, others about their reflection with the peer observer, and still others reflected on the students whom they taught.

Table 4.24

Participants' Reflections

Reflections	Participant Responses
Self	I spent much more time redirecting of addressing specific students then I thought. I also saw that there were a few times where I could read my emotions on my face or in my body language. I was somewhat shocked that I could tell when one student had really frustrated me by the way my face was set. (Participant 3) From teaching this lesson I learned that I am a very capable teacher, because I'm able to think of a subject, and find the

	standards that align with it, and write out a 5E lesson plan, and then execute the whole thing in front of students. I learned that I can plan a lesson and follow the steps in that lesson so that the end result is a successful activity with students learning and being engaged with the activity. (Participant 1) After doing the science experience, my first introspective reflection was, "Wow, that felt really normal." The entire process, from the search of the lesson to the application felt like a typical task and came naturally. This was not only promising for my science career, but it was also a welcomed confirmation that I am going to enjoy my choice of profession. This was one of the first times I have ever planned and executed my own lesson plan. This was a great experience and I learned, more than anything, to expect the unexpected in any lesson. (Participant 6) I don't know if my questions really promote higher order thinking though. I know I asked plenty of questions, but I'm having a hard time deciding if that is really what I was going for or got. Is there another way to think about it? (Participant 15) It was very surprising how large teamwork's role was in this science experience. I was also surprised by how some of the student's responses were incredibly off- topic. I mean nothing to do with dominos, nothing to do with knocking things down!

	(Participant 6) I also learned that teaching is a learning experience and there is always room for improvement. . . . things never go exactly as planned and it is important to be flexible and creative in my thinking and my planning. (Participant 2) I tend to get a bit preoccupied with the aspects of a lesson that wee frustrating and fail to recognize all of the things that went well. For instance, I do not always think about wait time but in this lesson I gave each student a chance to process and reflect before answering a question. (Participant 9) If I were to teach this lesson again, I would make it a more creative activity, like an actual mystery, or stations. I would love to teach this lesson in a unit about light instead of as an isolated lesson. (Participant 9) Something I've learned about myself is that I am a control freak. I also learned that I get frustrated when I ask questions and the students don't come to the answers. I really need to work on my wait time and rephrasing questions in a guiding way. (Participant 15) The video did confirm my thinking that I need to slow down my speaking when it came to giving direction and feedback. (Participant 13) I learned that it is very hard to keep a whole class in line and

	focused. I realized the true importance of a good classroom management plan. Just because I was different for one lesson, the students were not going to instantly change the habits and behaviors they had been learning and practicing for months. (Participant 3) I think the lesson could have gone better if we had gotten to use the laptops and had some additional time, but I also think that all lessons can go better. I'm sure if I practiced this lesson on several other classes over several years, I would be able to streamline the successes and diminish the flaws. (Participant 1) What's more, I realized that some students need more scaffolding than other ones, and that I need to know my students so I can manage my classroom better. What I learned about myself and teaching is that I will feel more confident as I have more teaching experiences. I also need to take more advantage of the potential of each lesson by integrating more content. I noticed right away how students get distracted from time to time, and I need to know what distractions I am going to allow and which ones I should stop. I liked this assignment because it helped me to evaluate myself. (Participant 5) Even though I left some information out, I think that I did the most I could in a short amount of time. I felt like the students were in charge of their own learning and I did not just give them

	answers to questions, but instead I guided them in the right direction. (Participant 2) After watching the video I noticed a few more things I can improve. I focused on students that had questions, ignoring that a couple of them had finished and were wandering around. I could have had these students compare their fingerprints, and talk about them in the meantime. Another area of improvement would be to have modeled to the girls how they were supposed to explain on writing the pattern they had. There seemed to be confusion about this because I failed to model it. I also noticed that I seemed I little disorganized getting all the material from a desk. Next time, I should have everything ready. (Participant 5)

With peers	I also learned that my driving question of, "Does my lesson keep students fully engaged in learning?" was answered by my colleague and me the same way. Both my colleague and I thought that my driving question was answered successfully, because of how the students behaved during the lesson and the product that the students produced from the activity. (Participant 1) I asked my observer to focus on my use of space and interactions with the children. She noted that I needed to be sure I made eye contact during instruction. This is definitely a great critique that I need to improve upon. (Participant 2) I liked that my colleague noticed that I was not just giving the answers to the questions; I wanted them to figure it out and they did. She also told me "maybe review properties a little more so sorting is easier, but I like that they choose how to sort." I feel like I had a superficial understanding of how the lesson went and my colleague provided with more in depth details since she was an outsider looking in. (Participant 2) When I asked the teacher to please watch for student engagement she said that was a very important topic and something that she strives to accomplish every day. Half way through the lesson she approached me and said that almost all of the students seemed to be engaged. Afterwards she said that for

	the most part most of the students seemed to be participating and learning. She offered the suggestion of having students that were having trouble put their hands on their heads or put their head down on their desk until they could calm down enough to rejoin the lab. (Participant 4) My colleague's perception did match my perception, especially regarding me speaking too quickly. My colleague also commented on how well balanced I shared my attention between the boys and the girls. I too also felt I shared my attention equally. (Participant 13) My colleague noted that I did a good job of providing students with time awareness. At one point I told the students they had one minute left to finish sorting buttons. (Participant 2)
About Students	I am always so impressed at how smart young people are if you just give them the opportunity to let them show you what they know. (Participant 2) What I learned about my students was that they felt intimidated by the camera at the beginning, but they got used to it quickly. Furthermore, students need to be engaged by the teacher from the beginning of the lesson in order to ignite their desire to learn. (Participant 5) The little boy (ELL) was sitting directly to my right during our whole group discussion/instruction to fill out the chart, and

	something that I did not notice at the time but discovered upon later insight was that he was extremely diligent and insistent that he wrote down anything I wrote on the sample chart word for word. I wanted the lesson to be more student-friendly, and I was emphasizing that students put things in their own words. I wish I had caught it so I could have helped him find a way to record data and definitions in a manner that was more meaningful to him. At least through discussion I did assess that the little boy really did understand the new terms and understood at least some of what he was writing. (Participant 9) There were times that I wished I'd had more of the complete attention, but overall I think this experiment was a success. When we came back to class they were eagerly showing their classmates what they'd done. They asked permission to bring their cameras out to the playground to show their friends in other classes. The students asked if I could print out instructions for them to create their own cameras later. (Participant 7) To my surprise, the students finished very close to the same time for each activity. When I announced that one group was the done the other groups, on their own, quickly hurried to finish what they were working on; it was as if this science lesson was a competition to some of them. While the other groups were completing their experiment, I went and talked to the finished

	groups about what they found. I asked them to show me how to turn their magnet on and off and how they were able to make it do that. We also talked about any other questions the students had. (Participant 4) The part of the lesson that I noticed on the video that I hadn't noticed during the actual teaching of the lesson was how much the students were helping one another. I had noticed one or two students helping each other while I was teaching the lesson, but when I watched the video I observed many more students helping each other trace out a shape or move their paper to make more room for a neighbor. (Participant 1) Finally, I noticed that students like to apply new words they learn. For example, the students learned what "ridge" meant and they used it throughout the half hour the lesson lasted. (Participant 5) After watching the video I noticed a few more things I can improve. I focused on students that had questions, ignoring that a couple of them had finished and were wandering around. I could have had these students compare their fingerprints, and talk about them in the meantime. Another area of improvement would be to have modeled to the girls how they were supposed to explain in writing the pattern they had. There seemed to be confusion about this because I failed to model it. I also noticed that I seemed I

	little disorganized getting all the material from a desk. Next time, I should have everything ready. (Participant 5)

Assertion 8: The prospective teachers' implemented aspects of reform-based teaching when teaching their lesson.

The following table shares common themes from the participants' implementation of reform-based strategies while teaching their lesson for Assignment 4. They mention using inquiry-based experiences for their students. Also paying attention to not just giving information, but trying to facilitate student learning, using teamwork to make a prediction, and using observations to support conclusions in an investigation. The use of discussion during a lesson amongst students and as a reflection and summary of learning as a tool is noted, as well as making authentic connections to the real world and providing a student centered experience.

Table 4.25

Implementing Reform-Based Strategies

Aspects of Reform-Based Teaching	Participant Responses
Designing an Inquiry Experiment	I selected a hands-on discovery lesson about light and its role in determining objects as transparent, translucent, and opaque because it met my requirements as listed above. Participant 9
Facilitating learning (Not telling)	I made a point of not lecturing or giving answers and giving students the opportunity to explore and find things out for

information)	themselves. Participant 9
Working Collaboratively to Make a Prediction	This required each pair of students to discuss their thoughts and explain to each other why they predicted their number if they had different predictions. This also encouraged the students to think for themselves and figure out a way to communicate what they were thinking. Participant 13
Observations to Support Conclusions	Using the observations they class came up with each student had to work with their table group to classify what state of matter it (oobleck) is. Each group had to write a paragraph supporting their decision and then present their hypothesis to the class. Lastly, we will go over all of the ideas and then discuss why colloidal suspension is the proper classification for the oobleck. Participant 3
Discussion while Working	The role of discourse/discussion in this lesson is very important. First of all, I want the children to be communicating with each other throughout the lesson. This should be a fun and semi loud experience. Participant 1
Discussion as Reflection/ Summary of Learning	When the experiment is over I want to be able to have and engaging discussion with the children about what they noticed and what they learned. Participant 1
Authentic, Real World Connections	I think my lesson has a fair correlation between the realm of science and the real world because students are going to be able to notice tessellations a lot more once they complete my lesson.

	When the students notice the tiles in their bathroom or the scales on a fish, they'll have a higher understanding of how some things are designed, or why some shapes and patterns appear more frequently than others. Participant 1
Student Centered	I felt like the students were in charge of their own learning and I did not just give then answers to questions, but instead I guided them in the right direction. Participant 2

The participants made an effort to teach using some strategies emphasized in the methods course. These reform-based practices were evident in their reflections from assignment 4. The students explained that they used inquiry experiences with the students, tried to facilitate student learning, and not just give answers. They had students collaborate to make predictions, and to use their observation data in an effort to support their conclusions at the end of an investigation. Discussion was a tool used in many ways, for students to communicate ideas with each other as they work through an investigation, and as a closing activity to summarize and reflect on their learning. Real world connections and providing student centered experiences were strategies that were also mentioned.

The following table provides a summary of the assertions for the assignments from the course, Tables 4.2 - 4.25.

Table 4.26

Summary of Assertions from Assignments 1 - 4

Assignment	Assertion
Assignment 1 What is science?	*Participants had many different attitudes and beliefs about science.*
	The participants also described science as they had experienced it at school, usually in the context of "traditional" instruction.
	Participants sometimes expressed negative attitudes towards their ability to do science, or their experiences with science.
	Participants' visions of science and science teaching sometimes reflected current views of the nature of science.
	Readings seemed to have influenced some participants to see science in a different way.
Assignment 2 Status of Science?	*There were a variety of attitudes about science amongst those interviewed on school staffs.*
	Interviews conducted by the participants included comments related to the influence of standardized testing on Science Instruction.
	Participants perceived inconsistencies in the way the role of science is espoused by administrators, and districts and the reality of the classroom.
	Participants reported that school staff perceived a variety of ways science is being integrated, or could be integrated, into the

	curriculum.
	Participants reported that time for science varied among schools and teachers.
	There were some aspects of inquiry-based science reported.
	Participants perceived many challenges to science teaching and learning in elementary classrooms.
Assignment 3 Evaluate Curriculum	*Participants' initial impressions demonstrate some awareness of inquiry-based instruction in evaluating a lesson plan.*
	Participant modifications reflect a growing understanding of reform-based instruction.
	The participants identified inquiry-based ways to motivate student learning.
	In evaluating lesson plans, the participants seemed to focus more on assumptions about content than other areas, such as physical ability, special needs, giftedness, race/ethnicity/culture, gender or socio-economic status.
Assignment 4 Teaching and Reflection	*The driving questions the participants chose were often about student engagement.*
	Participants found ways to integrate their science lessons with other content areas.
	The prospective teachers used different types of assessment in the lessons they taught.
	In general, participants felt they were successful in teaching the

	lesson.

Assignment 4 Teaching and Reflection	*The participants were able to look critically at their experience and reflect on ways to improve.*
	The prospective teachers were able to identify pertinent challenges they encountered when teaching their lesson.
	The prospective teachers' reflections were thoughtful and meaningful regarding themselves, their peer observations and students.
	The prospective teachers' implemented aspects of reform-based teaching when teaching their lesson.

Reflections

Reflections could be hard copy or electronic. Sometimes there was a stated focus for the reflection, but often it was their choice. I found that often the prospective teachers did not have difficulty with choosing their own topic, and probably preferred that. The topics assigned were:

Week 1 – Describe your own experience of learning science and how you feel it is different in elementary classrooms today

Week 3 – What in your reading so far has been the most meaningful/thought provoking?

Week 5 – What are some "eye-openers" at your school?

Week 8 - What is the current status/politics of science at the elementary level?

Week 11 –Envisioning yourself as a science teacher – what does it look like?

The participants had a lot to say about interning, school settings, elementary students and themselves. Including the weekly reflections was an important part of the class. As the instructor, these reflections gave me an opportunity to get to know the students, and what sense they were making out of the course. The students often quoted from their reflections during class discussions. The writing out of their thoughts may have actually been a positive influence on the discussions. In preparing for the final, they found the reflections valuable reminders of their learning and thinking.

I chose to do a case study for this portion of the data interpretation for several reasons. First of all I see myself as a teacher, an inquirer, and a practitioner researcher, and case study is a methodology often employed in practitioner research (Stake, 1995, 2000). A case study provides a systematic way to get a more in-depth look at a particular circumstance. In the case I have chosen to examine, Participant 16, the interpretation of the data, (her reflections and final) provides a coherent image of what happened in the methods course. She was hard working, motivated and cared deeply about education and teaching and learning. Participant 16 participated frequently in class, and seemed to make a change in her perspective about science learning and teaching during the methods course. Her final was creative in that she chose to use an analogy she found in the readings from the course text book, which compared a carpenter knowing which tool to use for a particular outcome (job), to the teacher's ability to know what questions to ask and how to facilitate students learning. She also found interesting quotes and pictures to further illustrate her philosophy of science learning and teaching. I have shared this analysis with Participant 16 since writing it, and will include her comments in this section.

First reflection. In her first reflection, in response to the prompt, Participant 16 describes the difference between the science experiences she had as a student and what she read about science in the first chapter of her textbook, and the first chapter of *Nurturing Inquiry* by Charles Pearce (1999). Her responses are fairly typical of others as well. She explains:

> When I think back to my experience with science, the first thing I think of is textbooks. It felt like most of what we did in science was read from the textbook, maybe see something on the chalkboard that we copied down in our notebooks and then be prepared to take a test. There wasn't much about science that was all that interesting to me. It was just a lot of memorizing and boring reading.

Next (Participant 16) shares what she sees as different through the readings.

> After reading the first chapter in the textbook, it sounds like my experience was similar to most people my age. Science was something that you learned in a book and that was the way it was presented. The new goal of teaching science as inquiry is much more exciting for both me as a teacher and as a learner. Research shows that inquiry is the most effective way to teach science to students. I believe that if my teachers used a more

> hands-on approach with me than maybe I would have enjoyed it more and perhaps retained more information.

Her final comments are on the connectedness of science to other contexts and her hopes for the course.

> Science is very important and there are so many other skills that can be developed through science classes. Science gives students an opportunity to improve their reading skills, their writing skills and helps them develop critical thinking skills. I hope that through this class I can learn more about teaching science and find the passion to teach it in a way that will engage my students and help them to gain a better understanding of the concepts and of the world around them.

Her last sentence is my hope too. It is my hope everyday for the elementary students with whom I work and certainly my hope for these prospective teachers. The pressure I felt personally after reading this was a little daunting, but a humbling reminder of the task that all teachers face and must overcome for the success of their students.

Second reflection. In her second reflection, in which she was free to choose her own focus, Participant 16 notes the major contradiction of science time in her classroom. She states:

> Spending time in my field experience classroom has given me a chance to see how science is (or should I say isn't?) being taught in our schools today. If you look at the classroom schedule on the board, it shows science will be taught every afternoon, however, according to my teacher she rarely gets to it. In fact I have only heard her mention science once.

Participant 16 then goes on to talk about how the teacher should be integrating science into language arts.

> I think that we need to take the time to work science into our reading and writing assignments. There are so many ways for us to work on language skills simultaneously. I think we are lucky that we are learning this in school now (methods course) so at least we have the tools to integrate the two subjects. I think if you would have asked me a month ago what language arts had to do with science, I am not sure I would have been able to see the connection; a connection that seems so obvious now that it has been presented to me.

Third reflection. In the next reflection, in response to a prompt asking what reading was the most meaningful/thought provoking, this prospective teacher thinks about chapter three of the textbook. What she feels is most interesting in this chapter, which is entitled *Learning Science for Understanding,* is threefold: students' misconceptions, how to challenge their misconceptions, and appropriateness of science lessons as determined by students' developmental phases. One of the pieces upon which she comments is about Piaget.

> Another part of Chapter 3, that I found both interesting and enlightening was the idea of really thinking about the student's cognitive development when selected science activities for them. Now I know why we spent so much time learning about Piaget! I can imagine that for children who have not reached past the preoperational phase and have not yet learned to conserve, many tasks can seem quite confusing. This chapter showed how

> important it is to take all of this into consideration when created science lessons for elementary school students. I thought that table with the characteristics of learners in different grade spans were very eye opening. When you stop and think about where children are at different developmental stages it all makes so much sense. If we don' t consider these things when creating our lessons, we will have a classroom full of frustrated and confused students, which is clearly not our goal.

The textbook also mentions that with elementary students are capable of doing more that previously assumed by the Piagetian model. It refers to confronting alternative conceptions, as does *Taking Science To School,* (NRC, 2007) which reminds us that students, with the proper support students can "learn much more about science than previously suspected" (Bass, Contant, & Carin 2009, pg. 78).

Fourth reflection. In the fourth reflection, Participant 16 chose to write a description about praise and reinforcement.

> I think praise is important, but never considered that by praising an idea you may give the students the impression that the answer you are praising is the only right answer. Being specific about praise, or using the suggestion of following praise with a statement such as 'your idea is one we will consider' allows us to open up more opportunity for discussion in the class and have more students sharing their thoughts.

Fifth reflection. In writing about 'eye-openers' at their schools in the fifth reflection, every prospective teacher commented on the lack of science instruction in schools. Participant 16 found that in the first six weeks of her placement there was no science, although her mentor teacher had shown her the FOSS kits that were in the closet. She states, “It is sad to think the school district is investing so much money on something that is sitting in a teacher’s closet and not being used. My teacher actually had to cut off the plastic ties to even show me what was in there. So she has had this all year and she has never even opened it!” She goes on to say, “It is unfair for me to judge a teacher for why she does or doesn’t do science in her curriculum as I have no idea about the pressures of being a classroom teacher full time; however, I hope I will keep all of this in mind when I do have my own classroom so that I can make the adjustments I need to keep science alive for my students.”

Sixth reflection. In her sixth reflection, Participant 16 chooses to write about questioning and wait time. She explains very clearly one of the common issues we all have had with wait time and silence. “Wait time is something I never really thought about before. We are programmed to want to fill the silence by talking or to try and get as much content into our already overscheduled day.”

She likes the analogy the book made between the teacher’s tool of questioning and carpenters tools. “The carpenter needs to know what tools to bring in advance, just as the teacher needs to stock her ‘tool box’ with questioning tools. As teachers, we need to increase the use of open-ended questions.”

This is an important observation on her part, and one that no other students commented on. The idea of wait time and questioning in ways that expect students to reason is a necessary skill of the science teacher. It made me wonder if I were doing this well in my interactions with the prospective teachers. All of my most influential predecessors had these skills honed to a tee. These were attributes that I desired to replicate. I was glad to see that this student had seen the importance as well.

Seventh reflection. As a science instructor, one would like to believe that all of the students believe or will come to believe that science is a quintessential subject. Participant 16 begins her seventh reflection, also her choice of topic, with words that were music to my ears: "Science is the content area that can meet the needs of all students and give the feeling that they are all on the same level. It is the one subject where students can work with hands on activities and perhaps not feel like they are different than other students."

Differentiating instruction she feels "would be one of the biggest challenges for me as a teacher. I know that my class will most likely be made up of a variety of different learning levels and students who come from different cultural backgrounds. Students with learning disabilities can really benefit from science that is activities-based." She goes on to report that she has seen teachers during her internship who don't take the time to differentiate. "They choose to teach a lesson one way and if the students don't understand, it is their own problem. This not only scares me as a teacher, but as a potential parent one day."

Eighth reflection. Participant 16 reports in her eighth entry that she is somewhat disillusioned by the status of education in this state in response to a prompt from me asking the students to share their understanding of the current status of science in their setting. Participant 16 explains:

> My only real measurement of the current status would be my internship
> site and that is a very sad thought. I really do think that political/

government officials have taken over some of the decisions that really should be made on the school level or at least the district level. I think that if other professions had to deal with some of the government involvement that educational professionals have to abide by it would never be accepted. Although the government is involved in everything, I am sure that doctors would not permit the government to tell them how they should best diagnose their patients. I think that in some ways the profession of teaching has become devalued and there is not respect for research done by true educational professionals.

She refers next to what she believes are the reasons for the decreased emphasis or elimination of science:

> Science is yet another thing being swept under the rug and taken out of the schools or relegated to the bottom of the importance level because it isn't the focus of standardized testing. It seems that reading and writing and math are the only subjects that matter and so few seem to realize that all of these things can be taught in conjunction with science. They do not need to be taught independent of each other. I think there has to be some changes made in our schools and in our governments so that people can see what is being lost by not teaching students' science in our schools.

Participant 16 resolves to be different when she gets into her own classroom. She states: "I know that if nothing else it is something that is on the forefront of my mind and therefore I plan to do what I can to ensure that my students are given a full education."

Ninth reflection. Her 9th reflection is about using technology in the classroom and the advantages she feels technology brings. In choosing to write about this topic, she compares the restrictions of high stakes testing with the benefits of the Internet.

> Technology has made a huge impact on education in general, and science is no exception. Although there are many challenges that come with being a teacher in today's world of NCLB and high stakes testing, the internet is one thing that will make our lives easier as teachers. On a more basic level, the enormous amounts of resources that are now at our fingertips are endless.
>
> We can also have our students use technology . . . to support our instruction. . . . through simulations, online testing and interactive lessons like web quests. By giving our students the chance to work on computers and use them for research we are helping them to build skills they will surely need to be successful in the future. Another way we can use technology in our classroom to enhance learning is through virtual field trips. In our current economy I am sure field trips are one of the first things to be cut by districts. A virtual field trip is a way for students to see something they are learning firsthand even if it is only through a computer screen. Virtual field trips can also take students to places we could never travel on a field trip. We could explore space, other countries and or an interactive science center. For students who have never seen snow or can't even fathom the seasons really changing, we can transport our students to the northeast to see a snowstorm or the leaves changing in fall. All of

> these things will make a tremendous impact on our students' learning.
> Although teachers are more restricted in modern times by " teaching to the test," these modern times also have the benefits of technology to give children experiences they might never have without a computer.

Tenth reflection. Participant 16 is very thoughtful and has a positive attitude. She seems determined to find ways around the current roadblocks she has seen in her placement settings. She admits to having her perspective about science change during the course of the method's class in her tenth reflection in response to the prompt; how do you envision yourself as a science teacher? I have combined her comments here with the last reflection (free choice), because she chose to continue the discussion about the change in herself and how she sees herself performing differently than the teachers she has observed during this semester.

> If I were to envision myself as a science teacher a few months ago, it would be a very different picture than today. Science was never a subject I was particularly strong in and so when I thought about teaching science it wasn't a happy thought. I feel very different about that today. This semester I have learned a lot about science and I realize that it is apparently very easy to avoid teaching science. This is a very sad reality, but it is nothing something I want to continue. I have the power to make a difference in the education of my students. I can continue the way things are going or I can make a change.
> This class has opened my eyes to a lot of the things that are missing in schools today and I don't want to be yet another teacher who skips over

> science in my classroom curriculum. My goal as a science teacher is to get students excited about science. I hope that I can instill a love of learning in my students and show them science in a new and exciting way. I don't want my students to leave school feeling the same way I do about science. I think that history keeps repeating itself because we learned science from textbooks and then if that is all we know we go on to teach it that way and the cycle continues. I really think that we have the power to break this cycle. I want to create an inquiry- based environment where everything is very hands-on. I envision a classroom where the students want to learn even more then I give them and who take the learning outside of my classroom and seek out more information on their own. I am grateful for this class for changing my perspective on science and I have every intention of passing that perspective onto my students.

These words obviously are wonderful to hear. But the same science instructor is also working in schools in this state where not only is science not being taught, but teachers are not often permitted to make decisions about what goes on in their classrooms. I am sure this is not true in every school district in the state, but in those with whom I have interacted, teaching what you believe should be taught, and following the state standards as is required (and include science) is not necessarily what will be permitted or encouraged.

Participant 16 is able to identify changes in her thinking that occurred as a result of her placement classes and the methods course. She originally felt somewhat inadequate as a science teacher and was afraid to be "caught" without the right answer.

> At the beginning of the semester, I talked of my fears about teaching science. I have learned that this is a common fear and is one of the main reasons why so many teachers avoid science in their classroom. I think by hearing about other teachers and seeing their own insecurities with the subject has helped me realize that I am not alone. It has also shown me what fear can do to your classroom. If we were to avoid all the things we aren't confident teaching, I know I would be in trouble. I know now that science doesn't have to be so scary. I have learned that I don't have to have all the answers. In fact, it is better that I don't. By letting the students figure things out and ask questions, I am giving them the chance to be scientists. I know that my role as a teacher is to guide my students learning. My goal is to be the facilitator of learning, not the person who stands at the front of the classroom and lectures my students all day. I think that this course has shown me that science can be very fun. It has taught me that there is a lot more to science than you can find in a textbook. I have been able to think beyond the way I was taught science and set new expectations for my science classroom.

Participant 16 claims to be determined to become an agent of change for the science education community! She also believes her classmates will join her in this quest.

> The most shocking discovery this semester is the lack of science instruction in the schools. I know that standardized testing is the ruler of schools these days, but nothing can justify children not learning science. I think the education system is doing a great disservice to the future rulers of our country by denying them this curriculum. It is sad to think that principals seem to be turning a blind eye to it. It is even sadder that many districts are spending so much money on sophisticated science programs that are now sitting in classrooms all across the state. I think that our class can bring science back and I think it is up to us as new teachers to make the positive changes necessary to give students the best education possible.

In summary, the weekly reflections were both free choice and assigned. They documented Participant 16's evolution of her thinking about science and science teaching and learning. Participant 16 begins by sharing her experiences as a science learner, and describes science as reading from a textbook and copying things down from a chalkboard. After doing the assigned reading she found that the same kinds of experiences as she had were described, and then compared to science teaching as inquiry. She ends hoping that she can learn to be a good teacher of science. The second week, the reality of the classroom sets in and she is frustrated by the fact that science is not taught in her placement classroom. She also sees opportunities for science to be integrated, but it is not being done. Her reflection for the third week of class she shares that she now understands why Piaget was a focus of a previous class, but is glad to know that current research shows that young children can learn much more than we previously understood. Her fourth reflection is about the importance of sincere praise, and reinforcement. Her next reflection is more frustration at the lack of science being taught, even though there are unopened FOSS kits in the teacher's closet.

She vows to keep science alive for her future students. The following reflection reports that she has found an analogy she likes for effective questioning: the carpenter's toolbox. The seventh reflection shows that Participant 16 has changed her attitude about science, and moved from hoping she would be a good science teacher to realizing that science is a content area that can meet the needs of all students, if the teacher tries to differentiate to meet the needs of diverse learners. Her next reflection is an echo of the frustration she feels because science is not taught, but she recognizes this is due in a large part to the effect of standardized testing. The ninth reflection talks about the wonderful ways in which technology can be used to support instruction, and she mentions virtual field trips to provide students some experiences they may have not had. Her last refection shows she has realized she has made significant change in her thinking about being a science teacher, and providing students a very different experience than the one she had. She talks about confronting the roadblocks to teaching science in her own classroom and "breaking the cycle" of just reading about science in boring textbooks, or not having any science at all. From not being to excited about science learning and teaching to being passionate about science learning and teaching during the methods course – an interesting journey.

Keep Tool Kit Final

For the final, I asked the students to put together a multimedia website that showed what they had learned over the semester. They were encouraged to review any assignments and reflections from the course to use as examples of their learning. They were to use the Carnegie Foundation's free software for building websites, the KEEP TOOLkit (now available at www.merlot.org). We were in a computer lab for this class, so I had all of the students log on to the KEEP TOOLkit website, and practice uploading pictures and text, using the tools that were available to them to change the color of the text, the background, the size of the space they needed, etc. I dedicated the better part of two different class periods for the participants to actually practice using the KEEP TOOLkit. Some of them began work on their final because they found the program so easy to use. There was not much of a learning curve – I had even used it successfully with a first grade class. I asked the participants to produce a website synthesizing what they thought they had learned during the semester. I encouraged them to use any parts of previous assignments, reflections, and student work samples that they felt exemplified what they had learned. I urged them to be thoughtful and creative in their design and interpretation. I knew that this was a tool elementary students could use as well, because I had used it with elementary students.

Once they were okay with using the tools, I shared with them some of the websites from my methods students from the mid-Atlantic university. I showed them a few that I thought were pretty good, and others that had room for improvement. I told them I was looking for a synthesis of their learning. I was interested in what things had struck them profoundly, even what questions they still had, and what they envisioned themselves taking back into their classrooms. The instructions for what exactly needed to be included in the final were open-ended and that was intentional. Some participants were still unsure about what to do to get started on the final. I encouraged them to try to work on it and send me the pieces as they put them together, and I would give them feedback on it.

Two of the participants chose only to cut and paste all of their assignments into the multi-media snapshot, and one of them said in a refection:

> I think that the webpage should be a collection of the work I have done in this class from the beginning to the end. I will include my journal reflections, and my four assignments, which all talk and analyze my viewpoints of science in the classroom. I think that this webpage would be a very good collection of the work I have done this semester and that if I ever needed to reference this work later on in my career, I will be able to access the webpage and look back some of the entries and information done during this semester. Overall, I really think that this could be a helpful assignment so that my work can be stored for my own uses later on as well as having this information available for other students to access when they need directional guidance."

This was a very different idea than I had originally had. I was happy that the work would continue to get used and that it seemed like a helpful assignment but I was disappointed that no further reflection was evident.

All of the other participants added something new as well as included excerpts from their work throughout the semester. Participant 16 thought that putting together the website was a beneficial activity. She said she realized that her thinking had changed over the course of the semester. She states in her last reflection, “It is amazing how much your thinking can change over the course of a semester. Working on the KEEP TOOLkit has given me a chance to look back over my old reflections and see how my thinking has grown.”

I chose to examine Participant 16’s final for several reasons. Her approach was creative. It was different than the other participants in the way that she organized her website as a “teaching toolbox.” The analogy from the textbook that she had mentioned in her sixth reflection had stuck. She also chose specific quotes that portrayed her philosophies of teaching and learning science. The key ideas she took from the class are represented by her own reflections, by quotes, and by beautiful pictures that complement the topic. She demonstrated a synthesis of her understanding in multiple and varied ways.

Participant 16 begins the first webpage of her final with the title, “Teaching Science.” She quotes a piece from her first reflection in a section entitled: My thoughts on Science in the beginning. . . . Then she goes to “My Thoughts on Science Now” which quotes one of her last reflections. Then “How I Hope to Teach Science” which also comes from one of her reflections, (these ideas were quoted above in a discussion of the reflections). Next is a section called “Beyond the Textbook.” In this section she states that:

> Children are authentically motivated to do science for one basic reason: to find out. The focus of science teaching today is giving students the chance to think critically and guide their learning rather than providing them with the information. Allowing students to discover things on their own gives

> them a deeper conceptual understanding than they get from direct instruction."

She also refers to a quote, from *How to Ask the Right Question*s by Bosser (1991, pg.6) that says "If we want our science students to develop skills in problem solving and decision making, we need to ask them the questions that will stimulate higher-order thinking."

The second page of her website, or "toolbox," entitled "English Language Learners," she begins with a quote,

> Initially beginning English learners may not be as verbal as other students, but provided with opportunities to show what they know the results can be inspiring!
>
> (Nyberg & McCloskey, 2008)

On this page she also includes a brief discussion of the benefits of cooperative learning. She lists these as:

- Allow students to learn from one another and challenge one another
- Stronger students can those who are struggling, and struggling students help reinforce learning for those who are helping them
- Builds self confidence

She has included more information on ELL learning and two beautiful pictures that capture the ideas of diversity and cooperative learning.

The third webpage of her final is called "Always Engaging." In the center of the page she has a picture from what looks like her placement classroom, with students sitting around a table, and science materials in the center. The students are engaged in various stages of an experiment. They are working together, girls and boys, diverse in ethnicities, hard at work. This is the science lesson that she taught as a requirement for the methods class. This is a thoughtful representation of engaging students. Here again, she chooses to pull text from one of her reflections.

Thoughts on Engagement

> I want them to enjoy science and I want them truly to be engaged in our lessons. I hope that I can instill a love of learning in my students and show them science in a new and exciting way.

She quotes Angela Maiers (n.d.) who feel that not only do educators have to create classrooms that are engaging; they need to support and encourage other educators in efforts to do the same. She chose another quote from Jablon and Wilkinson (2006) that describes engaged students. They believe students who are engaged, are active, attentive and committed to do the assigned task. Engaged students also do the task because they believe they can and they value the end result.

The fourth webpage of her final, and the fourth tool in the tool box is "Creating Connections: Real World and Across Curriculum." In the center of the page she has what looks like a child's drawing of the Earth and the Sun above it. In the corner of the page, she has a picture that uses symbols and words for all of the content areas. She includes other information from Angela Maeirs (n.d.) about real world application. Maeirs states that students need to understand the relevance of an assignment to their lives, to the real world. She suggests that helping students see that connection motivates them to do the task.

Participant 16 also includes several quotes from the article *Integrating with Integrity* (Nyberg &. McCloskey, 2008). One is on assessment, and emphasizes the idea that science can be assessed in multiple ways, just as scientists communicate their findings in multiple ways, drawing, writing, models, and diagrams. Another quote she chooses to include is about literacy. The author claims that literacy is a crucial part of science and is important to everything done in a classroom – and Participant 16 adds her own thoughts:

> It makes me wonder why people such as the literacy coach, and one of the teachers mentioned they could not see the connection between science and literacy. I just don't understand how anyone could think that all a student needs to learn in school is reading and writing. There are so many ways to incorporate these things into our science curriculum and strive for more. By linking the reading and writing to everything we do, we can be assured our students are receiving the best education possible.

Participant 16 is also the only one who wrote anything about home involvement. This was something I thought I stressed during our class, but she picked up on it, and is the only one who included the topic in her final. This new page is called simply, "Home Involvement."

In the center of the page is a little house, with a little girl outside, and what appears to be a mom peering out an upstairs window. She writes an answer to the question she poses, Why is parental involvement so important?

> I think involving families in the classroom is so important for success. If the students can make connections between home and school, their learning is enhanced in many ways. It is important to find ways to

> connect with parents that will not intimidate them. There are many things we can do that don't require the parents to have a strong science background.

She discusses the moon journals that she read about in the article I gave them called *The Sky's the Limit* (Roberts, 1999). She presents several quotes from that article as well. She thought it was important for a home-school connection to be made to support the learning of the students, especially for ELL students.

"Inquiry Based" is the section or "tool" that follows home involvement. There are two pictures on this webpage. One is a picture of the inquiry cycle from Charles Pearce's book, *Nurturing Inquiry* (1999). I used this cycle during the first class. First I had given it to the prospective teachers blank and asked them to fill it in as best they could, and then after we discussed our positive science experiences, I had given them another blank one to fill out. Finally by the end of class and much discussion later, I had given them a copy of Pearce's cycle filled out as he had it. The fact that she included this is a nice demonstration of the fluidity of teaching, learning and doing science.

The second picture is that of a drop of water onto a larger body of water and the rings that forms out from the center. With this picture she included a quote she credits to Martinello and Cook (as cited in Llewellyn, 2004, p. 1), "The pebble that drops into a pond is like an idea that sparks inquiry. The concentric ripples represent new questions that emerge from the first gem of the idea. The greater the interest and the more probing the question, the more encompassing the study, the bigger the ideas that develop, and the deeper and more meaningful the knowledge the inquirer constructs."

The next "tool" in her toolbox is about differentiation. She calls it: "No One Learns the Same: the Importance of Differentiation. " On this webpage, she includes quotes from others and her own reflections. She explains:

> When it comes to differentiation, my teacher said it was difficult with science. She said the most important focus for an ELL student, with science and everything else, was always about vocabulary and language acquisition. Many of these students are not exposed to things like this outside of school, so it often requires a lesson on background knowledge just to get started. I am sure this is yet another piece that makes the instruction challenging and time consuming. Although I can imagine this would be a challenge, I think there is really no excuse for not differentiating.

Then she refers to a quote from Tomlinson (without a reference, unable to find source). Participant 16 states that Tomlinson feels science is a content area where students are evenly matched, but that differentiation is still possible and necessary. Knowing each of your students as learners is the key to differentiation.

Last, but not least in the toolbox is a section entitled, "Guess the Mystery Substance (and other favorite experiments)." I am assuming the mystery substance experiment was based off an experiment I did with them in class, and also with my fifth graders. In this experiment the students use four of their five senses to try to figure out what some white powder is. When water is added to the powder it increases up to 40 times its original volume. This substance is a polymer, and is used on movie sets to make snow.

The pictures on this page are many. At the top is a picture of a young boy surrounded by different colored bottles that appear to be chemicals and holding something over a candle flame. He is wearing goggles and using all of the necessary safety equipment. Nice touch! At the bottom is a picture of two hands holding some snow (which is what my mystery powder was, fake snow). Then there is a picture of a bowl of milk with many different streams of color in it, an experiment that she did in the methods class, and with her elementary students, called magic milk.

Participant 16 has both of the experiments and curriculum that she did for assignment three and assignment four included. She also lists the state standards addressed by each as well as both experiments re-written in the 5 E format.

Participant 16 put a lot of thought and effort into her class work and into the classroom she was working in. She was able to see the difference in her initial thinking about science learning and teaching and her thinking towards the end of the course. She mentioned more than once that when she got her own classroom, she was going to find ways to integrate science into her curriculum. She was irritated initially when the literacy coach at her site was unable to see a connection between science and literacy. She felt that all students were entitled to an education that included science learning.

In the creation of her final, she spent time finding both visual examples and quotes from different sources that illustrated her beliefs.   She used an analogy from the textbook of the teacher's toolbox, which really synthesized her current perspective on science learning and teaching. She added her own thoughts and included pieces of articles that we read in class. She created a final product that was representative of her learning, reflection and visions for teaching.

When Participant 16 read this account of her reflections and final, she said, "Wow! I seemed much more insightful than I am now. I am teaching first grade, and the second year is better than the first, but in some ways more difficult. I have a much better grasp on the curriculum, however I don't think I was as strict on my rules and procedures in the beginning and now I am trying to fix my mistakes! I loved reading this because it made me think about a lot of things that I am (sadly!) not doing in science right now. Thank you!"

Will this be the catalyst for implementing what she so eloquently shared in her final? Or has the reality of schooling usurped the vision?

In this chapter I have shared my reflections on the constraints and challenges that I encountered as the methods instructor in this course. Additionally an overview of the course was provided. In the description of course activities, I shared insights, and my developing commitment to these activities. Also included was an in-depth interpretation of participants' responses to the four main assignments in the class. I closed the chapter with a case study of one participant's reflections and final.

In the next chapter, I will share my interpretation of participant interviews, by question and by the strands of scientific proficiency after they had completed the methods course, but had not started teaching yet. First I interpret the interviews by question, as I believe there is valuable insight to be gained that may not be obvious through only the lens of the strands of scientific proficiencies. Next I use the four strands of scientific proficiencies articulated by the National Research Council (2007), as a framework for interpreting the assignments and interviewees' comments.

CHAPTER FIVE

Interpretation of Interviews

This chapter presents and interprets data that provide evidence of the visions of new qualified teachers and their instructor based upon the interviews. In addition, the four strands of science proficiency (NRC, 2007) provide a framework for interpretation of the course activities and assignments as well as the interviews.

Research Question 3:

What visions of science learning and teaching do newly qualified teachers bring with them as they graduate from a teacher preparation program?

Seven participants responded to questions during interviews after they graduated and before they started teaching. I have divided the questions that I asked these participants into groups. The first group is called *Visions of Science Teaching* and these questions are mostly related to teaching. The next group of questions is entitled *Visions of Science Learning*, again with questions related to how the participants see science learning taking place in their future classrooms. The third group of questions is about the participants *Vision of Science in Practice*. The section that follows, *Lesson Plan Reflections* are their reflections (after at least six months) on the lesson plans they created and implemented during the methods course. The final section is a group of questions focused on the methods course and is called *Methods Course: Participant Reflections*.

Visions of Science Teaching

The participants interviewed were asked three questions about their visions of science teaching. The first question was, a). *What are the characteristics of a good science teacher?* This question aimed to understand what the participants believed were the important attributes of science teachers and how they envisioned themselves as teachers of science. The second question was b). *Imagine that you now have a job teaching in an elementary school and you will be responsible for teaching science, what does your classroom look like and what evidence will there be that you are a teacher of science?*" This question was asking about the physical characteristics of the classroom. What did they envision a classroom would look like if teaching science occurred there? The third question, c). *If I walked into your classroom during science instruction, what would I see?* sought to understand how the prospective teachers thought science teaching in action would look in their rooms.

Question A: *What are the characteristics of a good science teacher?*

The participants had very specific ideas about what the characteristics of good science teachers were. Their ideas had some overlap, but also there were many differences in emphases. Their answers were complex, and articulated a wide range of attributes. These visions of science teaching included: being flexible/creative, appreciating how students think and learn, doing more than just telling information, being patient, helping students question and think critically, reflecting, being exciting and enthusiastic, engaging, following student interests, making science relevant to the students lives, engendering a passion about science learning in their students, scaffolding learning for students with different needs using exploration and discovery, and encouraging students to reflect.

Participant 1, for example, recognizing the attributes the teacher must have, believes that teaching and learning must be flexible. He also shows an understanding of how students develop their science ideas, emphasizes learning for more than the "test" and notes that science teaching is "more than just telling students the information." He cites patience as important in thinking about students' thinking:

> Well, I guess I would have to describe a good science teacher as a teacher who appreciated kids' learning and had the patience to think about how kids think. I mean, it is more than just telling the students the information and have them regurgitate it for a test. It is more about finding things to interest the students and then giving them the space to think about things, try things, and then talk about it with their peers. Then they almost always have to try things again, because someone else may have found out something they didn't, or found out something differently, or they may feel challenged by what another student did. The teacher has to be a person who knows how to structure the class so that this can happen, but not in a wild, or chaotic way, with some kind of flexible framework. Patience is the one word I would use.

Participant 2 agrees with Participant 1 on the characteristic of being flexible. Participant 2 describes a vision of responsive teaching in which student questions influence what a teacher plans to do next. She also wants science teachers to demonstrate the characteristic of being fun and exciting:

> I think a good science teacher should be fun and exciting and consider their students - take their interests into consideration when planning their lessons – it wouldn't just be about what they want to teach; it would be about the students and what they want to learn. So if a student asked a question and it wasn't in their original science unit or lesson then their instruction for that day or maybe the next day might incorporate that (the question), so being flexible.

Participant 6 is in agreement with Participants 1 and 2. She also envisions science teachers as being flexible and creative. She acknowledges the importance of thinking about students' thinking, within contexts mandated by standards. She also envisions inquiry teaching and learning taking place with a good science teacher. She goes on to explain how she plans to encourage her students to think critically and "help them to question things and not take things for face value." She also refers to reflecting on practice to facilitate students attaining conceptual understanding.

> I think a good science teacher helps her students think critically about whatever concept it is that they have to meet for their standards; they help them to question things and not take things for face value. They teach them how to do correct investigations, how to properly use evidence that they have gathered to prove something to show that you know this might mean this cause and effect. I think a good science teacher has to be little bit of creative, when their kids aren't quite getting something, "ok what's

> another route I can take? I thought that was going to work and it didn't so, how can I do that?"

Like Participant 2, Participant 4 values the attribute of an excited and enthusiastic teacher. She wants to know her students well enough to know what they want to learn, and agrees again with Participant 2 that it is important to follow student interests She explains:

> I think someone who is excited about what they are doing and who – something that I have learned is – in the classroom that I am in now is that if I am not excited about something and if I am bored, then of course the kids are going to be bored, you know and so I feel like you need to be inquiry based and asking questions and things like that, but what are the kids interested in that's what I would want to know. If they really want to learn about UFO's there's ways to connect everything to the standards, I think and so why not? I just feel like why not. That's why I left the first classroom I was teaching in because I just could not teach the things I was being asked to teach. It's not who I am. I am not - I just couldn't stand at the board and ask kids to write paragraphs all day.

Participant 7 is another who agrees with Participants 2 and 4 that a science teacher needs to be exciting and enthusiastic as well as able to engage the students and excite them. He envisions science learning as being relevant to the students' lives and wants to "engender a passion about science learning" in his students.

> Umm, a good science teacher is excited, and needs to engage the students, needs to get them excited about what they are learning, needs to make the learning relevant to their lives and hopefully can engender a passion about

science learning in their students. I guess it varies, too, on the different levels at elementary school you would probably want to be able to get a firm understanding of the basic ideas of what all the rest of science classes would be built off of like simple machines and stuff and the basics ideas of chemical reactions and physics and stuff and then in high school - I guess that's where its really important to have it be very engaging so that, well I know that when I took science in high school my enjoyment of the science subject was directly related to the teacher. I had a physics teacher that was really excited about what he was teaching and he made it fun, made it interesting. And so I loved that - but then on the same hand I had a biology teacher who seemed like he didn't care, so I didn't care. It seemed more like a chore. The teacher needs to make it fun and make it engaging and make it worthwhile too. I've noticed in a lot of, when I was interning in Phoenix, they hardly ever did science, in fact one of the teachers I was interning with never did science the entire time I was there. But then the other teacher, every time that they did it, it was kind of boring. And the kids were like oh its science and it was cool cause it was different than what they were doing but it just, just wasn't exciting. So I think a science teacher needs to engage the students, get them connected to what they're doing, make it realistic, make it such that its not just playtime it's learning.

Participant 3 echoes the comments of Participant 7: a good science teacher needs to be engaging, and connect learning to the real world. Participant

3 refers to her placement experience, where she apparently observed some engaging science learning and teaching in action.

> I would say for any age especially engaging, but I would say for the younger kids really needing to have them being able to connect the reality of whatever they are learning about to their lives, not just broad scope. Because they have such short attention spans, and they like to be really hands on so - we didn't do a lot of science - but what we did was really hands on, and working on cooperation and fiddling around with stuff.

The characteristics of good teachers the participants described illustrate a vision of a teacher who is enthusiastic, energetic and engaging. This teacher is tuned into the interests and thinking of the students, is able to make connections to the real world, and is flexible and patient.

Question B*: Imagine that you now have a job teaching in an elementary school, and you will be responsible for teaching science, what does your classroom look like and what evidence will there be that you are a teacher of science?*

The participants described visions of how their classrooms might look. They visualized displaying student work, displaying posters that are related to science or science topics, possibly dedicating a section of the room to science, having science artifacts in the room, environments that would foster inquiry-based teaching and learning, desks or tables for group work, and having science articles or magazines.

Participant 1, for example, wants to have student work on the walls "whenever possible." He would like to dedicate a part of the room to science, and hopes to include the students and their parents in bringing in artifacts for the science area. He also admits to not having thought about this before.

> No cemetery rows, like you said in class. There would be student work on the walls whenever possible. I would like to have a certain part of the room dedicated to science. Maybe with some cool science stuff that I could get cheaply – rocks, shells, magnifying lenses, an aquarium, like that. And then I would let the kids bring in stuff to add to our science area. If they went hiking and found some neat pinecones, or leaves, or they went on a trip and bought a fossil. Maybe stuff they already have at home they could share with the class. Anything that they were interested in or curious about. Maybe one of their parents is a scientist and could give us some things from their line of work - I haven't really thought about it that much, but I will. This question made me think about it more.

Like Participant 1, Participant 6 would like to have "lots of student work" displayed in her classroom. She would also like to have posters related to science and the doing of science.

> Ok well, lets see first lots of student work up, we will have lots of student work and I am planning on doing themes so we are going to have lots of themed work and up around the walls, and that will be I think in itself my evidence that and probably some things on um inquiry and even the scientific method and how to question things and good questions to ask,

> like how to formulate good questions will be up around and some of those types of things.

Participant 2 agrees with Participant 1 and 6 about displaying student work so that students will take pride in their work and parents will be able to see what the students have been doing. She envisions having a question board as a poster in her classroom, so she shares this vision with Participant 6. She wants to put out artifacts that she has already been collecting, as well as some kids magazines that are science related.

> I really like the idea of the question board, from the articles we read and what we did in class. That was one thing that was interesting. I want to try that, and there would be student work all around, and different science items; I have started collecting them, like shells, and nature things, also some little toys – like the ones that have water and oil, I think inside and the oil is a different color and when you turn it over it moves. Maybe some things they could take apart. I would put these around. I would also like some kids magazines, like *Ranger Rick,* so that they could read some things that were interesting to them.

> I really like to put a lot of student work on the boards in the classroom, not only so when parents or anyone comes in they can say wow! We worked on this - see what we've been working on and so the students will be excited and they will take pride in their work (if it is displayed) and I will take pride in their work. It will let them know that they are important and

> what they do is important –if they know their work is going to be displayed in the classroom they might put a little more effort into it. Also out in the hall of the school I would love to display their science work and everything. I would also for people to know for example, we're doing a unit on living things, so we could have like plants and flowers, maybe projects – just things around for everyone to see.

Participant 3 took some ideas from her placement classroom, and like Participant 1 and 6 would display student work. She shares the idea of Participants 2 and 6 in thinking about having posters that are related to science or science topics. Both she and Participant 1 envision dedicating a part of the room to science.

> I guess what - well I never thought about how I would set up a class, but hmm, I guess I would do what we did in my placement classroom – her classroom walls were like in sections and although we didn't do a lot of science – like maybe 4 or 5 days in the two months I was there science was promoted, she had a section for science. Like we studied water in the beginning, so she had a sink area set up where kids could pour water from one thing to another and I think that would be really neat, so if I think that would work, and I would pick units that you could integrate more subject areas, having an experiment area where kids could do things in the class, a science word wall – even though you would have words from other subjects, make sure science is up there so they could learn the vocabulary from whatever unit we were working on, or reading about, and sight words

would be up there too – I think that's about it. Probably I'd display kids work.

Participant 4 claims to not have thought about this question before, but still has ideas. She concurs with Participants 2, 3, and 6 that she would put up posters on the walls that are related to science. She prefers to have small group tables, and claims not to be a "fan of the whole desk thing."

That's a good question, I haven't thought about that. As far as the classroom looks like, for me I really don't want the desks all facing forward or anything like that, I table, or small group tables or things like that but for most part I feel like kids need space; they need the space. Kids would rather sit on the ground or on their belly or whatever. I am just not a fan of the whole desk thing. So I guess that for me that's a good part for the science so they will be moving around to do different experiments and things like that and uh I guess that another way would be to cover the - put science based things up on the wall at least, to show them that I am excited and that this is what we're going to be learning about. But I hadn't really thought about that yet.

Participant 7 was very excited about his ideas to have an ideal classroom, and is enthusiastic about having a science area in his room, as Participant 1 and 3 are. He likes the idea of science artifacts, as do Participants 1 and 2, and thinks that they could be used to engage the students. He would like his classroom to be an environment that would foster inquiry-based science teaching and learning.

That's one of the things I am most excited about like being able to design a classroom and in my ideal scenario I would be able to have like little areas of the room like devoted to like different subjects like so you would have your math wall with like number facts and stuff, reading wall with like different words that you come up with that are cool and in the science area I think it would be really cool to have almost like a mad scientist laboratory type idea. That was one thing I always thought was really cool when I was in a science classroom in high school; it was like you had the fancier the nice cool black tables and there'd be like beakers and Bunsen burners off to the side, but unfortunately like at my high school we never got to even use any of that stuff; it was almost more decorative. But I think it would be cool when you get those big science kits from FOSS to not just keep it in the box, but to put the stuff out so that while the kids are sitting there during free reading time, or they come in and they are just milling around. They can come in and just look off to the side and see all these cool things that we are going to be using, and that would also be the keys to actually then use them - instead of having cool stuff in the classroom that's just for decoration.

Yeah, yeah get them interested; to engage them like to see, like they're going to start talking amongst themselves saying, "oh what do you think that is used for?" I always think its great when kids are talking about their learning with themselves because they start to like to kind of hypothesize about what they're going to be doing and a lot of times their guesses might

> be right on, but at the very least it is going to generate excitement about the subject which then when you do get into the lesson and you are trying to engage them half the work is already done they're already engaged. And it may have been if that stuff has been sitting there and lets say your doing something about solutions and you've got like beakers out and stuff, they've been getting engaged about it for the whole week and then when you finally use it it's like, yes, they're already bought in. I think making the classroom needs to be part of the engagement process, its got to feel cool - like reading *Harry Potter*. And to me, the potions class that's the science class, and just imagining like all the beakers and cauldrons and stuff that Snape would have and that would be a pretty cool science classroom. Although Snape wouldn't be a very nice teacher, but the classroom would be pretty cool.

Participant 5 is in agreement with Participant 7 in having an environment that fosters inquiry-based teaching and learning, and also with Participant 4 in having students in desks or tables for group work. She envisions student work posted, so she concurs with Participants 1, 2, 3, and 6.

> We will be working in groups, so there will be tables all around. There will be posters for example, hurricanes tornadoes whatever they are studying on the walls, their own work posted as well, and working in groups, definitely. And cooperative learning each student will have something to do, to report. One is the recorder one is the timekeeper, materials person, whatever.

> I would put emphasis on groups and cooperative learning - They learn better that way. They learn when they talk to each other; they learn when they have an assignment to do. They know they are a part of a team; they are going to accomplish something. That is important to their life and they have to start learning it in science.

These visions of a science classroom for the most part describe student desks or tables in groups, student work displayed, science-related posters or information on the walls and some science artifacts or toys. The participants want their classroom to foster science learning and teaching and one participant would like his classroom to be "cool" like Professor Snape's potions lab.

Question C. *If I walked into your classroom during science instruction, what would I see?*

The participants described their visions of what science in action would look like. Common ideas were shared about hands-on learning, cooperative learning, teachers moving around the room, students talking to each other, small groups, asking questions, posters and student work up on the walls, one participant mentioned modeling for the students, one repeated dedicating a part of the room to science and another envisioned all the subject areas being integrated, and taking the students outside for science.

Participant 1 envisioned a classroom with hands-on learning taking place, possibly cooperative learning, because he says the students would be working together.

He reiterates that he would have posters and student work up and a dedicated section of the room for science.

> I guess if I was teaching 3rd or 4th grade and had to teach all subjects I would probably try and have maybe some science posters or articles, things that we were maybe studying, some kind of unit kind of things, you know what we were working on. The students would be working together, and they would have stuff they were using on their desks – like what ever the experiment was about. I guess if I was teaching in middle school though, and I was only doing science, I think that might be a little different looking, like the whole room is science. And probably there would be those big black tables and so kids sitting there, and doing their investigation and what not. In the lower grades you might want to have some of their writing assignments or art projects or other things like that so I think it would be a little bit more mixed. But I would definitely want to have something, like a corner or a wall, something like I said before.

Participant 2 sees hand-on activities taking place, as did Participant 1, and posters and student work as he did as well. As the teacher she sees herself moving around the room asking questions of the students, who are talking with each other.

> For me, it would look a lot like our classroom looked only the students would be smaller. So, kids working in groups, hand-on materials, you might see my question board, and I would be walking around the room listening to the kids talk and asking questions. And you would see evidence of whatever we had been working on around the room.

Participant 3 prefers small group work to centers, and heterogeneous groups. As Participant 1 and 2, she sees hands-on materials for the students.

> I think I like the small group work more than the centers, because my experience in working with centers, as a student teacher with my teacher and a teacher assistant with three centers was that all of them needed attention. But I think in a typical classroom where I was the teacher I would want kids like in little groups so that they could help each other, and try and make them not homogeneous groups but heterogeneous groups - so that the kids could help each other and work with each other and bring some of the at risk kids more into the group, instead of having them all sit there doing nothing. So definitely in groups and especially with younger kids, they can't really read on their own, they can follow directions, but generally orally, so just a lot of hands- on whatever it is, have enough materials so that each group could be doing the same thing, or maybe if there were building parts to a project, they could rotate from one table to another as a whole group, but definitely having something for all of them to do with their hands and be exploring and maybe have some type of notes they could be writing, or if they see something and they think it's cool, they could go draw a picture of it.

Participant 6 would like to have hands-on activities she feels will benefit the ELL students, so she concurs with Participants 1, 2, and 3. She envisions “lots of cooperative learning,” with the students “trying to figure things out.”

> You are going to see group work, lots of cooperative learning, so kid’s talking to each other, trying to figure things out. Hopefully, a lot of hands on things, especially since I have a high percentage of ELL’s. So a lot of hands on relating what they have been told in class and then like being able to touch it and see it and prove it.

Participant 7 echoes Participants’ 1, 2, 3, and 6 vision of hands-on activities to engage his students. He describes himself in his future classroom as very mobile, so he is similar to Participant 2. He believes that being mobile might be stimulating to the class.

> Well, whenever I am teaching, I am very mobile – I am moving around the classroom I don’t like sitting still, that’ll be part of it. There’s going to be a lot of hands on stuff, um, because I know when I was a student and I was sitting in the class and the teacher was just talking I would just tune out. I would find something else to do, whether it was just drawing or reading a book under my desk or talking to my neighbor. So when I teach I always try to be very mobile – very, I don’t know, very stimulating to the class so that they’re not bored. I want them to be working with the stuff, because if they are manipulating stuff it is easy to tell that they are engaged. When you are talking to the class and they are just sitting there staring at you it is hard to tell - like are they paying attention to me? Or are they just nodding like every once in a while, so that it looks like they are paying attention.

> But if they are actually moving stuff on their desk, if they are working with things, it's pretty easy to assess their participation level.

Participant 5 envisions seeing herself circulating throughout the room, as Participants 2 and 7 did as well. Again, like Participant 2, she believes she will be asking questions to facilitate learning. She mentions that she will model for the students first before they do the activity.

> I will explain to them first what they are going to do without them touching anything! That's very important. All my instructions, then I will have them, after listening to the instructions, I will have them do whatever – prepare the materials and then umm, well I will model first of course, and then they will be working on whatever their assigned task is, they will be working.
>
> I will be observing. I will be walking, I will be talking to them, I will be asking them questions about what they are discovering. What does this mean? What does that mean? Helping them by asking questions.

Participant 4 has a strong emphasis on integrating the curriculum. She would also like to take the students outside to explore nature, and wants to facilitate learning by asking questions not by giving answers. She, like Participants 2, 5 and 7 is moving from group to group. As Participant 3, she notes that the students will be in small groups. Additionally she is asking questions of the students, which is also a vision of Participant 2, and 5.

> Well, I really when I think of science, I don't think of it as just science I think of it as other subjects all being integrated, so its hard for me in the place I was just in because it's like this is reading and this is writing and I just don't think like that. I think that science and art and reading and social studies and math are all intertwined together so I think that in science there would be a lot of reading there would be a lot of writing . . . I am a big fan of going outside doing exploration, but I don't see like studying a textbook or anything like that. I see an integration of the subjects so I don't know if you would know that I am specifically teaching science – but I'm not just science, I'm everything.
>
> I think you will see small groups and I will probably jump from group to group to group. When I am with the group I think I see it more as asking questions than helping students by giving directions. I hate, I really don't like the "do this – do that," because I want them to be experimenting for themselves, so I am not sure about exactly how that looks but that is how I feel about it.

Many of the ideas that the participants had reflect inquiry based science teaching. They mentioned using hand-on materials, having student-focused instruction, using questions to facilitate learning, integrating other content into science, and encouraging discussion. The ideas they shared were modeled for them during the methods course. Many had placements where no science was taught at all and so some of their ideas have come from their own experiences.

Visions of Science Learning

To better understand how the participants envisioned science learning for students they responded to four questions. a*). If you had a classroom and you were teaching science, how would you maximize science learning for your students?* I asked this question to better understand what the participants believed about science learning, and what they believed to be optimal science learning. The second question*, b). How are you going to know that your students understand, when they get it?* was an inquiry about assessment. I wanted to know how the participants would recognize if and when the students had developed an understanding of a particular science concept or topic. The third question *c). How do kids learn best?* was asking for the participants to identify ways in which they thought their students would best be able to acquire science understanding. The last question was actually a statement I asked them to explain *d.) Science is a social process.* This was asked to ascertain perceptions of the participants in regard to the collaborative nature of inquiry science learning.

Question A. *If you had a classroom and you were teaching science, how would you maximize science learning for your students?*

The participants had very diverse ideas about how to maximize student learning. These ideas were making time to do science daily, integrating science and other subjects, aligning science learning to student interests, teaching them good study habits, letting them learn on their own, through hands on activities, having activities that interest them, with individual attention, when the topic is relevant and applicable to the students lives, through meaningful assessment, by making connections, constantly assessing and walking around listening.

Participant 1 thought that he would maximize science learning by setting aside time for it, rather than keep putting it off, and also by tying it in to other subjects so that it was integrated.

> If I had a classroom and I was teaching science I would maximize it by at least setting aside time everyday for it, at least having time like where I would have to get to it – as opposed to "well – we are out of time for the day – oh well, no science." I think if I was real slick, you know really figured it out you know I would try to tie it in to other things so that the students were learning the other subjects but they were almost like layered, integrated.
>
> Participant 2 elaborated on the idea of integration.
>
> One of the first things is by not teaching things in isolation. I know when I did my science unit we were talking about math and science and literature and it all kind of comes together. In math – there might be a question about science and in literature we might be reading about science – it all helps comprehension better so I think integrating all the subjects together. I could take today's lesson and instead of doing everything in order, I can look at the science lesson and say I am going to pull this children's book to go with the science and I if we are talking about fractions in math, I could talk about the fractions of an apple and I'll find a

way to tie that to the science and I think that is the way to maximize learning.

Participant 6 wanted student centered learning that focused on their interests as well as helping them with study skills, especially for her ELL students.

> Maximize student learning… umm, Well, I think first of all I'll take what they are interested in so whatever, … If I notice that this group of kids has a strong interest in some aspect, or some animal or some insect, or some natural disaster, I'm going to see how that will fit in with my curriculum and kind of go from there. See, you know, fit it around the kids interests so we have student centered learning - where you know, they kind of hone more of what they're doing.
>
> Yes so that's it, so then they'll be wanting to learn, and then hopefully I think also teaching them generally all kinds of good study techniques and how to be a good student. So I think it will help their learning if they know, such as ELL, you know like with flash cards and different types of learning methods that they can utilize, or outlining, or how to really utilize a study guide for an exam, so I'll be teaching them that.

Participant 4 thinks the students need to learn on their own, to experience science that they are interested in through hands-on activities.

> Students learn best learning on their own. As much as I can I want to lead them to the right answer, not just tell them the right answer. I feel if its something they do with their hands, or something they act out or something they experience they are going to remember that a lot more

than if they are just taking notes in their notebook or I am lecturing, so that's kind of at the heart of my whole teaching philosophy. I think kids learn best when they are interested and through hands on activities.

Participant 3 states that the students need individual attention and science instruction that is some how connected to their lives

I would say definitely as much as individual attention as possible, so however that is set up. I think I do like centers, so having centers that only one center needed teacher attention, so that I could work with one small group of students. Especially if it is a new topic like in math or something, while the other centers would be set up so that the other students could work on their own, and then rotate, so that each day each student sees the teacher for that subject area at least once. I think as far as science – it would be to have it meaningful and applicable for the kids. So if it's something they don't care about or isn't applicable to their lives they aren't going to learn it. So if they have no need, not need, maybe have no desire to learn it – than pick up something and go with what they want to be learning. I think also just the type of activities that are done a lot of times its just easier to pop out work sheets, but I think those are the things that they just sort of do, and not absorb any of the information, but, so its better to have meaningful instruction, but also meaningful evaluation, and to consider how to assess the kids so they know it. Not just a test question and the test is over. More like talking to the kids and saying, I talked to you the other day and we talked about this, so we are going to talk some

> more. Or, can I see how you would do this, so that it is like, so that after you assess them they know – so its not going to be like now lets work on this there is going to be some follow-up with this.

Participant 7 sees himself constantly assessing students informally throughout an activity to maximize learning.

> That's a tricky question, lets see I guess just I guess constantly assessing like their learning. And in an activity like that it is pretty easy to see whether they were learning. You can walk around and see if the groups are all like participating and see if some kid is sitting to the side. And then like in that experiment I talked about, the group that slashed the car cost the most slashed it by more than 50%, and there were like three or four other groups that had slashed it a lot so they really understood how these cars worked and how to put them back together. And then there were some groups that only slashed it by a few hundred dollars off of like a $9000 car and it was like they really didn't understand how to put the car back together cheaply. They only took off a couple pieces so that was an easy one to assess. Did they learn it? I think it is a lot harder to assess when you're doing like outside the box stuff like the cost lesson, but I think it can have much more impact than the just doing the safe easy to test stuff. That's more assessing their ability to memorize facts in a short period of time than it is really teaching them about science.

The vision the students have here of maximizing student learning has many of the components of inquiry. Hands-on activities, high interest with connections to the real world, teachers moving around the room, assessing informally and through performance of a task and through asking questions. They envision integrating the science lesson with other content areas and students working in groups.

Question B: *How are you going to know that your students understand, when they get it?*

The participants envision assessing student understanding in a variety of ways. Teacher observation, students journaling, explaining, making connections to other science learning, by student questions, teacher questions, by tests, understanding what it means to achieve mastery, and by talking with and listening to the students were all strategies they envision themselves using.

Participant 1 offered that he would get an idea of what the students understood through teacher observation as he walked around the room, He also mentioned using journals as a summary of learning and checking those to see what the students understood.

> I guess a good way to see if they understand is while they are doing it. I guess the science I have taught, we usually have some set up at the beginning, so I'll say this is what we are doing, this is what we are going to try to figure out, so then once they can sorta start a lesson, if it seems like they are kinda doing it properly, or they are on the right track, I'll think to myself ok they kinda understand what we're trying to figure out

> or where we are trying to go. So, I'll walk around. That's what I would do during, and then probably with the wrap up afterward, whether they have science journals where you can right down what you observed, or what happened, so I would probably look at that kinda feedback too.

Participant 6 will know what her student understand by their explanations, to her or a partner. She also suggests that when they can make connections to other science, they will show understanding by building on previous concepts.

> I will know when they can explain it to me and/or show it to me, or they can explain it to their friend, or when they make connections, like when they are talking to somebody and they say, "oh yeah, it's like when we were doing that!" and then you know they pull something out from something I've tried to build upon and then I am like, "yes they get it!"

Participant 2 envisions students asking questions and the teacher asking questions that require critical thinking. She says that through constant assessment and an understanding of what it means to achieve mastery, the teacher will be able to see student understanding. She also discusses testing, and then reteaching for those students who were not able to achieve mastery.

> Part of it is by the kind of questions they are asking and part of it is by the questions I ask them, and asking them a lot of questions, not asking yes no questions. If I can ask them questions that require critical thinking on their part I think that is a good assessment. I guess you have to have to be constantly assessing students and know what it means for achieving

> mastery. Oftentimes though - you might give a test and they didn't get it and you realize you have to go back and re-teach because that was part of your objective. You can't move on if they weren't covered, so you re-teach before you move on.

Participant 4 also mentions she will use teacher observations as assessment but also believes in the value of student talk and teacher listening.

> I think the thing to make sure they understand is to take lots of informal observations that you use as assessments so like today I modeled for the students and then I had the kids work in partners and then I said, "Give me what you learned with your partners," - just talking with the kids I would listen to them. A lot of times they'll say, "I don't get it, I don't get it," so I have never had a problem with them not telling me so far so – and then I ask questions, "are you doing ok? What's this? What's that?"

Participant 3 used science journals as an assessment tool in her placement classroom and felt that she would do the same in her own classroom.

> What we did in our science class there was that we had journals and it actually worked pretty well, so on the days that we had science we'd either do it in the form of like centers or like a whole group activity, that they would have to do a journal entry. I think that's really helpful because if they have like a worksheet or something that you wanted them to do while they were doing the activity, they were just regurgitating the information we were telling them or copying what was on the board or whatever, but

> using the science journals it was easier to tell if they understood it or what they remembered. I know for me, in my classroom, I would be looking at younger grades, so this would make it helpful to see what they remember. Even if it was like bell work in the morning or something they wrote about what they learned in science the day before. So for each project you could do a check up like that to see what they remembered.

One participant had a very logical starting point for her vision - how to understand when the students get it – what does it mean to achieve mastery of this concept. Others mentioned many ways of assessing, such as teacher observation, journaling, showing what they understand, explaining the information to someone else, making connections to prior learning and listening to what the student questions are, and by the teacher asking questions of the students.

Question C. *How do kids learn best?*

This was a follow-up question that I only asked some of the participants. The four responding to this question offered a variety of ideas: Interacting socially, limiting direct instruction, relating learning to prior knowledge, being involved in learning, and experiencing the teacher as a co-learner. The ideas of integrating subjects, responding to students' interests, and engaging them in hands-on learning appeared again as responses to this question.

Participant 2 states that students learn best when they can interact socially, have an integrated lesson, and limited exposure to direct instruction. She also envisions students learn best when the lesson is something that connects to the prior experiences of the students.

> Social interaction, integrating subjects, and in every subject I teach I try to limit the amount of direct instruction, I kept a timer and I asked my mentor teacher to observe me on that as well. I don't think they learn as well with all direct instruction, I think they learn more deeply through interacting with one another. Social interaction works best though, and when I pick a lesson I try to pick a lesson that will be something that relates to the kids prior experience, both in and outside of school. And when I start out I try to build on kids' previous experiences, prior knowledge, and then I might do a little direct instruction, some modeling, the whole time I am going back and forth to involve the students, I might have one of them come up, and then of course, they will do something independently – like small group work whether it is with a partner. I walk around and I monitor them.

Participant 4 repeats her beliefs that the students need to be interested in the science lesson and engage in hands on activities.

> I think kids learn best when they are interested and through hands on activities.

Participant 5 says that she learns best by experiencing learning and that students learn best through experience as well.

> By experiencing learning, by doing whatever they are supposed to learn, that's how I learn best. I remember the most from your class, like I said

> before, because I did things, I remember every single experiment, because I did them and I remember other stuff because we did it. If I learned something just because my teachers told me, I forgot already, and if I learn from I book, and I forgot, then I need to go over it.

Participant 7 agrees that when the students are doing the learning, they learn best. He also emphasizes being interested, as does Participant 4.

> When they're involved in their learning, when they're taking an active interest in it, um, I think that when they are actually doing stuff and involved, when they are teaching their classmates, when the learning environment I guess is designed to be more participatory, where a teacher is more like a co learner, so at times it's like "ok we are going to find this stuff out."

Participant 7 goes on to give an example from his placement of a lesson he did, and learned along with the students.

> When we did like the cost lesson, I hate to keep going back to that lesson, but I have had so little experience in teaching science that that one just really sticks out to me, but when we are doing it and I presented it to the kids and they were excited and they said, "So, (Mr. ___) how cheap can we make the car?"

Participant 7 then expounded at length about his belief that it is okay for teachers to admit they do not know something and to become a part of the learning team.

> So I told them, "I don't know I haven't even tried it out. I don't know how much money we can shave off the price, we're going to find that out

> together." And I think that might have helped to because it's like you know, its helps kids know that we are all in this together as a group and it's kind of like a group experiment. Like sometimes it is good. Like teachers I think a lot of times are reluctant to admit that they don't know everything, because even in my personal life I am always an insufferable know-it-all. But sometimes it's good and its healthy and it helps the kids to know like even the teacher is still learning. One of the things you always hear is that you want to make students become life long learners and if the teacher always pretends that they know it all, then the kids aren't going to be able to see that it is possible to be a life long learner and if you let them know that "I don't know the answer, we're going to find it out together," I think you can do that in more than just science class - that goes on to like everything else. When the kid has a question and the teacher doesn't know the answer, they have two choices. You can either say "you can look that up later" or you can say "we can look that up right now, we can find it out together," and I think it is a lot more conducive to creating a learning environment if the teacher does admit when they don't know something and they acquire that learning with the students.

Again we have visions that have many elements of inquiry. Experiencing learning, hands-on activities, social interaction, connecting to prior learning, integrating the other content areas, and finding things out together are all part of reform-based teaching ideas.

Question D. *Science is a social process.*

I asked the participants to explain what this statement meant to them. They had varied answers but the idea of collaboration is loud and clear. Sharing information and ideas, and even building off of each other's thinking, were common responses to this question.

Participant 4 envisions students learning from talking with each other and through debate.

> Students can learn from each other. There is more learning in the classroom when the kids share ideas and work together. When they can talk with each other or maybe with other groups who got a different answer, they learn more. Even if they have a debate about it, and they have to explain to each other how they are thinking, whether or not the debate is resolved, both sides have learned something. Even sharing their prior knowledge might help them understand a new concept. If I have never been to the ocean and you have and we are studying water, you can tell me that the water from the ocean tastes salty, and I can relate to that. I think really most of our learning is social but in science, in science especially, people are always building off each other's ideas.

Learning from each other is an important aspect of what Participant 4 envisions for her classroom. She believes it is a part of building a community of learners.

> Social process is like what we talked about – that learning from each other, that discussion, that you have a voice and it's important, and socially what are you interested in – what's something for the whole classroom? What builds that community? I think that the standards -

they suck or whatever, but there are ways to incorporate things that are exciting for the kids – you just have to take the time, so I feel like a lot of it just comes down to the classroom community, how do the students feel about each other and themselves? If they are confident and they are comfortable well then the whole social experience is going to be different than if they are afraid to say the wrong answer, or if they just sit in the classroom and they don't feel their voice is valuable and things like that.

Participant 1 agrees with this idea of community and collaboration.

Social process is what science is it's all about collaborating and working with each other. Listening to each other's ideas and building from there.

Participant 5 sees learning as sharing in discussions, in whole group and also in small groups or partner work.

They learn by sharing information with the other students because each student has a different view and they all might agree on some of the things if they share ideas. Sharing is social and we all learn from each other. That will happen in all discussions, the whole class and the small groups or partners.

Social collaboration increases potential for learning and is the way science has developed according to the perspective of Participant 7. He shares an example from his placement classroom.

Science is definitely a social process. If I go out and do experiments on something and then I don't tell anyone about it, or when you think about stuff like the Earth revolves around the sun, I didn't have to think of that, someone else already did and shared why with the world. So now we can build off of that knowledge. Thinking more of knowledge as something that is shared socially – that's important. Someone invented the Ipod. Well if someone hadn't invented electricity and shared it a hundred years ago, that Ipod would be useless to us. So sharing that knowledge and building off of it, even expressing to the kids that if someone else comes up with an idea that you didn't come up with – that's ok – we can take their idea and go even further with it. That's why you want that classroom that's collaborative, one kid makes a discovery and that gets shared within that group and then it gets passed around the whole class and it is as if the whole class made the group discovery. It is not like "Hey, Billy figured that out. " As a social group, as a classroom, we are all discovering things.

Participant 7 shares an example from his placement classroom:

I noticed with that cost lesson I referred to many times, kids would start putting up their privacy folders cause they didn't want other kids to see it. But then some kid would inevitably say, "Oh they took away the front wheel, we could do that. Wheels are pretty expensive; we'll get rid of one of the wheels." And so they all would be sharing. In that context it was social learning, even though I don't think they wanted it to be. I had promised to give the winners classroom money (money they could earn in class to buy pencils, or erasers or stuff like that) so in this case there was like a competition. But the kids were sending spies to find out what the others were doing. It was social and whether they knew it or not, they didn't have to figure everything out on their own; if someone else did –

they just used their ideas, and took them even further. I think social collaboration in the classroom - you have a lot more potential for learning.

The participants have visions of science as a social process that have as key ideas collaborations with other students. Also included are discussions that take place before, during and after an investigation, sharing thinking about how this connects to prior knowledge and the importance of sharing and building off of others' knowledge as a tenet of what science is all about.

The students' visions of science teaching were replete with ideas about reform-based science. They had vivid memories of what went on in the methods class and in their placement classrooms. They easily articulated how they viewed their future classrooms in terms of what the classrooms looked like physically and what they thought the classrooms might look like with students in them working on science. Hands-on learning, experiential learning that is relevant to the students' lives, discussion, questioning, integration and engagement were all key factors they mentioned for science learning. They described teachers moving around the room, assessing informally, asking students to explain, and looking for the connections the students make to other science learning or prior knowledge.

Visions of Science Practice

There were four questions related to science activities in the classroom. The first one is: a). *Let's say you are going to have kids do science investigations. How would you* *start?* I asked this question to understand what the participants envisioned science investigations to be for students. What did they believe should happen first?

The second one: b) *Imagine you have just had kids do an investigation how do you get them to support their conclusions with evidence?* The goal of this question was to see how the participants thought about students using evidence, and what ways participants might go about helping students to use evidence in their investigations. The third question was: c) *What do you think the role of discussion is in science?* Because discussion is so important in student learning, I wanted to understand how the participants envisioned discussions happening in their classrooms. d). *How do you go about making sure everyone is participating equally?* Having all the students to participate is a difficult task at times and I was interested in how the participants pictured encouraging equal participation.

Question A: *Let's say you are going to have kids do science investigations. How would you start?*

This question explored what the participants' priorities were for student investigations. Their ideas were varied and diverse but there were some common themes. The strategies the participants suggested included pre-assessing student knowledge, curricular planning, modeling, exploring, using student questions, being metacognitive, differentiating, providing background knowledge, facilitating through questioning, providing clear guidelines, supervising and motivating, assisting with the final product, backwards planning, being flexible, teaching as a co-learner, and nurturing student independence.

Participant 1, 2, 5, and 6 all mention the idea of pre-assessment. Participant 1 discusses pre-assessment in terms of topics to find out about as well as experimental design.

> I would probably start out with kind of a general question to see what they know, or what they think they know, then probably talk and ask them about find ways they think they can find out – Do they want to find all their information on the computer? Do they want to ask parents? How would they find this out? Or even if I asked the question – what if we don't have computers? What if we don't have books? What if we don't have prior knowledge, how else could we find this out? I guess just kinda get their thought patterns so they can start figuring out how to come up with the answers whether it's naturally, "Ok if I set this up and I kinda find data on that," or even if they just kinda find answers through research. I think it's just kinda that whole "I have a question," or "I need to know" – so how do I do it? Kinda practice makes perfect.

Participant 2 envisions using a KWL chart (1986, Ogle) for pre-assessment. She also notes that students learn differently at different ages, and discusses ways to differentiate instruction. In addition, she describes modeling an experiment for the group as a way to support their science learning. In the local school districts, the term *modeling* means that the teacher does first whatever the students will be required to do and the students just watch.

> I think first I would ask them what they already know – like doing a KWL – involve them in the process as much as possible, and the first time around it might take a little longer to get through, but it might solidify it in their head. I don't want to just rush through it and just get it done. I might do it whole group just to do an example – but I might even use one of the examples from your class that we did – like with the film canisters. I don't know if that would be appropriate, but I think it would – and I would do it once whole group. Unless they were a little bit older, then maybe I could just give them a set of instructions and see whether they can follow instructions – are they doing it correctly or incorrectly and see what they can figure out. Give them the chance to fail, and then say, "ok. That didn't work; let's try it again." So I guess depending on the age group I could do it whole class or give a set of instructions and see what they can figure out. If I needed to I might model or just see if they are the kind of group that just likes to go at it and go do it. It would depend on the group of kids. Some groups of kids might just like to have at it, and another year, you might have a group of kids that needs more time, or support, and you have to adjust.

Pre-assessment and modeling also are prominent in comments by Participant 5. She envisions starting off with questioning, suggesting that some background knowledge might be necessary. She ends with an expression of confidence in her students, and states that she will be ready to facilitate with questions, if they need help.

> Any experiment? Let me for example, the parachutes – I would say, "Have you ever seen them? Have you ever watched a movie with parachutes?" And if no one had any experience, I would hold it up and say, "What would happen if I drop this?" Starting off with questioning - They might need for me to explain some background and to model. They'll need the materials. I expect them to be able to do everything – they can do it. And if they need help, I'll be there – I'll be there to ask them questions about it - so they can figure it out.

Participant 6 also envisions starting investigations with a pre-assessment and describes modeling the process of an investigation as a way to support the students. She includes doing a think aloud for the students, so she is also modeling metacognition. She discusses webbing and brainstorming as her pre-assessment and then moves to having the students generate questions about the topic. She then states that she would ask the students to develop experimental proposals about those questions.

> How would I begin? Ok so let me see if I know what you are saying, I'm thinking that I would give them like a topic. Or something like – all right we are going to start studying plants. So, ok, then I would probably do like some webbing or about brainstorming about plants and then just start talking to the kids and I think that as we get through more topics, we'd get down some questions about that they have about that; they would start asking me and I wouldn't answer, I would just say, "ok, let's note those on the board," like you know have a question board and from there we could

start formulating some experiments. Well I'd have them like write up some experimental proposals or . . .

They would need I would think like a lot of like process support before actually how step by step, they would need a lot of support, step by step. Everything from how you go about formulating your question to, how you actually perform the experiment, to analyzing the data, putting it into the chart and I think they'd need support along every step of the way.

I would do like a whole process model with the class, I would call it like a class experiment. I would introduce it like, we will one day be doing this in small groups, but for now, so you can learn it, we are going to go through it all together. And we'd go through and I would do like think out loud, ok like "this is what I'm thinking as I do this," and then have them do it on their own, and then go through every process like that together.

Participant 3 does not mention pre-assessment in her response, but she does join other participants in her idea of modeling the investigation for the whole class. She envisions building off science knowledge that the students already have. She believes they will stay motivated and focused if they are interested in the investigation.

Definitely going over it as a whole group first, whatever the expectations are for the activity or the investigation. Actually the first thing I would do before the investigation is like model one for the class so that we did it all together and then try to split them up into groups for the next one – say we were doing like – where can you find water in your house as an exploration of what is water – like an introductory activity for a water unit.

> Just make sure the guidelines are clearly established for what they should be doing and try to build off knowledge or activities that they have done in the class so that they can say ok this is what I am going to be doing and this is what my expectations are. So make sure they know those things and then send them to working probably in groups.

Participant 3 was working with primary students, so she includes some thoughts about guidelines and supervision for this age group. She notes that it is often more difficult to encourage primary students to complete the final product than to do the investigation.

> I guess I would, well generally with the age group I was with, when you give them something to do and they understand it, they'll stay on task as long as they are interested which can be quite a while. For support they definitely need like one or more people to walk around and make sure they are staying on task. Or to see if they are having trouble or if they are doing things that they think are right way to do it but they are actually pouring the water into the microwave tray – just saying, "hey let me show you this is what you do." Keeping them on task, keeping them motivated, and as far as the outcome that's desired, I think that's going to be like the hardest part. They are ok with doing the stuff but the final product is a little harder. Like writing a journal observation about it or the group together trying to think of a model of what they did or just really they need help in the final product more than in the actual experimentation.

Participant 4 and Participant 7 both discuss using the curriculum as a starting point for planning an investigation. Participant 4 envisions looking at the standards, posing a question, providing the materials, and inviting students to learn by exploring.

> I think, umm, the thing I would do first is to look at the standards and figure out what exactly I need to be addressing, because that usually gives me like some ideas. After that I would I think pose things as a question. I think its fun to let the kid's just try to figure things out first amongst themselves. Just say like, "Okay today were going to be learning about magnets so what do you think all the pieces on the table mean? Play with them and see what you can find out about magnets from these, from what I have given you."

Participant 4 also notes that reflection on what the students have learned, through writing or drawing is important.

> Exploration is the big one and then with the writing I think they need to reflect on what they've learned and then use the new vocabulary, and a lot of drawing too – I am visual, I can look at a picture of what I've learned and I can understand it, so incorporating the writing and the drawing and technical reflection as well.

That experimenting needs to take place in a classroom environment where students feel comfortable is another idea that Participant 4 espouses.

> I think they need to be in like a comfortable classroom, where they feel they can experiment. And that's something I feel like I am having trouble with like at the public schools – I feel like kids are just nervous 'cause

they feel like they are going to get the wrong answer so they don't even try. They get in trouble for having fun and being kids, it just doesn't make sense to me – like walking in perfectly straight lines. I just don't get it at all. So maybe I don't belong there. Anyway, they need to be in a comfortable place so they can experiment, that's exactly what it is. And I know sometimes it's tiring to be a teacher, but I never want to be the type of person that says – oh that's wrong to come down on the kids – I think that stays with them. It changes how they think - why would they want to try? Why is it exciting? "When it comes to the classroom you're just going to tell me what I need to know, like my opinion doesn't matter. Teachers don't value my ideas or what I contribute" – like they should have a voice, it just seems like - what they say doesn't matter sometimes, cause they are kids and I just, I just don't believe that.

Participant 7 wants to start off student investigations by consulting the curriculum and using backwards design. Starting out with the end result in mind is part of his vision for science investigations.

> I guess it depends on what your goal is for them to learn. Backwards design is always a good way to go in lesson planning. Sometimes when kids are just being natural scientists, then whatever happens happens. I'm out playing and I'm going lift up the rock. But when you are designing the lesson it can't be willy-nilly. There has to be a goal. You have to figure out "what do I want them to take away from the lesson?" and have that be almost your starting point even though that's your ending point.

> Everything you do should be designed toward that end, and if it is following student inquiry the first thing you want to do is get them hooked and get them paying attention. If you are following student inquiry then half of your battle is done, almost.

Participant 7 next repeats his idea of teacher as co-learner and guide for student learning. Engagement and scaffolding instruction so that students can become successful in their learning are other strategies he views as important.

> But you still want to make sure for those kids who didn't come up with that question that you need to give them a reason to be engaged. You need to give them a chance to explore it on their own; to find the answers on their own, and then to try and expand upon what there is at the time. If you take the idea of the teacher as a co-learner, a more able co –learner, you can steer them in directions that they can get that knowledge on their own but you are giving them that nudge in the right direction.
> So for experiments it would mean having experiments that they could do on their own and find the answers; if it's a research question it would mean pointing them in the right direction as to where to find the answers. A lot of times kids just want the answers given to them – its almost like give a man a fish he eats for a day, teach a man to fish he eats for a lifetime. If you just give the kid the answer, they got the answer, and that's where it stops. But if you teach them how to find the answer on their own, they can continue to find the answers on their own as well. Lesson design needs to take all of that into consideration. But the most

important thing is have in mind what you want them to know at the end of the lesson is the best place to start.

Several participants' visions included looking at the curriculum and the standards as a starting place to begin the lesson. Most acknowledged pre-assessing the students' prior knowledge as an important part of where to begin. Providing background knowledge if needed, and the idea of modeling the investigation for the students were all part of the thinking about where the investigation might start. One student mentioned using meta-cognition and Participant 7 sums it up with "have in mind what you want them to know at the end of the lesson is the best place to start."

Question B: Imagine *you have just had kids do an investigation. How do you get them to support their conclusions with evidence?*

In asking this question, I was interested in how the participants thought about evidence and having students have to use data from experiments to validate their conclusions. The participants envisioned their students defending their conclusions with evidence through discussion, through multiple trials, by demonstrating their results to the teacher, through use of data, discussing variables and error, by asking more questions, and one participant thought that having students prove it wrong would help. Their answers were complex and multi-faceted, as is the teaching of science!

Both Participants 1 and 2 envision that discussion would help students support their answers with evidence. Participant 1 suggests that they could defend their conclusions, by getting with partners or in groups to compare different conclusions and try to find out why these were different. Participant 1 also wants his students to look at the factors or variables that might have affected the outcome.

> So, I would say almost have them defend their conclusions. I guess you could maybe have like groups of kids, or individuals or pairs and maybe find the kids that came to a different conclusion, and then have the two different groups discuss – like "why are your conclusions different if we all did the same observations?" So that way the kids are sitting there saying the theory is everyday the sun is going to shine and one kid went out when it was raining and one kid came out during an eclipse, and one kid came out in Arizona, so its like – well why are they different? What are the factors? Teaching from the start about these different factors or these different variables in everyday life, observations, and then sort of questions and answers. I don't know - like have them think outside the box, like, what if what you observed is different – what if it had been raining during the experiment, or what if there was an additive or try and change some variable, and have them question themselves about it.

Participant 2 thinks discussion will help, that the students learn from each other. She also mentions that the students have to have data and/or research to support their answers, and the need for multiple trials to replicate experimental results.

> I think discussion will really help with this – this is just real science – when you get a conclusion, you have to know why. You either have to have data, or done research, you probably have even more questions. I think by walking around during the investigation and maybe talking with

> each group I can see who has "got it" and who has completely missed it. And doing an investigation and coming to a conclusion might lead to more questions. I might say, "Oh, this is what you think? Ok, well I have a few more questions for you to think about," or "Well I think you all might want to try this step again," or "Why don't you talk with this other group and see what you come up with." I would work with the group that doesn't seem to understand the why. Or maybe a whole group discussion would help because if one group got the "right answer" – whatever that is, and we talk about what the class did, the other groups or students might say, "Oh, now we get it" – and go back and do it again. And tell them it's important that they can tell me why – why this conclusion – go back through your steps. And if it was a situation where the whole class missed it, maybe the experiment was a little too challenging for them, maybe they need a little more guidance, or to go back as a group and do it together. I think it's important not to just skip over it and go to the next thing – we'll need to go back and do something similar or do it together.

Participant 2 elaborates on what she could do, including recognizing that she might become a learner too if she doesn't know the answer:

> They could show their conclusions are right by using proof -
> They could write about it, I could ask them questions either as a group or individually they could address that topic. I could ask them to show me what they did and how they did it – I could walk around and observe – maybe the answer was right but the procedure was wrong – I could ask

> them to replicate it again. I could talk to them and say, "Hey what have you done so far, where are you going with that?" I also know I will learn things from them, that they might do something or have a question about something that I don't know the answer to – and then we'll have to go back and figure it out. I'll give them the benefit of the doubt, and have them go back and show me again what they did – so, talking with me, or writing it down or doing the experiment again.

Participant 6 agrees with the idea of talking about variables with participant 1, but she adds human error in experimentation. She and participant 2 both discuss the use of multiple trials to confirm conclusions with evidence. Participant 6 also uses data in her discussion of supporting conclusions with evidence, as does participant 2 above.

> Show me – I would ask them to show me. Hopefully by then they would know how to make a chart or a graph, or how to analyze the data or how to record, how to methodically record, and accurately record your data. And then teach them you know about independent and dependent variables, what goes on what axis - and if we're using a chart, you know how many times something happens, so that they would be able to - so then they'll have, ok now "I know this because look, you can't take this away, this happened," you know rather than just "Oh, but I saw it."
>
> And if two groups doing an experiment get different results? - Well that's good, that will be good, that's going to happen in every experiment and if they do it a third time we'll get different data again. Just talking about, I think I would bring up the idea of idea of experimental error and uh, just

> what outside variables affected this experiment. Other than you know, did the same person water everyday, if were still talking about plants or does it, you know what I mean like if we were measuring – yeah measuring is a good example. Exactly, and if it was the same person, do we know for a fact that he did this much and just talking about areas of error as humans that we're going to have.

Participant 3 discusses the collection of data, as well, through the senses when talking about supporting primary students in using evidence to support conclusions.

> I think by teaching them the correct way to write down like using their senses, it smells like . . . It feels like, it looks like. Always giving them simple things so that they can always follow these steps in order to help themselves see why they came to that conclusion. If they look at something and they think it is baking powder they can say like it smells like the stuff in a box that my mom puts in the fridge, or I remember we made clay one day and we used laundry detergent to make it feels the same as the stuff we used. Tying it in to things they have done before, because I think for kids in general their observations are related to something else they did when they were younger – their prior knowledge. So using their prior knowledge to support that, but then tying it in to their senses I think is an easy way with coming up with multiple things. So using feel, smell, look, see, hear – those can be used for comparison. That's evidence right there – they're collecting evidence.

Participants 2, 6 and 5, all envisioned asking the students to demonstrate their conclusions by showing the teacher their evidence. Participant 5's comment follows:

> I will say to them show me, and not just show me your conclusion, but show me how you got that – they would have to demonstrate it to me.

Both participant 2 and participant 4 noted that helping students support their conclusions with evidence might lead to more questioning, or that even the results might cause students to ask more questions. Participant 4 thinks that sometimes trying to prove a conclusion wrong may help in verifying a conclusion. Participant 4 also alludes to the idea of variables when she asks questions about what happens if?

> I think that something that helped me the most is how to not prove it first – so that's what for me it is overwhelming to think about this is right - for me it is how can I prove this wrong and then go from there so that's how I learned it and that's probably how I'll teach it. Asking questions – "Does that happen every time? What happens if you change this? Can you change this? Then is it still the same?   And that kind of stuff.

The vision of having two groups with different answers, or having a class discussion to evaluate answers was common. Other responses included asking students to show them and back up their information with data. One participant suggested discrepant results would be a teachable moment for talking about variables and about human error that may occur. Another participant said conclusions may often lead to more questions. Sounds like a scientist!

Question C: *What do you think the role of discussion is in science?*

This question elicited a number of ideas from the participants. Those that were mentioned by multiple participants include: pre- and post- assessment, students learning from one another, students making connections through discussion, the need for students to explain own thinking, and having discussion go from whole group to small group and then back to whole group, Those ideas mentioned only by individuals were: helping to identify misconceptions, as a way to engage, helps formulate ideas, and to facilitate understanding and/or new learning.

Participant 1 envisions discussion being used in many ways. The first use he discusses is assessment. What he describes sounds like post assessment as students share answers.

> I think classroom discussion is very important, especially when you talk about assessments and that was one of them, class discussions. I think its interesting because this is one of those places where you can have students kinda share what they know, explain to their friends their answers, - and I was sort of looking at it on the basis of math, so if you say, "What answer did you get?" And one student says, "I got this," and another student says, "I got a different answer," you ask them, you say, "How did you get to that answer? "

Participant 1 points out that students can often learn from each other, when they did not grasp the idea from the teacher. He also states it helps students when they have to explain their own thinking.

And I think if students discuss it they get to hear different ways of getting the answer – they can even back up and look at their own conclusions of how they got there. Whereas, whether they got the right answer or the wrong answer, they're still having to explain their methods for getting there, their thinking, And I think that way you can find out, "Okay that's where you were kind of off track in your thinking or that's where you were right on, but you just missed this one step or you were totally on the right track." And I think the students can start hearing – like- "Oh wow, Billy over here is seeing this other thing and I didn't even think about that, that makes a lot of sense." And I think even with students sort of hearing from each other, it's a lot different from hearing it from a teacher, or even "hearing" from a text book sort of thing. Where as the student might just be like, "Oh yeah it's like this other thing," or "Remember last year?"

And then other students are like – "oh, yeah, yeah, yeah – I get it! I get it!"

Like Participant 1, Participant 6 concurs with the vision of discussion being used as assessment but she articulates assessment before an experiment. Pre-assessment, during the experiment to keep students moving along and after as a summary or post assessment is described. She also agrees with Participant 1 because she sees students learning from each other as a benefit of discussion.

The role of discussion. Well, I think it has a lot of roles, like I think it fits in I mean before you start an experiment, to get ideas about what you should be hypothesizing, brainstorming, and then through it to work through what your doing. You have discussions on what you're seeing,

> your work, like if you had an experiment that was ongoing, like for one week or two weeks so you could talk about, "Hey what do you think is going on here?? Or again at the end definitely, to see if the kids understood, the discussion could serve as an assessment, of ok did they actually learn anything or where do they still have questions? Where do we need to build on?

Participant 6 agrees again with Participant 1, when she explains how student discussion can help the students formulate their ideas so that they can explain their thinking.

> There are benefits to sharing, as long as they are on topic. I mean It helps them, well I know for me it helps me really formulate my ideas, it helps me know, "Ok what am I really thinking up here? What do I still not quite understand?" And I think they can build off each other, because sometimes, someone will say something, and they will make a connection to maybe something - you know like kid talk rather than teacher talk; they'll say it maybe in a way that helped you know little Pedro over here understand when I have said it a million times and he still was not getting it - but Mario said it and he got it and yeah!

Participant 2 agrees with Participants 1 and 6 about using discussion as assessment and that the students can and do learn from each other. She describes discussion as part of the science process.

> It's always crucial I think. I think it's really powerful after they have gone through the inquiry process to get back together and say, "Ok now what did you learn?" I think it's really a part of the science process, - I think

> discussion is really important; I think it's how they get a chance to learn from one another. Sometimes even in the same group, somebody got something different out of it, so if I am able to hear what my group member has to say – in a small group, or in whole class, we learn from one another. I really like to make sure that the students who are kind of shy talk up and have a chance to be heard.

Participant 3 agrees with Participants 1, 2 and 6 about assessment. She mentions using discussion as pre-assessment with a KWL chart (Ogle, 1986) and then at the end of an investigation. She states discussion keeps the students motivated and "on the same page."

> I think that discussion is very important like I saw with the KWL chart, just like helping them understand that water isn't a completely foreign object, or like when we were talking about planet earth, they knew like about continents, countries and cities. Some of the kids knew there were layers, which was cool for six year olds. The stuff my kids were learning, the second grade class was doing the same thing and the fifth grade class was doing the same thing – you can tell the state really believes in the spiraling curriculum or whatever. But as far as discussion, I think it is really good at the front end and at the back end for science. Especially to keep kids motivated, and for empowerment I guess, cause they think, "Hey we know about this. It's not that scary" or "It's not that out there." You can actually do and learn with science, where with other subjects it's more like "Hey this is what we are going to learn." You don't have to get motivated. Well you do but it's not like say vocabulary, we learn

vocabulary all the time or spelling words, but science is like – we haven't talked about water, I don't know what you mean – what is water? What is a river? What is a stream? So motivating kids and then discussion is really good to go over like "Hey what did we talk about today? What do you think?" And sort of pick out what they've really grasped and then what their weaker areas are so we can go over weaker areas again; find out the areas that might still be confusing. With discussion I think too it's just making sure that everyone is still on the same page. Not just the kid who is saying, "I know all this, I got this stuff," but making sure that kid sitting in the corner – asking, "Hey what do you think?" You know giving everyone a chance.

Participant 4 finds the main use of discussion is for students to learn from one other, that they can teach one other; possibly in ways the teacher has not been able to do. She agrees with participants 1, 2, 3 and 6 on this idea.

> I think it's important because there have been so many times when I haven't understood what the teacher is saying that then somebody else said something and I totally got it. I feel like more than anything the kids are actually teachers and students of each other and that's how that discussion happens even if its like the quick, turn to your partner and tell each other this. And what do you think about this because that's where I feel I would really learn the most is from somebody that wasn't necessarily even the teacher.

Participant 5 concurs with Participants 1, 2, 4 and 6 about students learning from one another. She agrees with Participants 1 and 6 that discussion works well from whole group to small group and then back to whole group again, She also agrees with the idea of discussion helping students make connections to prior learning. In addition, she believes that discussion can bring to light misconceptions that may need to be clarified and may also be instrumental in engaging the students.

> Discussion is that people who know can refresh other people's minds – maybe not only refresh but also teach something to others. Some students will be able to enlighten other people's minds**.** Also it helps so that we can clarify any misconceptions that they have, or to bring up experiences that they have had, to engage them as well.
>
> Discussion can start out whole group and then while we are experimenting they will be discussing in their small group, and I will go to the group and we will have our own discussions there and then at the end we will draw back together for a discussion. Because one kid will say this and another will say, "Oh, yeah" – so every group has a different perspective maybe about something. And then they help each other understand about it.
>
> They (the other students) engage sometimes the students who aren't engaged and because they see that somebody else has experienced that or that somebody else is excited about it, they get excited too.

Participant 7 believes that students need to explain their own thinking in order to make the learning more permanent. So he is in agreement with Participant 1 and 6.

> Well whole class discussions are great, but sometimes kids fade into the background with that. They may not feel comfortable speaking in front of the entire group, so I think that sometimes having smaller group discussions, maybe groups of 3 or 4 discuss their learning with each other, kids are much more comfortable. And that is a way to get equal participation, too. And if they can talk about what they learned, their learning is like cemented a little bit more. It's like Bloom's taxonomy, synthesis I think was the part where if they can explain what they did and explain what they would do in other circumstances, learning is a lot more permanent than if it's like a chant and response boring classroom. "What happens to iron if you get it wet?" and the kids say – "It rusts," or something like that – temporary learning.

Participant 7 also suggests that discussion is a way to facilitate understanding and new learning.

> But if they talk about an experiment they did in class and they explain why they think something happened – then it's better. And in science often there's not always one right answer, and that might be something different for kids, cause when you are in math class 2 + 2 is always 4. But in science, there are interpretations. Scientific learning evolves over time. The Greek's didn't always know that the Earth revolved around the sun, but that doesn't mean that they were dumb. It just means they hadn't acquired that knowledge yet. Science is always evolving throughout the centuries and the way we come up with new learning is through discussion. One student might have an idea –"I think it did this because

this," and by having that classroom discussion their understanding changes and letting them know that it is all part of learning.

The participants' visions include a variety of ways in which discussion plays a part in science learning. Most found discussion to be a good assessment, a way to access prior knowledge, to assess thinking as they go along, and to check for understanding at the end of an investigation. There was a strong response to the idea of students sharing through discussion being an asset to the learning of other students in the room. Two of the participants mentioned that having students discuss and share was a way to help them formulate thinking, and make it more concrete. Participant 7 talks about how science evolves over time and that discussion and sharing of ideas are crucial to that happening.

Question D. *How do you go about making sure everyone is participating equally?*

This question followed the previous question in the interviews. A group of participants shared a desire to scaffold discussion participation, although some with different emphases. Making sure to call on non-participating students was a perspective shared as well. Other visions of assuring equal participation included asking the opinion of a non participating student, encouraging small group/partner talk, creating a safe environment, using proximity and moving around the room, making mental notes or just paying attention to which students are participating.

Participant 1 envisions scaffolding discussion first by having the students talk with a partner or talk with a small group, that this could facilitate equal participation. He also sees himself making sure to call on those students who aren't participating by asking for their opinion. He explains that moving around the room and listening to the students, paying attention to the students who are comfortable in sharing in a small group, but not in the whole group, will help him support those quiet students. His idea is to encourage small group discussion and set up a classroom environment that promotes students sharing.

> One of the things is if you are like in a large class, like a whole class discussion making sure that everyone is talking. The one kid who is always raising their hand, maybe not calling on them all the time - the one kid who is sort of hiding in the back, you've got to find a way to get to him so you ask him – "What do you think? Do you agree with what she just said or disagree?" Not so much putting them on the spot, you don't want to make them feel uncomfortable, but even if you just kind of ask them, like "Hey we haven't heard from you in a while. Do you want to agree? Disagree? Add something?"
>
> Of course I think using groups is good, "Turn to your shoulder partner," "get into you small group and talk about the question on the board," or "talk about what Billy just said." Moving around a little bit as a teacher, listening and saying to yourself, "Ok, this kid never talks whole class, but I can hear him talking in small group; I can see that he is more comfortable just talking with two or three kids as opposed to in front of everyone."

> And you have to set up that environment, that classroom family environment, where everyone feels comfortable, and everyone is good at sharing. You can talk, and I think that's sort of in most classrooms what you want to get to, so that everyone feels cool to say what's on their mind or add or whatever. I remember feeling kind of shocked coming in from undergrad and then coming into here where it was like we were always encouraged to talk, always having to do Think-Pair-Share and stuff.

Participant 2 agrees with Participant 1 on scaffolding discussion participation for students by having students talk with their partners or small group. She follows up with an idea for the reporter of the small group to use the name of the student who commented as a way of giving voice to those reluctant to participate.

> To make sure everyone participates you might have to scaffold it that at first, they just talk with their partner. And then in the small group or then when someone raises their hand to represent the group, I made a comment and I am shy, but maybe the leader of our group shared my idea with the class, I could say wow – my voice is being heard. They might even say, "Oh so and so said this," so I think that is important. Discussion, discussion is important.

Participant 5 shares the perspective of Participants 1 and 2 on scaffolding, but with a twist. She has an idea to scaffold individually so that students feel supported when participating, but are not excused from participating. She also concurs with Participant 1 in regard to calling on students who don't raise their hand. She feels that by supporting students in these ways they will build on their prior knowledge.

> My idea is to ask the ones who don't raise their hands and if they don't know say to them, "Ok well you don't know so let's find out." To me it's like going back to that one and saying, "well lets see what you know, you know something about what we are doing," and then guide that person to go where I want. Because if I don't, then I just go to the next person and they say, "I don't know," and the next person as well. I need to help them help themselves. I will take whatever they have and then build on that knowledge.

Scaffolding is a concept that Participant 6 shares with participants 1, 2, and 5 but is not sure how she will do that for her ELL students although she is aware of the need. She has thought of several strategies to ensure equal participation.

> I definitely think that there will have to be some times in groups, different roles, whether they are assigned a role or someone will be, I don't know. I don't know how I am going to do it yet, but I think there will have to be some kind of, either a number way and I really like that one where you gave us that we did in class where you highlighted something that we wanted to discuss. So if I was giving them an article, I think that would actually be a really good way. And then they say it and have everyone take their turn responding so I know that everyone is responding. I would have a rule too where you can't talk more than once until everyone has spoken -spoken up, until everyone has participated and then that would be it, but if they didn't know, or someone was really struggling with English then I would have some kind of alternative.

Participant 7 answered both questions at the same time so his response is included in the question above. The idea of scaffolding discussion in small groups so that students are more comfortable is an idea he shares with Participants 1, 2, 5, and 6.

Participant 3 believes that by paying close attention she can make sure everyone participates. She also notes strategies that were used in her placement classroom.

> I don't know, I would say just really pay attention. I know my teacher would make little lists of people who never talk in class and then she would make sure to call on them. Instead of asking a question to the whole class she would say like, "Carlos, what do you think?" "Jessica, what do you think?" You know picking out the kids that need to share and giving everyone a chance.

Participant 4 has a similar idea to Participant 3, but instead of paying attention, she says she will make mental notes about who is participating. She also wants to take some anecdotal notes. She envisions moving around and using proximity to help ensure equal participation.

> Oh that's hard, I think because I'll be moving around the room a lot, proximity is a big thing, making mental notes and actually writing down what I see, and things like that – is it the same kids answering every time? Who haven't I called on? Is it all boys, is it all girls? And proximity is what I have learned works the best. You just go and stand next to somebody and they tend to start working. Plus, it's that classroom community too. If they're excited about learning, I don't think they are going to need me to stand over their shoulder as much whereas, in the last

> classroom where I was, it is constantly – "What are you doing? What are you doing? Get back to work, get back to work, get back to work." I just feel like there has to have been something that wasn't set up or things that need to be changed, otherwise, we have read so much research about that kids want to learn – so what's the – there has to be something missing in that kind of classroom.

In order to ensure equal participation there was a range of visions. Some participants believe they will pay close attention or make mental notes to keep track of who is sharing. Others had ideas about how to scaffold or build capacity for those students less inclined to share for whatever reason, and were sensitive to the range of personalities or need they may encounter in their classes. One participant believes if you are going to ask them to share, don't let them off the hook by accepting an "I don't know", but stay with them and encourage them to share what they do know, and then help them find out what they don't know.

The vision of science in practice for those interviewed included many components of inquiry-based instruction. The students' comments tend to support the importance of experiential learning, science process skills, discussion and making sure that all students have a voice in classroom discussions. At times it seems that their responses are similar despite the question being asked, but I believe that is because there is such an overlap in ideas. Discussion is a tool in defending conclusions as well as in starting an investigation, for example. Asking questions is another tool of inquiry that may occur in many different aspects of instruction. The idea of modeling is an idea that came from their placement classrooms and is often a requirement for teachers in high poverty schools in this state. Modeling is not what is typically thought of in a science classroom in terms of a set of ideas or physical model used to explain ideas. It is a required strategy in many schools. Teachers must do a particular task or problem themselves in front of the students while the students sit in silence and observe. Then the modeling continues with the students joining the teacher in the task. If they are considered to be capable after this step, they are then permitted to try the task on their own. Participants observed this enforced practice in some placement classrooms and seem to have incorporated it, along with inquiry ideas, in their visions of practice.

Lesson Plan Reflections

The lesson plan assignment has been described in detail in Tables 18-24 on pages 182-205 of Chapter Four. The participants who interviewed were able to complete and implement their lesson plans in their internships. Each interviewee's reflection on his or her lesson plan is interpreted below.

Participant 1 recognizes that his lesson used both math and science. He considers it to be integrated and remembers mentioning in his original lesson that it could be integrated with art, but now realizes it would have worked with language arts too. He thinks he needed to find a way to grade or assess the student work, maybe through getting their reasoning in writing. When not teaching the lesson as a one time only situation, he could pull in more resources. He discusses using patterns in nature rather than only referring to them as he did in his lesson plan. He envisions letting the students talk about these examples and discuss what they see.

> I guess one of the things I was thinking when I was designing this lesson was that I was interested in math, so when I saw the lesson on tessellations it kind of caught my eye because I figured I could use it for math or science – so it kinda was integrated. And as I looked into more I realized you could even add other concepts – you could add, like a language arts or an art to it. I think I mentioned art in my lesson but I don't think I mentioned language arts. But you could definitely add like a writing piece, which would be a change I would make. The other change might also be maybe about how to grade or assess – a lot of times in a lot of my lessons I'll think, "oh this will be great, we can do this or we can do that" – as long as the students do something, you know, mission accomplished. But I think if I had had more detail on what they are producing or the reasons behind it – like their thinking in writing, it would be good.

His next idea is to look at tessellations that are man-made and talk about those examples as well. He would add some probing questions to make students think about why those particular models are being used. Spending more time on the lesson than he was allowed is something other participants noted as well. He thinks he would look for ways to hold the students more accountable and recognizes that if the lesson were a part of a unit of study, he might have to change it even more.

> Hmm, well one thing I also think I would change is I would first have the students look at patterns in nature. I am not sure how I would do this – maybe find some really good images, or, real things, like a honeycomb, and anyway just give them some examples and have them talk about what

> they see. Then we could look at some man-made kinds of tessellations, like brick walls, or chain link fences and talk about them. Why do they think they are that way – what are the advantages? I kinda think that would help them before they had to create their own.
>
> I would definitely spend more time on it – and somehow find a way to keep them more accountable. I'm not really sure, I would have to actually do it again, and it might be way different if it had to fit into the curriculum.

Participant 2 did a lesson on classifying buttons with first graders. She comments that, "so I already know right now something about grouping," but I am not sure what she is referring to – grouping items, or grouping students. She goes on to mention different items that could be used for grouping that would provide instruction in other areas as well. She describes using letters (to practice recognition) or shapes (to practice recognition), which are both good ideas. She adds numbers to the list of things students could classify.

She also realizes that buttons have many different possible attributes so that they could be grouped in a variety of ways.

> This was a lesson with first graders so I already know right now something about grouping, you don't necessarily have to use buttons, and it's first grade so, for classification you could use words or letters, or shapes, or I could give them math and do shapes. I could make colorful cutouts of letters. I know that we are always worried about do they know their letters, or numbers, or you could do both. As for the buttons, you

> could have them organize them once, and then you could do the buttons again, how many holes there are according to different things about the buttons. You could do different foods; you could do different seeds for science – it could be a math and a literature lesson. You could do plants, how are these alike, how are they different?

She continues brainstorming the many ways classification could be used, foods, plants and, seeds. She refers to another lesson she did with students in which they all brought something with seeds from home and she had them do multiple classification and comparison activities, and included the addition of literature. She furthers her ideas by describing it might be fun to make students aware that things can by sorted in different subject areas, to help them make cross–curricular connections. She also describes increasing the complexity of her lesson as she went along.

> For example with third graders, I had them practice with seeds; they each brought in something with seeds from home, they brought in a food with seeds and we counted the seeds and we grouped the seeds and we compared the seeds. That connected with math and science and then we read about seeds and that was literature, I guess I just like to find ways I can weave all these lessons together and that way. It also might be kind of cool, to show them that look we sort things in science, and we can sort things in math, and we can sort words in reading by the pattern or by verbs, nouns whatever, that sorting or classifying is a skill we use in different subjects, so, help them make connections. The first graders worked in pairs and did the little bingo cards to find buttons to start, but

> even that could be used with anything. We used the cards for informal assessment. We got more complex as we went along.

Participant 3 conducted her lesson near Halloween, so she chose to make Oobleck with the students, hoping to discuss with them some aspects of solids, liquids and colloids. In her reflection, she comments that she could have improved the materials management part of the lesson to make things go more smoothly. Because she wanted the students to be excited about the lesson, she states that she "put a lot of hype" into it so the students would be more enthusiastic. She felt that she could have focused more on the science aspects. She used writing as an assessment. If she did it again she would have liked more time so that she could have done an introductory lesson first. She notes that these students don't normally get any science instruction.

> I think just practicality wise I would have had the materials set out in like sections because it took a long time just having everything in front for the kids to come and get their own. There were thirty kids and to have each of them mix their own, if I had little groups so that they could have worked on it together and made a big batch and then split it up so everyone could have had their own. I think, I put a lot of hype in the lesson because I wanted them to enjoy and be excited, not to be just like uhhh; oh we're mixing stuff. So I could have focused more on the states of matter of what we were using – solid, liquid, we did do some writing. I think if I had it to do it again, I would have done an introductory discussion about it the day before, but since I was only going in once a week, I did the discussion the

morning of. If we could have talked about colloidal substances and solids and liquids, and they had thought about it the day before and came in expecting the experiment, instead of just like, two hours of science one day, when they don't get any –

Participant 4 echoes the issue of more time. She did an activity with ants with the class she was with and believes that if she could do it again, presumably in her own classroom, she would have the students do observations at multiple times during the day. She had the students write and draw about the activity and would keep that in her lesson. She thinks that after several observations, she might encourage the students to research about ants, and compare what they found in research with their observations. Her other change would be to ask more questions.

> I would obviously give the kids more time – it just wasn't enough time, and maybe have them do observations at different times of day – hmmm, this is hard. I really liked having them write about it, I would definitely keep that in and the drawing was good too. I think more time and then also maybe give them some time to research and read about the ants, after they had them for a few days, and maybe compare what they read with what they are seeing. I don't know - there's just so much you could do. It would be nice to do in my own classroom without the constraints of someone else's classroom. I would probably ask more questions at the beginning too. I know I would.

Participant 5 refers to the management of her lesson, as did Participant 3. The change she would make is to have better management. She believes that doing the lesson with a small group might have been easier than whole class. She thought if she had initiated the activity within a real life situation that might have helped. If she redid this lesson with a whole class she envisions students working together in teams. She referred to possibly breaking down the lesson into steps to facilitate the amount of time the students had for the tasks. She also referred to more pre-planning, a list of questions she might ask, and the next activity ready to go just in case!

> Hmm, most of what I would change is the actual doing of it. I needed a better "management" of it. The kids were so engaged; they liked doing their fingerprints. I only had a small group, if I had a whole class – oh my! Maybe we could have started out with like a mystery about whose fingerprints were on . . . something. . And then we could have to work together in teams to figure it out – I would have to do a lot of pre-planning and even make a list of my questions first. I think mostly I need to think about how to break it down into steps, so that they don't have too much time or too little time, and definitely be prepared with what is next just in case.

Participant 6 describes the main change she would make would be to not teach the lesson in isolation. She describes the importance of helping students connect their new knowledge to other (prior) knowledge. She knows that if she had integrated the lesson, she would have gotten more from the students.

> Now what would I do differently, oh I know for sure what I would do differently now be cause it seems so isolated to me. It just seems like you know it didn't have any connections to anything. Because I know for me

> if I learn something new and I don't have anything to connect it to that's just a fact that disappears for me. Like even if you meet someone and you know someone they know, you are a lot more likely to remember them and you do the same thing with materials with content. Ok this domino thing (lesson plan) we had talked about math and looked at the dominoes and now I am doing this thing for science, and I think you know now there's just more connection, where now I am thinking I could have taken this to math instead of just isolating taking this one shot, I could have gotten so much more.

The idea of more time is repeated once again with Participant 7. He comments that he did not have the lesson organized in such a way that he used his time wisely, he complains of down time for the students. He envisions preparing the materials in advance of the lesson, and some kind of pre-assessment before the lesson. Then he states that he would have done follow-up. He then describes some activities that could have been done after the investigation, for example, having the students design investigations to modify their pinhole cameras. He also reflects on how he would do the lesson for the whole class, instead of just part of the class like he had to do for his placement class.

> Well, I remember there was some down time – and I should have had all the materials ready ahead of time. And also, I would have done some pre-investigation investigation – like I guess really pre-assessment. And then follow-up. There's so much more that could have been done with this. One thing, one thing that would have been really cool would be to have the students design an investigation to maybe modify their cameras – what

materials would they use? What improvements could they make? And I never would have done it only for some of the kids - but then that was based on the situation.

The reflections on lesson plans sounded similar to reflections I have had as a teacher. Some common ideas for change or improvement were making more connections to the real world, not teaching the lesson in isolation and bringing in some models the students could explore first. Making problems relevant would have improved the lesson. Time was an issue for all the participants. Because they were implementing this lesson in someone else's classroom, they were subject to some constraints. In addition to providing more integration, one of the participants pointed out that she could have made cross-curricular references to the concept of categorization. These are ways we use categories in science, these are ways we use categories in math, in social studies, etc. Managing materials was an issue, and "less hype, more science" was a comment one participant made. It is easy to get caught up in the " hands-on" part, and let the conceptual slip sometimes.

The Methods Course: Participant Reflections

There were four questions asked and analyzed about the methods course. The first was: a). *During the methods course, what attempts at best practices did you see your methods instructor modeling for science? Give examples*. Since it had been at least 6 months since the class, I was interested in what they remembered. What were the practices still in their memories? And which practices did they classify as best practices? The second question was: b). *So how was the science methods course different or similar to other methods courses?* This question was an attempt to find out how they viewed this course in relation to others. The third question was: *c). What are the key ideas from the methods course that you will take with you as you begin to teach?* I was interested in what the students believed to be important and/or useful to them as they began to teach. And the fourth question was d*). If there were anything that I could have changed about the methods course to prepare you for actual classroom teaching, what would it have been?* This question sought to understand what they believed was missing, or could have been done better.

Question A. *During the methods course, what attempts at best practices did you see your methods instructor modeling for science?*

The participants all had very different ideas; only about half of the aspects described had comments from more than one participant. The aspects with multiple comments were the following: Preparing to teach by example, student focused, good facilitator, small group work, valuing inquiry, piqued our curiosity, made us reflect, integration, gave me confidence, and actually did experiments. The other comments were: Enthusiastic, meaningful assignments, clear expectations, our learning was through inquiry, examples from your own classroom, encouraged participation, asked questions, didn't tell the answer, cooperative learning, believed in us, respected us, and understanding.

Participant 1 described what he believed was being prepared to teach by example. He thought he could then go to a class and teach something in a similar way. He also described the class as student focused because as he said, "the students did everything."

He described the instructor as a good facilitator, and considered that learning about ways in which to integrate science were "eye opening."

> I thought our classes were like good models, I could have gone from our methods class to another classroom and been able to pretty much do what we had done. I think because we (us, the students) did everything. I think that you were a good facilitator and like always part of the group -
>
> I thought it was eye opening, I mean I had never thought about it (science) that way. All through school it was sort of now it's math and now it's reading, and now its science and now it's social studies and you kind of do things that way, but I think that's what I found interesting about the methods class, it was like, why don't you just have them all integrated, where it's just you know it flows from one to the next.

Participant 2 agreed with Participant 1 on the idea of the class being student focused. She concurred with Participant 1 also on the instructor being a good facilitator. She commented that the instructor was enthusiastic, liked that the students worked in groups and reported that she felt the instructor had given her the confidence to push for science in her own classroom.

> I really thought you did a good job at being student focused – it wasn't all about you because you were the instructor. And you always listened to our answers and when there were problems to be solved you helped us to solve them. You were enthusiastic, and I know these don't sound like best practices but they are.

> We had to work in small groups and we had discussions and you asked questions – most of what you did was what we should do when we teach science. You gave us confidence to think about where we teach and maybe say a good teacher needs to be selfish. She needs to say, “Ok my students are still reading and writing, but they can read and write about social studies and science. We’re not taking separate time out for them; we are still incorporating them through lessons.” I realize I can’t go in a classroom and just do whatever I want; I have to do what the district wants me to do; I have to take what they’ve given me, but I am resourceful. I can take the curriculum and I can get other things in. I know how to think independently and I know how my students learn best, I know what needs they have and as a teacher I need to incorporate all the subjects together.

In mentioning teaching inquiry by example, Participant 3 was also in agreement with participants 1 and 2. Participant 3 saw the instructor as valuing inquiry and believed that meaningful assignments and clear expectations were given. She appreciated the reflections as well.

> I would say for sure that the science methods class I took was better than all of my other methods courses, although social studies was pretty good – we did some projects. But I think the weaknesses of the methods courses here are generally like standing and teaching math to students which best practice would tell you is not a best practice – like you need to have modeling, but then let the students do the work, and let the students try whatever the method is you’re teaching or the practices that you’re

teaching. You know you can teach it and then say – you've heard it now go and do it. That's practical even for young kids, but even for adults. That was one thing I really liked – is you would explain something and we would talk about it as a class, and then we would do it as a group, or one group would do something and show the rest of the class, and then we would all try it. And then you would see what we would recommend and then we would all discuss it, not just you as the teacher talking the whole time. Giving meaningful assignments – that was another thing, like the activities that we did, the journals or reflections on what we were learning in class – not just assignments to do because, hey, you need points for this class. Like the teaching of a lesson, I would not have ever had practice teaching science if I didn't have to do that. And it wasn't just teaching we had to pick a lesson, we wrote it up, we had to teach it and think about it – all practical things. And I think for each there were clear expectations and clear assignments instead of like oh, go write five lesson plans.

Participant 4 concurred with any of the others but had her own set of ideas about best practices being in evidence. For her, learning through the inquiry process helped her understand how to teach science. She found stories from the instructor's classroom to be useful, and believed that the methods class gave her the confidence to learn the science content she might need to know.

My guess was like learning through inquiry is a best practice and that it is also student led inquiry, so I feel like I remember your story when you walked around the school yard with your kids (nature walk) and that was really good because you were not telling them what to pick up, they were choosing and asking about things that were interesting to them and then you were building based on what they were interested in.

I think the whole thing that you did well was helped me reframe what I thought about process, and what scientists do, right, and I know we learned content, but I am not thinking of any right now – I am sorry, I am so stressed. I know that I will need to pick up the science book and teach myself some things that I don't remember, but I am confident that I can learn the science content. My biggest problem was that I didn't know how to teach it – the process- and that's what I remember the most, because that is what changed my thinking about science. The inquiry was totally new information and that's what I remember the most.

Preparing by example is a best practice Participant 5 saw evident in the class, like Participant 1 and 3. Valuing inquiry and reflection are elements that Participant 5 believed the instructor exemplified, as did Participant 3. Participant 5 agreed with Participant 2 on small group work. She added that the instructor encouraged participation, piqued her curiosity and asked questions without telling the answer. She also noted that each class started with an experiment.

In everything we did, in every class, we always started with an experiment, and then you had us think about that and be curious about what we were doing, and about the things that were happening. You picked your materials, all of the students were in teams and we all participated, and you made us very curious, I don't know how to say it –

but we had to find out. Inquiry learning. Science as cooperative learning, reflection, teacher walking around, and questioning are the best practices I saw.

I think I did, that thing we did with the pennies and the salt water, about the water being denser. If I knew that before, I didn't remember, and I still remember now after your class almost a year ago, because I did it, you didn't tell me or just give me the answer. You kept asking us about it.

Participant 6 agreed with participants 1,3, 5, and 7 about preparing the students to teach by example. As with Participant 5, she seems to have enjoyed the experiments and notes that the instructor made her curious as well. She commented that she knew the instructor believed in the students and their abilities. She is anticipating teaching science that is "different than any science they (her students) ever had."

A lot of hands- on, a lot of experiments, loved that, and then, making like mysteries, making us all learn; making us want to figure out something. You know you would like give us, show us something and be like well why does this happen, and not knowing and kids too, you know I think it makes kids crazy even more than like the 25 or 30 year olds who were in this class. It's like "why is this happening? What is going on here?" So I think I am going to be using that method a lot. And you believed in us and thought we could do it. I really like that. I want to use some of the solar beads, 'cause I really want my kids to do that - you know just to give them a couple each. I already know it's one of my first week things I want to do, just to get them to start recording things and building up what they

> know about how to do experiments. **B**ecause I know like this science has to be different than any science they have ever had, or any approach to education that they have ever had so its going to be a very slow process for them, showing them along the way.

Participant 7 agreed with Participants 1, 3, 5, and 6 as seeing evidence of best practice as preparing by example. He also concurred with Participants 5 and 6 about the instructor piquing curiosity. He deems being respected and understood by the instructor were best practices.

> Well everything we did in that class really followed the method of designing lessons where you want to engage the students, get them hooked, expand on their knowledge, explore and you – it was interesting. I knew that coming to class, I knew that I was going to learn something new, whether it was something that I like was interested in knowing beforehand. Like the Oobleck, I had never wondered, like, "Oh I wonder what would happen if I mixed baking soda" – was it baking soda? What was it? But you got me curious. Oh yeah, borax and glue water. I had never wondered that - and it was interesting. I had never wondered about that. I always felt that like you welcomed our opinions, which was different from the other methods courses I took, and in my math course, for instance we got in constant arguments with the professor because she would present the knowledge about the subject as if she were the defining authority on the subject, which is impossible and she should have known that was impossible.

> And I felt that our discussions in the science methods course were much more positive and that every student took something new away. There was never any conflict, not that all conflict is bad, but there was never any animosity in the class and in the math methods course there was full blown animosity between the professor and some of the students. I would try to be on the sideline in that but sometimes I got drawn in to the middle, and it wasn't enjoyable. But I always enjoyed coming to science class on Mondays because it was interesting.
>
> I thought the assignments we did were fair, and I remember one time, I was thinking about this yesterday, there was one time when I had forgotten an assignment at home, gotten to campus, and you l said I could go home and get it and bring it back, and I thought that was very reasonable of you – whereas another professor would have said sorry you don't get any credit for an assignment that was already done. When you are a grad student trying to juggle a part time job, an internship, and 19 credit hours of master's level classes, it's very nice to have an understanding professor who lets you get your paper.

The best practices described in the question above are an interesting assortment. The participants found that the instructor believed in them, gave them confidence, respected and understood them. One of these comments is based on a very simple thing, letting them break for a snack during an almost four hour class at the end of a day. Simple to do, understanding the need to eat, but meaningful for them. They believed doing investigations (learning through inquiry) was a best practice. Valuing inquiry was a comment about best practices that goes along with some of the practices of inquiry. For example, "you were a good facilitator, you asked us to worked cooperatively, you asked us to worked in small groups, and you asked us to reflect on our learning." Giving meaningful assignments and clear instructions and teaching by example were additional ideas shared.

Question B. *So how was the science methods course different from or similar to other methods courses?*

The answers to this question were very diverse and very complex. There were many more differences than similarities. The similarities were: it's a little like social studies, which also had projects, and there were hands-on manipulatives in math. The differences noted were: in science methods there was lots of integration, but little integration in other courses; the science instructor shared stories and student work from her own classroom, other methods courses were teacher focused/lecture mode, little student discussion or interaction in other courses; the environments were different; science methods was fun, in science methods we did things/hands-on learning and moved around; change in attitude about science and science teaching from science methods course; in other courses group work was done outside of class; don't remember my learning from other courses, but I do from science methods. In science methods we had a classroom community; we worked together.

Participant 1 commented that the science methods course was different because there was discussion and planning that was integrated. He felt his social studies methods course touched on integration, but that the other courses did not. He valued the stories and student work from the instructor's elementary classroom.

> Um, I thought it was different, because we really did sort of talk about it and plan lessons in an integrated way – it was like how would you teach a science lesson and incorporate something else - I think the stories you told us from your own classroom, when you said – like just last week, my students were doing this and that, and showing us their work was just like wow!
>
> Where I think like other methods classes I had, not that they were bad, but it was just sort of like ok we're going to learn how to teach math, or social studies and it was very (chops the table with his had counting, 1,2, 3, 4) like that. I guess the social studies class is the only that touched a little bit on how you could bring in other things, but it was smaller amounts. I think we had some reading classes and some writing classes, but they were a lot more structured - how do you teach kids to read, how do you teach them to become good readers and stuff. If they tied it at all – it was like throw in reading and writing, and I get a little tired of hearing it, reading and writing, reading and writing, which I understand is very important from what everyone is saying, but at the same time it's like you can tie it to other things as well –

Teacher focused was the description Participant 2 gave to her other methods courses. She notes that that there was little student interaction or discussion. She would have liked to have had more opportunity to ask questions. She comments that the science environment was different "because science was exciting and you didn't do all the talking, we got to interact with one another."

> Well it was different because there were all like a lot of teacher focus. You know these classes are like three plus hours long, and I don't care what your attention span was, even thought it is at a master's level, I guess it's supposed to be longer - but we get bored as well. It's a lot of information and information we wanted to know – for instance – social studies. She was talking about social studies integrated with literature and it was something I was interested in learning more about – but I really don't feel like I got into in that class at all; I mean she was just talking at us the entire time and there was minimal opportunity for us to interact with one another. It was the general consensus that we would have liked for her to talk less.
>
> We would have liked more time to ask questions – like I remember I had my hand up and then I thought oh – no, it's not going to happen so just stop. It was a really different environment – and I know that she really knew a lot, and I know that she did a lot with her district and all, but there are some people who just can't adjust. Working with third graders and then working with adults – you have to adjust. It didn't have the environment that we had in science; it was different than science because

> science was exciting and you didn't do all the talking we got to interact with one another.

Participant 3 mentioned the projects in social studies as a similarity. She agrees with Participant 2 that her other methods courses were teacher-focused, "do as I say," and that there was little student interaction or discussion. She comments that the science methods course was fun!

> It was way different than most of the methods classes, but a little similar to social studies. The rest of the methods classes were like "do as I say" – and science wasn't. In social studies we had some cool projects to do too- they were fun. We did the most in your class though, I mean with all the hands-on activities and stuff. And I would say in the other methods courses the instructors would say they wanted class participation or discussion or whatever – but then it never seemed to happen. The other classes were more teacher focused – but in your class, well it wasn't like you weren't the teacher, but you were like a part of the group. And you always seemed to like what you were doing. It was fun!

Participant 4 agrees with Participant 1 about the social studies methods course having a little integration, and that in science methods there was a lot of integration. She agrees with Participant 2 that the other courses were teacher-focused, "– but mostly it was just lecture." She valued doing the hands-on activities and moving around in class. She did not like doing group work in her other methods course that was to be done outside of class. She claims to have had a change in attitude about science, "I learned a lot in all of my classes but the science was the one I was least excited about and didn't really care about and now it's the one that's at the forefront of my thinking."

> It was different for the fact that I really feel like it was the class I got the most out of. I learned a lot in all of my classes but the science was the one I was least excited about and didn't really care about and now it's the one that's at the forefront of my thinking. I've always, I always thought about the arts and things like that and I've always known that kids really love to do that, and then I learned about the science and I thought well ok I can have a fun exciting classroom. My other courses were only focused on whatever content we were in so - I had one other course where we had a big project and they asked us to integrate other standards, it was social studies and they asked us to integrate the writing and the reading and that. And then language arts, was only language arts and then reading we only focused on reading – we did do genre studies. In math, she sometimes did some reading or writing in math so I did learn how to make it a little more interesting – and I learned about some literature books but your class was the one where I felt that it was really about how to integrate everything and the rest were just kind of separate.
>
> The other classes were just basically lecture classes, for the most part, which I really don't mind so much. I feel like I am here to learn so give me what you have and I can read for myself, you know? So that was fine for me, but in the science, well we did so many more activities. In the other classes there were activities every once in a while, but they were

> activities I felt like - why are we doing this? You could have just told me about this, or given it to me on a piece of paper. I know how to make kids line up in a row, or choose color partners. I don't need to do this in a class – it was a waste of my time.
>
> But in science, like with the apple one, it was like – what does an apple have to do with anything? But then I learned about it, and it was like cool! The activities that we did were learning, real science learning and I don't think they were activities I could have just read about.
>
> There was never moving around really. In one of my other classes there was like a group project but it was like outside of class, which I hate because, its difficult. So that was miserable and it's stupid to think its group project, because you just split it up anyways you know – and its not even group work. And then the other ones, one we had some kind of partner activity I think – but mostly it was just lecture.

Participant 5 concurs with Participant 3 that there was not a lot of student interaction in the other methods courses. She comments that she was excited to go to the science methods course, and agrees with Participant 3 that it was fun. She remembers what she learned because she experienced it.

> The ones I remember the most were the ones that were hands on, probably due to the topics. What I remember the most, was being excited about going to your class, because it was fun – and we learned right from the beginning and that was different than the other ones because, I don't know I can't say they were boring but I don't remember the learning as much.

The methods courses were only a little bit hands on. Math a little bit, social studies – she gave us a lot of ideas and I have them in a folder – somewhere. But then I have to go back to the folder, because I don't remember. Because it is science, it is better to experience and not so much the others, but I remember a lot.

Participant 6 found that the math methods course had some hands on activities and that was similar to science. She agrees with Participants 1 and 4 that the science methods course had a lot of integration, but the other classes did not have as much. She also commented, as did Participant 4, on the hands-on activities. She felt that in the science methods course she could think about both how to teach a lesson, and how does it feel to be a student of the lesson.

Let's see, well its similar because even though we were science, I feel like we focused on literature a lot, like how we do literature, and I liked that and then um it was different a lot because I think more than any other you talked about cross curriculum planning, more than where I am in my own language arts so we only talk about language arts rather than talk about ok how can we incorporate that into this? And it was similar to my math class because in my math class we kind of did a little bit of same stuff about literature and math and how to get kids to write about and hands-on math like science and we used manipulatives and more things different than similar though.

Our class was much more hands on though, I think you and the math did the most, where we actually did things in class, you know where you know we became the students for a little bit, and so if I were actually in this class, how would I want this to be taught or how does it feel to be on the other end of this which I think was very good.

Participant 7 agreed with Participant 4 and 6 about the hands-on activities in the science methods course. He also agreed with Participant 2 about the environment of the science methods course being different. He describes it as a classroom community, "Our class had about twenty people in it, and most of those people were in my other classes, but in science we were a community. Not in the other courses. . . . The atmospheres were very different - science was more conducive to learning.

There was much more a sense of classroom community, which I thought, was great and especially in a graduate level course you really want to engender it. It wasn't a cohort per se, but it kind of turned into that. Science and math were offered on Monday, so if you took science on Monday you were the same people on Wednesday because that was the only other time you could take math. Our class had about twenty people in it, and most of those people were in my other classes, but in science we were a community. Not in the other courses. In math our community was in the parking lot afterwards when we got together to complain about math.

Science and social studies were my favorites. I liked science because a lot of the stuff we would have to do in our classrooms, we got to do in the

> course. It was really fun to have that hands on stuff and in science we had those experiments, every single class we had some kind of experiment, whether the professor led it or it was student led – and so there was a lot of hands on stuff. And everyone worked together. It was expected, and we did it.

Participant 7 went on to describe being allowed to bring in food. The students took turns bringing in snacks. He thought it was unreasonable to expect graduate students to go for almost 4 hours (4:50-8:20) without food, since most of them were either coming from a job or from an internship.

> One of my favorite things was the snacks. I thought that was awesome. That was important – to have food. It was a little thing, but it made class more enjoyable. And I knew when I was running to class that even if I didn't bring the snack for that day, there was going to be food. It gave everything a much more positive side. And on the flip side, in another class we had gone to Chipotle before class and the professor told us not to bring the food in because the smell irritated her. It seems unreasonable – we're adults, you are going to tell us not to eat dinner? The class started and 4:30 and went to 8:30 – we are not supposed to eat? The atmospheres were very different - science was more conducive to learning.

The students seemed to appreciate the inquiry-based environment that the instructor attempted to put in place in the classroom. Integration of other content areas into science was something they seemed to value, as well as the sense of community.

In comparing methods courses, the students found that the science methods course was “a little” like social studies because they did projects in that class, and somewhat like math because manipulatives were used. They found many differences. They did not discuss cross-curricular integration in other courses as much, and they found the teaching approach of the science methods course to be student-centered in contrast to the lecture mode of other methods classes. They valued the stories and student work that were shared with them from my classroom, and hands-on activities, group work in class and being able to discuss their ideas and questions. Several comments were made on the environment and the community that was built in the course.

Question C. *What are the key ideas from the methods course that you will take with you as you begin to teach?*

Again the participant responses were wide-ranging, and many. Three of the participants stated that you must do science in your classroom and push for it. Two of the participants agreed that they would integrate, two participants were happy to have learned there were so many resources to help them teach science. The other responses included: this course challenged my belief about education, now I like science, science is not scary, be enthusiastic, examples of activities, how to approach science, inquiry-based science, get students to think critically, students are active participants, students are natural scientists, tools for science, for teaching and for classroom management, the structure from your class, classroom community, digital portfolio and practical things.

Participant 1 states that a key idea he is taking with him as he begins to teach is to do science, and push for science to be taught. Integration he believes will help him accomplish this.

> Well, definitely that you should do science because the kids love it. And integration – I would have never thought about teaching that way – not just science but teaching. As a teacher I think we have to follow the school rules, but we also have to kinda push for science to be taught. So that's where the integration comes in if you can say but look they are reading and writing and doing math. They are practicing their language skills and they are enjoying it – you should be allowed to teach it.

In agreement with Participant 1 on the need to push for the teaching of science, Participant 2 states, "I know we have to make sure science gets in to schools." She goes on to say that science should be taught with enthusiasm. She claims that now she likes science and she valued the structure of the methods class and the classroom community that was created, that valued questioning.

> I guess the main thing is that now I like science, and I know we have to make sure science gets in to schools – it doesn't matter whether male or female or if they may think that science is a harder subject. It doesn't matter – maybe I don't like science and you don't like math, but it doesn't have to be that way. I don't think if a student has that idea in their head it's not their fault, it's their teacher's fault. I think that's a main thing that I got from this methods class is – I have always enjoyed science, but it's one thing to just kind of do it, and another thing to do it with your students

> and with enthusiasm. If the students ask me a question I am not going to ignore them; I am going to give them the opportunity to ask questions. I am going to have the kind of structure like we had in your class. It's not often in a class that it was that open – we didn't always get to ask questions, but with you, and with the classroom community that you created, that we all created, it was okay to ask questions.
>
> We asked questions and we discussed and we engaged with one another and there was so much social interaction – and I mean it was science, but everything we did was fun and we got to –everything was hands-on, and we got to work with all of our peers –

In addition to agreeing with Participant 1 and 2 on the need the to push for the teaching of science and with Participant 1 on the idea of integration, Participant 3 says science is not a scary thing and that resources are easily found to help teachers.

> Basically that science is possible to be taught in your classroom no matter what your constraints are – you can integrate it; in you can take a little extra math time to put into science and teach some math there – its not a scary thing – so that you can't say –"Ooh I don't know anything about science so I can't teach it" – you can teach it. You might have to do a little research, find things out, do a little study, go on the Internet, get online and you don't always have to re-invent the wheel. I think that was cool when we each brought an activity, an experiment to do in class, knowing that almost everyone found stuff online. It was really helpful and

it was really neat to find out all the different resources that we could look for, including our textbook.

Participant 3 comments specifically on the digital portfolios and using these would be manageable and practical.

> And doing the digital portfolio at the end, that was way cool because it was a really manageable website and the whole set up. And if we ever had to do a website or a digital portfolio with our class that would practical and now we have experience with that. Like in Costa Rica my teacher had to do a couple of new pages for the website, and she always made a Power Point, but what we used would be cool and accessible and the parents could all look at it, and we could just change a few little boxes each week or whatever.

Participant 7 mentions that resources are readily available, as did Participant 3. Participant 7 also comments that students are scientists by nature and that the students "can and should be much more active participants in their curriculum."

> Well, I can go out and find other resources. The other thing well, our textbook was called *Science by Inquiry*, and one of the big things was that when kids ask questions, that's a teachable moment, take advantage of that, if they are asking you the question they are interested in that subject, go find, or help them find out the answers to those questions. I definitely took away from it that students can and should be much more active participants in their curriculum. Teaching is not something you are doing to them, it's not like we will now fill your brains with knowledge. They

are active participants – or should be at least and they will learn a lot more if they are interested in the subject even beforehand. That uh kids - one thing from the readings and from the lectures is that kids are scientists. It's not something you become; it is something that you are born doing. Children are always exploring, as a kid I'd go out to the park with my brother and we'd go catch crawdads and turn over rocks to see what was underneath them and do our own little informal experiments and you lose that somewhere along the way. When science in schools is very sterile, detached and boring, kids will start to dislike science and they'll move away from it. Teachers especially at the elementary school level need to take advantage of the fact that kids are naturally curious about the world around them and try to harness that.

Participant 6 had her own personal set of ideas of key things she would take away from the methods course. She commented that learning about inquiry-based science "challenged my belief about education as I whole, and it surpassed just science. It didn't only affect how I thought about science methods it touched all my, all my it …how I want to be as an educator really." She valued the ideas of getting students to think critically, and learning how to approach science.

So I think for sure inquiry-based science, I had never even heard of such a thing before. How would I have? I've never taught before or you know what I mean read too much for fun, so I really had never heard of it. You know, I mean really I kind of to a certain extent would have done it anyway, but not to such a big broad do it with your whole class like "let's bring a topic and let's make questions about it and let's investigate." To that depth and I mean that's huge! So from that comes so many different things, even how to approach science, and um how to get the kids thinking critically, where it's more, ok are my kids thinking deep about this or are they just like memorizing stuff anyway that they are not going to remember after the test? And what's more important? What skills do I want to leave my kids with, and really it challenged my belief about education as a whole and it surpassed just science. It didn't only affect how I thought about science methods it touched all my, all my it …how I want to be as an educator really.

> Participant 4 was most interested in the activities that were done in class. The activity with the film canisters and the beads, and paper clips where you had to hear and listen, the kids would really love that. The apple thing - the kids would understand that way. I never knew that science was not just this big abstract thing I would never get – never be good at. You can reduce it down to little things and then the kids build on their ideas and gain confidence and you can build off that. I really love the nature walk you told us about, and I could do that – it is so integrated. Those are the three examples I remember the most and they are all integrated.

Participant 5 believes the methods class gave her tools and ideas, not just for science, but also for teaching and for classroom management – which she terms "practical things."

> I like a lot that you gave us a lot of tools, not just for science but a lot of tools – and ideas. Like for grouping people, the clock, and the cards, and the foldables, what else. I remember you did science and teaching and classroom management and practical things.

Each of the students seems to have taken away different pieces of the methods course. Their ideas ranged from very broad as in challenging one student's beliefs about education, to motivating students to become advocates for science education in their placements, all the way to more specific as in particular activities students found meaningful.

Another example came from a student a year after the course. Although this was not a comment made in her interview, I believe that this interaction and comment fit best here. Participant 4 in particular expressed attitudes about science that were not very positive at the beginning of the course. She told me in a personal conversation that she did not really think she was a science person and to please be patient with her, she would try her best. A year later, she sent me this note in an email:

> I had a funny moment in one of my orientations the other day when the presenter asked if anyone was interested in teaching science and against all of my prior preconceptions, I raised my hand. I do not know if you know how much you and your class really impacted my life and changed my view about learning AND teaching and using science in the classroom. I now see how it is such an integral and fun part of learning for me and so vital for our students' success. Thank you for opening my eyes to this; your class was the most beneficial to me out of all of my other graduate

courses.

The key ideas students took from the course were interesting. The idea that science must be taught, that we have to push for it, is important in this time of standardized testing and meeting demands for Adequate Yearly Progress set by the No Child Left Behind legislation. The participants noted they were made aware of resources for teaching science, tools for teaching science, teaching in general and classroom management, as well as "practical things." They stated they learned how to approach science, about inquiry-based science, and the importance of critical thinking. They now understand that students must be active participants in science and that children are natural scientists. The structure of the course was a key idea they took away; the classroom community we built was another. One participant mentioned the digital portfolio and how she might use it with her students, and several noted a change in their own attitudes toward science and education.

Question D. *If there were anything that I could have changed about the methods course to prepare you for actual classroom teaching, what would it have been?*

The participants did not have many suggestions in response to this question. Again their responses were varied. Two participants said they were not sure yet and another said she did not know yet. Three participants felt that they were prepared well, and two wanted to know about their future positions. And one participant wished there had been some curriculum planning.

Participant 4, in addition to admitting to feeling nervous, states that she doesn't know yet if she is prepared for classroom teaching, but quickly adds, "But I can do it."

> Don't know yet – I haven't had the opportunity to try it yet. I am so nervous because I feel like there is so much more I need to learn about – cause I was never interested in it before this class, and I haven't seen it really in my placements, so yeah nervous – I don't know yet. But I can do it.

Participant 7 agrees with Participant 4 and states, "I don't know of anything," but goes on to mention that he believes he has received a "really good preparation."

> I don't know of anything because I thought that really did give me a really good preparation. It was one of the most informative and most enjoyable classes that I had in the Master's program. I'm not sure there was an area that could be improved upon.

Participant 3 expresses her uncertainty as Participant 4 and 7 did. She then agrees with Participant 7 in stating that she believes "good foundations were set in most areas.

> I think that this might be something that I figure out more as I went along, or had more experience. I think that good foundations were set in most areas, that I wouldn't feel – whatever situation I was put in I think I would feel prepared by either having the knowledge or knowing how to get the knowledge.

Participant 5 is in agreement with Participant 7 when she states that she feels prepared to teach science.

> No, it was good, I feel prepared to teach science. There are things from your class I can use to transfer to use in other classes – like manipulatives; I am a big fan of manipulatives, because that is how people learn. I can put excitement at the beginning of the other class, like engagement with something, I don't know yet – like an idea or whatever.

Participant 1 reminisces about his methods semester first, but then ends adding a very pointed question, "What do I need to figure out about myself to get out there?" That is definitely not something we ever discussed during the methods course.

> I guess one of the things that I liked was that we talked about how to make lessons for students, how to assess just – all these sort of things we need on a real teacher student level. In a couple of my classes they talked a little bit about the bigger picture. Ok you have graduated, now what? What to look for in a principal? What to look for in a district? What to look for when you are choosing a school? A lot of times you're in these classes and you're like everything's great and you are thinking about rainbows and lightening and you are thinking oh, I am so full of it. And then you get to the school and you have this other department, and you get into and they are like, "We don't do it that way." I guess it's sort of tough I think working where you might get out there and you think well this is how I learned it and you need to know how to find a setting that's going to fit you best. You can talk to so many teachers in so many districts and they are all going to tell you that their district is the best and their district is their favorite – what do I need to figure out about myself to get out

> there? But I guess that is sort of secondary – you need to know how to teach how to take care of a class first so –

Participant 2 states that she thinks the class was good, but goes on to echo the idea of the uncertainty of the future, like Participant 1, when she says, "I wish you could tell me what it will be like in my new job, new school, so then maybe I could give you a better answer. I just don't know really."

> I am not really sure there is anything you could have done differently. I think the class was good. I wish you could tell me what it will be like in my new job, new school, so then maybe I could give you a better answer. I just don't know really.

Participant 6 has some constructive criticism. She wanted to have some curriculum planning added to the course.

> In the methods course? I wish we would have done a little more curriculum planning, like your entire, like here's your standards and content that you have to teach, so how are you going to do it? Because like now it's like go and my school honestly they just, here you go honestly just that, no text books - nothing. So now I am like, yeah that's the only thing I think I felt I really needed – more like curriculum design. Exactly how am I going to plan my unit? How am I going to go effectively go beyond one lesson, oh yea like that's the thing – like even a long extended lesson, more than just a one day lesson.

This comment about curriculum design and planning was a valid and valuable concern. The questions about the future and the uncertainty of several participants were very reasonable as well. The three participants, who believe that they had a good foundation and are ready to go, were encouraging. My hope is that their confidence was maintained into their first teaching placements.

The methods course appears to have been a meaningful experience for the students. The school in which they are employed may determine if they are able to implement or use the beliefs and visions they seem to have developed and still remember from the course.

Research Question 4:

How do the visions of science learning and teaching that were promoted in the participants' science teaching methods course compare to the reform documents?

Research question 4 was a broad question and so I have separated this section into two parts. The first part of this section will address how the visions of science learning and teaching that were promoted in the participants' science teaching methods course compare to the reform documents. This interpretation focuses on the assignments and activities for the course to find ways the strands of science proficiencies are evidenced. The second part of this section will address what visions of science learning and teaching the newly qualified teachers bring with them as they graduate from a teacher preparation program. This interpretation considers the comments from the interviews with the participants for evidence of the strands of science proficiencies.

Interpretations of Assignments and Activities in Terms of Strands of Science Proficiencies

In this section I discuss the assignments and activities from the methods course as they align with the framework of the four strands of science proficiency as described in *Taking Science To School*: *Learning and Teaching Science in Grades K-8*. (NRC, 2007). This publication addresses three questions:

> (1) How is science learned, and are there critical stages in children's development of scientific concepts?
>
> (2) How should science be taught in K-8 classrooms?
>
> (3) What research is needed to increase understanding about how students learn science? (2007, NRC, p.1)

As a committee member, I was fortunate to participate in discussions around these questions. The book describes a "redefinition of and a new framework for what it means to be proficient in science" (2007, NRC, p.2). The committee chose to use the term *strands* to describe proficiencies in science because they thought that the metaphor would help illustrate that aspects of science are inextricably related, i.e., interwoven as 'science-as-practice" (2007, NRC, p. 38). The four strands are:

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 (2007, NRC, p. 2).

Strand 4 includes motivation, attitudes and interest, which were emphasized in the subsequent volume, *Learning Science in Informal Environments* (NRC, 2009) as Strand 1 (Developing interest in science) and Strand 6 (Identifying with the scientific enterprise). These aspects are discussed here as part of Strand 4.

Interpretation of Assignments in Terms of the Strands of Science Proficiency

The following section describes ways in which participants' responses to each of assignments illustrates elements of the four strands of science proficiency (NRC, 2007). It is to be noted that multiple interpretations of the strands are possible depending on the perspective of the person interpreting the task or activity. The discussion of Strand 1 in *Taking Science to School* (NRC, 2007) emphasizes the identification and use of knowledge that students bring to the science classroom. If prior knowledge was accessed and the concepts were built upon or if knowledge was applied to a new situation, I considered the comment to be evidence of Strand 1. I considered a comment to be evidence of Strand 2 if it involved or incorporated anything about designing and carrying out an investigation and evaluating evidence to draw conclusions and defend them. I found myself interpreting Strand 3 in two different ways: evidence of understanding the nature and development of scientific knowledge could be if the participants described science as a way of knowing or if they enacted science as a way of knowing. I considered a comment evidence for Strand 4 if it referred to discussions or to motivation and positive attitudes toward science.

Assignment 1. The first assignment, *What is Science?*, is described in detail on pages 113-127 of Chapter 4. As this assignment focused on the participants' understanding of science, their comments are most relevant to Strand 3, *understand the nature and development of scientific knowledge*. Many of their comments also refer to aspects of Strand 4, particularly motivation, attitudes, and identity (NRC, 2007, p 195).

Relation to Strand 3. Strand 3 is described as students' understanding of science as a way of knowing, (NRC, 2007, p.37). Some participants seem to have this understanding as shown in the following comments:

> Science represents my relationship and understanding of the world around me and my observations and questions relating to my surroundings. Participant 2

> (Science) explains the natural phenomena that happen on earth…To me, science is following a process that allows you to investigate, hypothesize, research, ask questions, and then do experiments to see if what you thought is true or not. Participant 8

> Science is any kind of investigation or exploration of the unknown. Any time a person encounters something that is different or unusual to them

> and they attempt to understand it; they are performing science.
>
> Participant 7

> Although there are certain areas of science that have continued to be proven and supported, there still is ample opportunity for established laws of science to be modified or disproved. This is the beauty of being scientific. Science continues to evolve and progress.
>
> Participant 11

These comments reflect that the students have some understanding that science is a "particular kind of knowledge, with it's own sources, justifications and uncertainties. Students who understand scientific knowledge recognize that predictions or explanations can be revised on the basis of seeing new evidence or developing a new model" (NRC, 2007, p.37).

Relation to Strand 4. Strand 4 "includes the norms of participating in science," and also student "motivation and attitudes toward science" (NRC, 2007, p.37). The three comments that follow illustrate that these participants have some understanding of what it means to teach science and help students to do science like a scientist:

> This means that we teach science in a way that actively supports curiosity and promotes hands-on learning. The children explore and construct ideas and explanations of the natural world with the help of instructors. This really coexists with my beliefs on how science should be taught in schools. In order to keep the students engaged in the material, we need to

> let them perform science, and not just show them science (Bass 3-4).
>
> Participant 11

> Giving priority to evidence to generate explanations and engage in "critical discourse" instead of not requiring any response at all.
>
> Participant 8

> This class and these readings are opening up my eyes. The skills that we build now will be relevant to our students as they move into adulthood. Science allows us to build up critical thinking skills, which will be something we will all need as we make decisions about our world.
>
> Participant 14

Participant 8 compared what she had read with what she had experienced, which were very different. The reading helped her to understand how to help students engage in the language and the tools of science; however, her own experience did not:

> Another difference that I saw was in the features of inquiry instruction in Chapter 4 (of the text). These include engaging the learners in scientific questions; giving priority to evidence as learners plan and conduct investigations; the learners connect evidence and scientific knowledge in generating explanations; learners apply their knowledge to new scientific problems; and learners engage in critical discourse with others about procedures, evidence, and explanations (Bass, J. et al, 2009). This last

> step is where I see the major difference. I was never encouraged to talk with other students and ask questions about the procedures, evidence, or explanations. We would pretty much just do our lab work, write it up and turn it in. There was no debating about the evidence, explaining how we all did it, or if there were other procedures that may have worked. We just finished one lab and went to the next.

Science is described as often characterized by people's excitement, interest, and motivation to engage in activities that promote learning about the natural and physical world in Strand 4 (NRC, 2007). In Assignment 1, the students were assessed as to their attitudes toward science. Some of their responses show a very definite interest in science.

The use of the word, curious or curiosity, to me connotes an interest in something. The following comments identify being interested in science. Participant 11 believes that "Science is for the curious and the intuitive."

Participant 7 states:

> The key to science is curiosity; it is what drives us to first engage in science as children. We pick up a stone to see what is underneath of it. We have to satiate our curiosity. The same curiosity that drove us to pick up that stone in our backyard is the same curiosity that drive adult scientists to continue their path of inquiry throughout their lives and careers.

The following responses also illustrate that the participants want to instill that interest in their students.

> Any time that a person encounters something that is different or unusual to them and they attempt to understand it, they are performing science. Our goal as teachers should be to take that love of discovery that is so fervent in children and cement it so that it never fades and they can become life long scientists…. Participant 7

> allowing them (the students) to be curious
>
> Participant 5

Not all participants described being interested in or curious about science. For example, these participants do not seem to have been very interested:

> Science was indistinguishable from the mess of general information we learned from boring textbooks and strict teachers who never gave us a chance to do any hands-on learning. Participant 12

> Not about what we were interested in.
>
> Participant 2

A common characteristic of interest is "that participants have a choice or a role in determining what is learned, when it is learned, and even how it is learned" (Falk and Storksdieck, 2005). For that reason, Participant 2 was not very interested in the teacher directed activities from her own experience, but appreciated those opportunities when she had a choice:

> Science experiences were often ones in which I didn't have a choice and was told to do something and follow a specific procedure with no room for flexibility or creativity. Anyone can follow procedures. . . For me, I appreciated the experiences in which I was able to have some freedom to explore my own thinking and design and conduct my own experiment.

Strand 4 is also about identity. " Students who see science as valuable and interesting tend to be good learners and participants in science" (2007, NRC p.37). Some of the participants could envision themselves as potential scientists, part of the science community, or their students as potential scientists.

> These students are learning by reasoning and verifying concepts themselves. They are learning skills that they will use as true professionals.
>
> Participant 5

> My experiences in science have always been extremely positive. Science is not just lab experiments and periodic tables.
>
> Participant 11

> We can show our students what a never-ending source of amazement science holds. Participant 6

> The 5-E model is probably the most impressive thing I have read in our textbook thus far. In my future science instruction I would like to

implement this model because I believe it functions as an incredible tool to engage students in science inquiry. I feel like this model promotes the pursuit of knowledge in an effective way. The students are not only asked to do the science, but also evaluate their findings, as well as pose their own science questions and theories (Bass 91-92).

Participant 11

Today teachers need to treat students as scientists

Participant 5

Others do not see themselves identified as a part of the science community.

My personal view of science is in one word, complicated.

Participant 12

I thought science was a subject "better left to someone who's willing to really understand and conquer the knowledge."

Participant 1

Although this assignment did not incorporate all of the strands, it still provided a great deal of insight for me, as the instructor into the thinking of my new students. Over time, some of them seemed to shift in their thinking about science and the teaching and learning of science, as shown through the subsequent assignments. They seem to have some understanding of the nature and development of science, as described in Strand 3.

An understanding of how to participate productively in science was apparent in Strand 4, as was motivation and both positive and negative attitudes expressed.

Assignment 2. In Assignment 2, (pages 128-155 in Chapter 4) the participants were to investigate the attitudes, practices and resources available in their placement settings by interviewing their principals, science specialist (if there was one) and mentor teachers. In this assignment strands that were most evident, were Strands 2, 3 and 4.

Relation to Strand 2. Strand 2 is evident in the interview Participant 4 conducts with her cooperating teacher. He describes students doing investigations independently.

> His approach to teaching science is very hands –on and student directed. He wants his students to investigate and observe in groups and individually without constant formal direction.

Relation to Strand 3. Strand 3 is evident in this assignment in the sense that it asks participants to look for the *schools' understanding* of the nature and development of scientific knowledge, as it would be enacted in the schools. "This strand includes developing a conception of doing science" (NRC, p. 39). A common theme was mention of science as an activity, something 'hands-on.'

Hands-on could also be interpreted as Strand 2, if it were being enacted in a classroom, because it also could be a description of generating and evaluating scientific evidence. Participant 7, for example, found that in his placement site:

> Both teachers say that they encourage hands-on activities and group work.

Participant 4 shares about the school and her mentor teacher.

> He has the students keep a science journal to focus on how the students are thinking, not how they write about what they are thinking. He doesn't grade for spelling or grammar.

Participant 4 thinks this "hands-on" focus may be due to the change in the state science curriculum and the school adoption of a science kit program.

> The school adopted this model (FOSS) after the state redid the science standards, which demanded that the lessons have a more hands-on approach.

The teachers who helped students understand science better, by relating it to real-life situations and taking the students outside of the school, impressed participants 6, 7 and 11.

> In addition, they all agreed that science is important outside the classroom, and provides them with "problem-solving skills necessary in life, and that science is . . . applicable to real life.
>
> Participant 6

> Teachers use field trips to augment the instruction they are doing to show their students the real world application of the things they are learning.
>
> Participant 7

> Both teachers combine their science efforts and make sure they take their students outside to see science at work first hand. Last year they built a hill with their students out in the quad and measured the erosion

> that took place when affected by rain. Because our downtown area does not experience much rain – the measurement was not very hard, and the hill still stands.
>
> Participant 11

Participant 15 watched a science experiment in one class that she believed did not give the students the full experience they could have had.

Participant 11 added his understanding as contrast to what he learned in the interviews.

> I feel that the hands-on approach to science is the best way to engage young students. Perhaps when we are older and have seen some of these experiments first hand it is not necessary to always have a live experiment in front of us. But as young scientists it can be difficult to understand how things work just by reading an experiment and the results.

Participant 5 reported that the school administrator saw the necessity for the students to learn science.

> The principal and the teachers I interviewed think science is important because it is part of everyday life, that can be applied in real situations, and it helps developing higher order thinking skills. The principal asserted that reading and math scores had gone up by consistently

teaching science. However, I found inconsistencies on the school's point of view and the reality of the classroom.

Relation to Strand 4. The emphasis in Strand 4 is on ways of speaking, including questioning. Participant 4 describes a classroom with a teacher who places an emphasis on questioning:

> He encourages the students to ask many questions and he asks them many questions as well, most of which the students are responsible for finding the answer to.

Participant 15 thought that her placement teacher was incorporating ways of teacher questioning that would nurture the students' development of scientific knowledge.

> I also like how the teachers ask students questions to get them thinking. My teacher corrected me when a student asked me a question and I answered. The teacher told me, the next time ask them "Well, what do you think will happen?" I also heard him asking, "How do you know that?" to encourage the students to explain their thought process.

The students found a mix of attitudes and interest in school staff in reference to the teaching of science. Participant 4 inferred that the principal of her placement school must have been interested in science because of his statement:

> The principal believes that the fourth and eighth grade teachers cannot have the sole job of teaching the students science for the test; it must be a cumulative effort that begins in kindergarten and each grade builds upon the grades before.

Participant 11's principal seemed to have an interest in science as well. He quotes her response:

> A few years ago there was no real science curriculum set because the school did not test for it. The principal made it clear that most of the teachers at the school rarely taught science in their classrooms and she is ecstatic this is changing.

Participant 7, frustrated by the difficulty he was encountering meeting with the principal, does not believe that his principal had a lot of interest in science:

> Both teachers (interviewed) agree that until recently their school hadn't put much of an emphasis on science. The new school principal has taken a greater interest but they implied it was because science was being included in state test. Judging by his apparent lack of interest in discussing science with three graduate students I would assume that this newfound emphasis is based off of standardized testing rather that a genuine interest in science.

Participant 6 did not find her principal to have much of an interest in science either:

> When I asked my first question (to the principal)- what is the school's perspective on science? She laughed and asked if I wanted her perspective or the school's perspective. She said that "in general" science is pretty much seen as an extra thing. She explained that because other subjects are so highly crucial in testing, that teachers focus on reading and writing.

Participant 9 found the teacher she interviewed to be quite blunt about her interest in science, due to standardized testing:

> It is unfortunate, but "science (test results) will not make or break the school."

Participant 15 got mixed responses; she found the principal to be interested but the teachers did not seem interested or perceive that their principal was interested.

> It was interesting for me to see the difference in the principal's ideas about science from the teachers. The principal described science as crucial, and a wonderful way to build language through integration. "Kids get so excited about science!" she said. The teachers didn't seem to be on the same page. My teacher seemed to think the principal would rather have him working on reading and writing with his ELD students.

Participant 5 also had a confusing experience when asking about science at her placement school.

> The principal asserted that reading and math scores had gone up by consistently teaching science. However, I found inconsistencies on the school's point of view and the reality of the classroom.

From these comments during the interviews, it seems apparent that the participants encountered a wide range of interest in and attitudes towards the teaching and learning of science. Those interests ranged from staff who were *ecstatic* that science was getting more attention now that it is included in the state testing (very interested, positive attitude), to those who were interested in science in order to have acceptable test scores (science is tested in fourth and eighth grade) and to some who appeared blatantly uninterested, "It is unfortunate, but "science (test results) will not make or break the school."

Again, three of the strands were represented in this assignment. The participants were interviewing school staff for attitudes and beliefs about science, so this makes sense. They heard about ways in which teachers engage their students in the nature and development of scientific knowledge (Strand 3). They found a range of attitudes and beliefs as well as motivation and lack of motivation (Strand 4). This made them aware of the potential issues and struggles they might possibly have to face as science teachers.

Assignment 3. Assignment 3 was an opportunity for participants to take a hard look at one science lesson from the science curriculum in their placement classrooms. The detailed description of this assignment can be found on pages 156-178 of Chapter 4. The participants were given some questions as a framework and asked to analyze the lesson for content and implementation with their placement students in mind. The strands that were apparent in this assignment were Strands 1, 2, 3 and 4.

Relation to Strand 1. In order to analyze the lesson the students had to be familiar with or analyze the conceptual ideas in the lesson. Then they would have to build on those concepts to be able to scaffold the lesson for elementary students. They also had to use their understanding of the students' science knowledge in order to evaluate the lesson. They had to first understand the "big ideas . . .to enable learners to construct explanations of natural phenomena" (2007, NRC, p. 39).

Participant 7 has concerns about the analogy used to begin the lesson and he believes it will confuse the students.

> The lesson opens with the teacher asking students a series of questions about a house being built. This is supposed to lead them into wanting to learn about skeletons. The problem with this is that I don't think the students are really going to get hooked by this line of questioning. If anything I think they might get confused by the home construction talk. Also I don't know if many 3rd graders would have knowledge of building frame supports to make a house.

Participant 6 has several concerns with the lesson she analyzes. She thinks that students without a visual aid will not have any idea of what a tsunami looks like and that most students will not have had experience with waves. She also points out that they may not have the conceptual foundation to calculate ratios.

> There is a major assumption that after a brief, 3 paragraph explanation (included with the lesson), that the students will be able to visualize a tsunami. Even more, this lesson supposes that children have the previous experience of either being to the ocean and having firsthand experience with the characteristics of a wave or that at some point in their life experiences/education have been properly introduced to the characteristics of waves. Granted, this is a 6th-8th-grade lesson, therefore, they may well understand waves. We do, however, live in a state without any coastline! There is also an assumption that students will be able to create ratios with regards to the buildings and land area. The assumption is that their math skills are at a high enough level to make those ratios with regards to the buildings and land area.

In thinking about asking questions, Participant 7, considers introductory questions she might ask during the lesson to elicit prior knowledge. (She presents this as a conversation, characteristic of Strand 1.)

> I would have the skeleton covered with a blanket so the students wouldn't see exactly what was under it. Then I'd ask the students if any of them have ever broken a bone. In a class full of nine year olds the odds are at least someone has broken a bone. If no one has I can tell them about my broken thumb from earlier this year. I'd ask some open-ended questions to fuel the conversation. These could be things like "What do think you do for a broken bone?" or "How many bones do you think we have?" or "Why do you think we have bones?" I'd base my questions off of the responses I get from my students. This way it would be like a normal conversation.

Relation to Strand 2. Strand 2 is evidenced here through the participants' comments on ways they will design, modify, or use the investigations with their elementary students. The participants have to think about "a wide range of practices involved in designing and carrying out a scientific investigation" (NRC, 2007, p.39). Participant 4 believes using live specimens will be an opportunity for the students to begin investigating ants.

> Students will love this activity to observe real ants.

Relation to Strand 3. In the plan for an investigation that Participant 4 organizes, the students will reflect on their learning, when they complete the chart on the whiteboard will be looking at multiple interpretations of data collected. Participant 4 discusses student observations and scaffolding data collection.

> After the students are done observing the ants, as a class we will fill out the I Notice - I Wonder chart on the whiteboard at the front of the class.

Participant 4 also wants to informally assess as the students work by listening to their discussion, which, hopefully, will help them develop and refine their explanations of data results and conclusions.

> I would informally assess the students by listening to the discussion that they had in pairs, and asking questions and then see how active and how good their explanations were to other students in the class discussions.

Relation to Strand 4. Motivation and interest are characteristics of students who tend to be interested in science, as Strand 4 suggests. The participants commented on ways they perceived these lessons would motivate the students. Participant 4 sees the motivation being high because the students will be using live specimens.

> I think that simply observing the ants would be a huge motivation to the students

Participant 6 believes the hands-on part and the creativity involved in the lesson and choice will motivate the students.

> The recreation of a village or city is a hands-on activity, which would motivate the students. It is also up to the students to decide how to recreate the city and to break into groups to be in charge of making all the components of a city. Choice almost always provides motivation. This lesson is like a classroom version of the computer game Sims City. From what I understand, this is a highly popular game.

Participant 15 sees students working in groups, and a change in the teaching strategy as motivational for the students.

> I think the students would really enjoy the engagement of the lesson, as they would be able to look closely, in groups, at the seedlings. I think they would also really enjoy a break from lecture style in the classroom to work with their small groups. I think working with others in groups would motivate the students.

Participant 7 is concerned about the lack of motivation students may have with the lesson as it is.

> It seemed very simplistic in scope and I doubt that many students would really be engaged by it

Strand 4 is again apparent when the participants discuss students engaging in the practices of science. Participant 13 notes some of these practices that will be a part of her lesson; collecting data, analyze and explain findings, using data to draw a reasonable conclusion.

> I would add these steps: They will record attempts in a chart
> Students will analyze and explain their findings with other students
> Students will be required to make a Venn diagram to compare and contrast with one other salad dressing, and utilize their data charts to draw a reasonable conclusion.

Understanding content, and understanding the conceptual structures necessary to implement their particular lessons (Strand 1), designing investigations for their students to do (Strand 2), and motivating and encouraging students to begin to use scientific practices (Strand 4) were all evident in responses to Assignment 3.

Assignment 4. Assignment 4 was the culmination of the other three assignments. This assignment is discussed in detail on pages 179-218 of Chapter 4. The participants first had to think about their own understandings about what science is, examine resources, practices and attitudes toward science learning and teaching in their placement settings, and analyze a lesson prior to teaching a lesson. Now they were asked to combine developing a lesson, teaching the lesson, having a peer observation, and reflecting on their lesson based on a driving question they created. That driving question was most often focused on their teaching of science, rather than science content. However, since this was a class on the methodology of teaching science I took the liberty of extending the idea of driving question (Krajcik et al., 2003), to include their questions about the teaching and learning of science. Their questions for the most part met the criteria for driving questions. Their questions promoted higher order thinking, were related to what scientists and/or teachers of science really do, were designed so that the participants could design an investigation around them, were anchored in the lives of learners, and were meaningful and related to real-world problems.

Relation to Strand 1. In looking at their own fingerprints the students in Participant 5's classroom were able to identify the shapes they saw on their own fingerprints and shared with Participant 5 that fingerprints were used to identify people. They even mentioned that animals might have unique prints as well. This is an example of Strand 1 in that the students were able to construct some possible "explanations of natural phenomena" in a similar but new situation. They were connecting prior knowledge with new knowledge and hypothesizing on how that might happen in a new situation.

> I wanted to assess the student's prior knowledge, so I encouraged them to talk about what they knew about fingerprints. I did this by listening to their comments on the shapes they saw on their fingertips and later by reading the journal entry they wrote when identifying their own pattern. Students were successful in learning this lesson; they told me fingerprints are used in everyday life to identify people. They believed that maybe animals would have different prints too. The students knew most of the vocabulary words.

Participant 2 described a similar situation.

> By the end of the lesson the students had a really strong foundation on classifying objects according to their physical properties and gave me ideas of new ways that they could do it.

Participant 9's experience showed her that the students could make connections to new learning as well.

> All of the students were very successful in learning and applying the new terms, classifying materials, and discussing their new knowledge.

Relation to Strand 2. Strand 2 includes a "wide range of practices involved in designing and carrying our a scientific investigation, including asking questions, deciding what to measure, developing measures, collecting data from the measures, structuring the data, interpreting and evaluating the data, and using the empirical results to develop and refine arguments, models and theories" (NRC, 2007, p. 39). With that in mind, the students articulating driving questions and designing their studies, subsequent collecting and analyzing of data, are examples of Strand 2.

Participant 5 and 11 had driving questions related somewhat to content.

> Would students be able to identify their ridge patterns by themselves?
>
> Participant 5

> Will this inquiry experience lead to a solid grasp on the basic physical traits of Earth? Participant 11

Participant 5 makes a comment about her students' ability to interpret data.

> I was successful in teaching them more about fingerprints. I noticed that the four girls had no problem in identifying their own ridge pattern, even without magnifying glasses. They quickly identified and described them.
>
> Participant 5

When evaluating their own data to determine how successful they were in answering their driving questions, many participants thought the data (from their own observations and that of a peer observer) were informative. Participant 9 notes:

> This lesson was a highly successful experience for me, especially in the areas of (giving) feedback, student engagement, and proximity as I focused extra effort to incorporate them into my teaching.

Participant 2 found areas in which she was successful, as well as areas for improvement.

> I asked my observer to focus on my use of space and interactions with the children. She noted that I needed to be sure I made eye contact during instruction. This is definitely a great critique that I need to improve upon. I felt as though I was interacting with everyone because the group was so small. My peer observer also revealed that I probably should have explained the rules for BINGO (classification activity). I did not notice that one of the girls tried to put a button in her mouth. It would have been a good idea to go over proper ways to handle the objects such as not putting buttons in the mouth or nose.

Relation to Strand 3. Strand 3 includes concepts that are often considered part of understanding the nature of science, "a conception of doing science that extends beyond the experiment" (NRC, 2007, p. 39). Participant 1 had a plan to use computers in his lesson to accommodate for a student with special needs, and because scientists often use computers/technology. He shows some understanding of the nature of science.

> I was able to find a technology component (website), which would allow a student who is unable to use scissors to participate in the activity. The technology factor was something I originally planned on using in my lesson as an additional step to students making a tessellation, because scientists often use computers/technology but had to get rid of the component the day of the lesson because the student laptops were being used by another class.

Participant 6 refers to the argumentation that scientists do:

> I will be sure that they are successful if they can correctly explain their findings and defend them, as "real" scientists would.

Participant 15 demonstrated an element of Strand 3 when she took a "step back from evidence" (2007, NRC, p. 39) to consider if it was valid or reliable.

> I don't know if my questions really promote higher order thinking though. I know I asked plenty of questions, but I'm having a hard time deciding if that is really what I was going for or not. Is there another way to think about it?

Relation to Strand 4. "Viewing the science classroom as a scientific community akin to communities is advantageous" (NRC, 2007, p. 40). This is a big part of strand 4. Participant 6 found some difficulty in having her students accept the idea that teamwork was a critical part of doing science. She had not realized it would so difficult to implement.

> One of the failures of the science experience was rooted in an over-looked detail: teamwork. I did not anticipate the skill of teamwork to play such a major role in the effectiveness of this experience. I am not exaggerating, though, when I say that this was the first science activity of the year for the students. At first when the students broke off into their groups, there was a lot of arguing about who was going to set up the domino wall. I had already explained that "working as teams, meaning everyone participates," the groups were to set up the domino walls, but they didn't seem to pay much attention to that detail. It was very surprising how large teamwork's role was in this science experience.

Participant 2 felt there were some things she could have improved in her lesson as well with respect to modeling the scientific practices involving classification:

> I could have been more thorough in explaining why scientists classify things and how they (the children) are scientists themselves. I could have also encouraged the students to get up and walk around to see how other students classified their buttons instead of going around the table and explaining (seated). I could have incorporated a writing component by asking the students to list all the ways there are to classify buttons but I do not know if time would have allowed this.

She adds, however that the group did give her some ideas for future classification activities.

> By the end of the lesson the students had a really strong foundation on classifying objects according to their physical properties and gave me ideas of new ways that they could do it.

My perception is that all four strands were represented in the participants' responses to this assignment. This assignment was the result of building knowledge of science teaching and learning throughout the course; that all the strands are represented is a positive. The participants noted that the students were applying knowledge in a new way (Strand 1); their students collected data to support conclusions (Strand 2); explained to their students that they would need to explain and defend findings like scientists would, (Strand 3); and found that their students participated productively and eagerly in science investigations and classroom discussions (Strand 4).

The following table is a summary of the interpretation of the assignments by strand.

Table 5.1

Summary of Interpretation of Assignments by Strand

Assignments	Strand	Evidence
Assignment 1 What is Science?	Strand 3	Science represents my relationship and understanding of the world around me and my observations and questions relating to my surroundings. Participant 2
	Strand 4	Giving priority to evidence to generate explanations and engage in "critical discourse" instead of not requiring any response at all. Participant 8 These students are learning by reasoning and verifying concepts themselves. They are learning skills that they will use as true professionals. Today teachers need to treat students as scientists Participant 5
Assignment 2 Status of Science?	Strand 2	His approach to teaching science is very hands –on and student directed. He wants his students to investigate and observe in groups and individually without constant formal direction. Participant 4

	Strand 3	His approach to teaching science is very hands –on and student directed. He wants his students to investigate and observe in groups and individually without constant formal direction. He has the students keep a science journal to focus on how the students are thinking, not how they write about what they are thinking. Participant 4
	Strand 4	I also like how the teachers ask students questions to get them thinking. My teacher corrected me when a student asked me a question and I answered. The teacher told me, the next time ask them "Well, what do you think will happen?" I also heard him asking, "How do you know that?" to encourage the students to explain their thought process. Participant 15
Assignment 3 Evaluating Curriculum	Strand 1	The lesson opens with the teacher asking students a series of questions about a house being built. This is supposed to lead them into wanting to learn about skeletons. The problem with this is that I don't think the students are really going to get hooked by this line of

		questioning. If anything I think they might get confused by the home construction talk. Also I don't know if many 3rd graders would have knowledge of building frame supports to make a house. Participant 7
	Strand 2	After the students are done observing the ants, as a class we will fill out the I Notice - I Wonder chart on the whiteboard at the front of the class. Participant 4
	Strand 3	After the students are done observing the ants, as a class we will fill out the I Notice - I Wonder chart on the whiteboard at the front of the class. Participant 4
	Strand 4	Students will love this activity to observe real ants. I think that simply observing the ants would be a huge motivation to the students. Participant 4
Assignment 4 Teaching/Reflecting	Strand 1	Students were successful in learning this lesson; they told me fingerprints are used in everyday life to identify people. They believed that maybe animals would have different prints too. Participant 5
	Strand 2	Will this inquiry experience lead to a solid

		grasp on the basic physical traits of Earth? Participant 11
	Strand 3	I will be sure that they are successful if they can correctly explain their findings and defend them, as "real" scientists would. Participant 6
	Strand 4	By the end of the lesson the students had a really strong foundation on classifying objects according to their physical properties and gave me ideas of new ways that they could do it. Participant 2

Interpretation of Activities in Terms of the Strands of Science Proficiency

In this section, the activities will be evaluated as to which strands were evident in each activity. The activities are also described in table 4.1 on page 102 of Chapter 4. I provide here a brief vignette of each activity.

UV Beads. *Taking Science to School* states, "The committee thinks, and the emerging evidence suggests, the development of proficiencies is best supported when classrooms provide learning opportunities that interweave all four together in instruction" (2007, NRC, p.37). Analysis of the first activity in the science methods course illustrates ways in which all of the strands can be intertwined in complex ways.

The opening activity on Day 1 is described in detail earlier (page 14 of Chapter 4). This first activity was the one in which I gave participants string and UV beads and asked them to make a bracelet. They were required to keep an observation journal from the first class until the second class. The beads appear to be white, but change to different colors in the presence of sunlight. The participants had all had previous experiences with things that change color and knew that the UV rays from the sun can change the color of their skin, affect the paint on cars, etc. In considering why the beads changed colors, they were using their prior knowledge to construct and refine explanations as described in Strand 1.

Some participants thought that light changed the beads, some were sure it was only sunlight but not room lights and others thought it was heat. In order to determine what was the actual cause of the beads change in color, the participants had to employ aspects of science articulated in Strand 2, "design and analyze empirical investigations and use empirical evidence to construct and defend arguments" (NRC, 2007, p.37). They found a variety of ways to test their ideas, including using a hair dryer to warm the beads, freezing the beads in ice cubes and then putting them in sunlight, coating them in different SPF strengths of sunscreen and putting them in a plastic bag out in the sun.

Strand 3 suggests that students need to "recognize that predictions or explanations can be revised on the basis of seeing new evidence' (NRC, 2007, p.37), and that is what happened to those who thought the color change was due to heat.

These investigations led participants to share and defend their evidence with their classmates, ask questions and think critically as described in the first part of Strand 4.

They were participating productively in scientific practices and discourse (NRC, 2007, p.2).

The goal of this initial investigation was to get the participants excited, interested, and motivated to learn science, as described in the second part of Strand 4. Identifying with the scientific enterprise is an important aspect of science learning. When the participants were debating the idea of sunlight or heat, they saw themselves as science learners and as individuals who were using what they knew about science. Participant 14 said that she had wondered why in the world I had given them beads and bead journals. But after finding out that the beads changed color, finding out through experimentation that it was the sun's rays that made them change, and doing the readings on inquiry-based science, she realized that I had taken them through an entire inquiry cycle:

> After the experiment was over, and I was finished with my bead journaling, I thought about the process I went through.
>
> - I was faced with a problem
> - I developed many different questions
> - Determined what made the beads "magical"
> - Developed questions that could be tested
> - Experimented with different types of sunscreen
> - Recorded the results/observations and made discoveries
> - Shared my results with other classmates
>
> I did it! I went through the **Inquiry Cycle** without knowing it!
>
> This is the best learning I have ever experienced!

This activity also was a way to begin building community amongst the students as they shared their experiences later.

Paper folding. I learned to do this activity at a science inquiry meeting in my county. I thought this paper folding activity would build on what the participants knew about folding paper, because almost everyone has had some experience with that, and what they knew about variables.

The activity involves taking a sheet of paper and folding it in half as many times as possible. Because the number of layers doubles with each fold, after seven folds, there are 128 layers of paper. Most people cannot do more than that. After the participants tried this individually, they worked in groups and tried it again. Sometimes, with multiple hands and force, they could get to 8 folds. That is when the discussion led us to new ideas: what if the paper was thinner? What if it were smaller? Larger? How would it work with another material, like transparency film, or cassette tape? How would we design an experiment for this? The participants all remembered talking about variables, but how would that work in this situation? These ideas I believe are representative of Strand 1 because they were building on prior knowledge and applying this to a new situation.

The ideas expressed also are illustrative of Strand 2, especially when they discussed designing an investigation, and collecting and analyzing data in a systematic way. The notion that in investigations, variables need to be considered was a way that they showed some understanding of the nature and development of scientific knowledge, as described in Strand 3.

The participants all worked productively in this investigation in small groups. They were very excited and motivated to do this activity. In the end, each group started out sharing their results, but the discussion quickly moved from a format going from group-to- group in order to a discussion in which there was a lot of debate and cross talk amongst the participants. Elements of Strand 4 were illustrated by these examples.

Apple activity. I adapted the apple activity, from an unknown source, to demonstrate the potential advantages for hands-on and interactive learning over very directed and sterile learning. After splitting the students into two groups, I gave a sheet of paper and a pencil to each person in half of the class and asked them to write down everything they knew about apples, individually, which is a way of eliciting prior knowledge, similar to Strand 1, but there were no links being made between any conceptual structures to understand or apply to a new situation. After splitting the other half of the class into three small groups, I gave each group three different kinds of apples, magnifying lenses, knives, cutting boards, colored pencils, and one piece of paper per group and encouraged them to write down everything they observed or knew about apples. These participants talked among themselves as they worked, sharing their prior knowledge and articulating connections to a variety of concepts as is typical of Strand 1.

Strand 2 was evident in the groups who had the apples, cutting them open, making detailed observations, diagramming what they were learning about the apples, and being amazed that they were seeing things about apples they had never noticed before. Their actions and conversations also illustrated for me what they understood about the collection of data from an investigation like this, as well as what they believed scientific diagrams were, which would show a part of their understanding of science as a way of knowing, which is relevant to Strand 3. Strand 3 was evident again when the students began to share in the whole group their observations and their explanations with evidence. The group with only paper and pencil challenged some of their claims, especially those claims related to taste.

Strand 4 was apparent in the higher engagement and motivation observed for the group with the materials. There was debate amongst the groups with materials. All of the groups with materials worked together in using scientific practices and discourse, and in the end the entire class was engaged in the discussion. Those who had not had apples to investigate, cam over to see for themselves the observations the classmates claimed to have made. The final discussion was the most interesting. This discussion was about the difference in experiences of the two groups, the differences in the information generated, and how the participants envisioned these kinds of experiences for their students.

Film Canisters. I drew the film canister activity from the textbook I had used in the course I had taught previously (Krajcik, et al., 2003). In this activity, I gave each group of students an assortment of small items, for example, marbles, thumb tacks, buttons, beads, pom-poms, washers, etc., and a film canister with the lid on. They were to shake the film canister, listen to it and try to decide which assortment of three items was inside. Using their sense of hearing, what they knew about the items, and how those items might sound inside of a plastic container, they needed to come to consensus on what was inside the container. Evidence of Strand 1 lies in their using their prior conceptual knowledge of sound and of the characteristics of the items (the sound of a glass marble as compared to the sound of something metallic), to "employ these conceptual structures during the interpretation, construction and refinement of explanations" (NRC, 2007, p.39) about what was in the container.

After doing the investigation, the participants had to write down what they believed was in the canister and why. This exemplifies strand 2, because they were collecting data, interpreting and evaluating data, and developing claims as to what was inside the canister. They shared their claims with the rest of the class before moving on to open the canister and verify. Another illustration of the intertwining of Strands 1 and 2 occurred when they created a new set of items in the canisters for their classmates to figure out. In doing this, they employed their prior knowledge again (Strand 1) by devising ways (Strand 2) to wedge items in the canister so that when it was shaken it would not move, or put multiple pieces of the same item, or even to muffle the sound by using certain items in excess. One group confused the others by putting only one item in, and the other groups were sure there must have been more than one and listed multiple items.

As the participants started testing their hypotheses, they began to "recognize that there may be multiple interpretations of data," (NRC, 2007, p.39) as Strand 3 suggests. Once they had finished recording the results for each of the canisters, the groups who had made predictions debated the contents with each other, and those who had put the items in the canister listened until they were asked to reveal the contents. After one or two group discussions, some groups were asking to go back and revise their predictions based on what they were learning. Motivation and interest was high (Strand 4).

What happens when M & M's get wet? The M & M experiment came from an activity developed by the American Chemical Society, (ACS, 2007, p. 13 – 43). In the initial activity, I gave the participants a paper plate and asked them to identify the center, and then draw two additional concentric circles on the plate, thereby dividing the surface of the plate into three sections. They then placed an M & M on the center of the plate and poured water slowly into the plate until the surface of the plate was covered. They then used stopwatches to time how long it took for the color coating of the M & M to reach each of the circles and then the edge of the plate. The groups had different colors of the candies to start.

This activity used conceptual structures the participants had about M & M's and the coating, (melts in your mouth, not in your hands), and what they knew about things dissolving in water. It inevitably ended up including the affects of the temperature of water on the dissolution of the color coating. These ideas, in addition to ideas about how to construct and refine explanations in investigations (in relation to the differences in times to reach the edge of varying colors of M & M's) reflect components of Strand 1.

Strand 2 is seen throughout the next part of the activity. The participants had some difficulties in using stopwatches to record the times for their trials accurately. Often they were so involved in watching the color reach its varying checkpoints that they neglected to look at the time. Making accurate observations and recording accurate data are aspects of Strand 2. After each group had one valid trial, the data was compared between the groups by color. The participants noticed that the rates at which the colors reached the edge of the plate were different. They then generated new questions to ask, for example, was the temperature of everyone's water the same? Were the same timing practices being used? And what constitutes the edge of the plate? This led to the design of new investigations, and applied the use of their evidence (data) to the new design.

When the students compared their initial data and designed investigations to test its validity, they were showing that they understood the nature and development of scientific knowledge, (Strand 3). These practices overlap with Strand 2 and with Strand 4. When they participated in the scientific discourse about sets of data, and debated and questioned each other's results, they were participating productively in scientific practices and discourse (Strand 4).

Fake snow. This is an activity I created that uses an "instant snow" polymer that expands to forty times its original volume when mixed with water. Prior knowledge about powders, and also about characteristics of powders was needed in this activity to determine what this particular white powder was. The participants needed to draw upon and apply this knowledge and their observational data (Strand 1) to design an investigation to determine what this unidentified white powder was (Strand 2).

The participants put a small amount of this powder in a closed film canister and started their data collection through the use of their senses. First shaking the canister and listening to the powder, then opening the canister and looking at the powder, wafting the powder to determine if it had a specific odor, and then touching the powder to determine texture, etc. Collecting and evaluating empirical evidence, and systematic observation is an illustration of Strand 2.

Strand 3 was evident in the multiple interpretations of what the powder was, based on preliminary observations using the senses. This led the students to have to revise their strategies for the design of the investigation in order to collect more data (overlap with Strand 2). In the end the students decided to see how the powder interacted with water, and were amazed at the results. The powder can absorb a great deal of water and the volume increases as it absorbs the water.

The students worked as scientists collecting data, changing variables, reporting, comparing and sharing data, and engaging in very involved discussions (Strand 4), and then continued to design new investigations to further understand the properties of the powder, which would be an overlap of Strand 2 and 3. Their motivation and interest levels were very high, as they perceived this as a mystery they had to solve. One student even made the comment that this made him want to become a forensic scientist! (Strand 4).

Oobleck. The facilitator of a Science Liaison Meeting of my county shared this activity. It differs from similar activities in its use of borax and white glue rather than cornstarch and water. The participants used prior knowledge about the states and phases of matter and applied them to a new situation (for most of them) in the creation of a non-Newtonian substance referred to here as oobleck (Strand 1). They followed a set of instructions to create this substance. Strand 2 is evident in their doing the investigation and comparing their results. Some participants did not get a very good sample the first time. Strand 3 is shown through their need to employ the skills to conduct this investigation using accurate measurements and considering various possibilities, as a scientist would. When they did this successfully, they watched a chemical change and were rewarded with their own sample of oobleck. Strand 4 was mostly illustrated by the discussion that followed their first attempts and the comparison of data to find out why one participant's oobleck was clearly more liquid, and another's perhaps more solid in appearance.

ADHD (Aero-Dynamic Heli-Device). I learned about this activity from a colleague. In this activity, participants incorporated a variety of conceptual structures (gravity, air resistance, how things fall, characteristics of paper, etc) and applied them to a new situation to find out what element of the paper heli-device would change the rate of its fall (Strand 1). The device is a paper structure with two "wings" and a stem. The students had to design an investigation and refine their model and their explanations (Strand 2). As they worked, they showed "an awareness that science entails the search for core explanatory constructs and the connections between them," which is relevant to Strand 3 (NRC, 2007, p. 39). Their trials included changing the material used (weight of paper), changing the overall size of their model, changing the size, shape and angle of the wings, and the size and length of the stem.

During the investigations, the participants had many ongoing debates and tried to convince each other that the variable they changed is the one that most affected the rate of the fall. Their also discussed whether they were making a fair test (were they dropping it from the same height each time?), multiple trials, and discrepancies in data (how much difference in time was significant?), all indicators of productive participation in scientific practices and discourse (Strand 4).

Pen and paper sports. This activity came from a session at a NSTA *regional* conference in Connecticut. This activity did not seem to have any illustrations of Strand 1 in that it did not involve eliciting and using prior knowledge. However, Strand 2 was evident in the participants' efforts to devise new methods of improving their achievement on a set of paper and pencil tasks. I gave participants a horizontal row, comprised of ten squares that were connected. They put their pencil on a point labeled start, in front of the row of boxes. They used the eraser side of the pencil to do a practice trial and put a dot in each box. They then put down their pencils, point down back on the start position, closed their eyes and attempted to put a dot in each box. They opened their eyes and evaluated their results. They had multiple chances to try, each time with a different color pencil so that they could evaluate the results. Some participants turned the paper in a different direction; some tried going backwards, using the left hand or the right hand, there were many changes made in methods to complete the investigation.

The participants seemed to understand "that scientific knowledge recognizes that predictions or explanations can be revised on the basis of seeing new evidence" (NRC, 2007, p.37) as in Strand 3. When one participant found a way that was more successful than another's they would try out the methodology of that person. The motivation was high, and a debate ensued about which way would have the best results, and then a lengthy discourse about whether or not a particular method would work better for some than other's and did handedness (right or left) make a difference. Several participants came back the next week with results from other colleagues to try to defend their particular belief (Strand 4).

Boat building activity. I adapted this activity from *Nurturing Inquiry*, (Pearce, 1999, p.25). The participants used a six-inch square of aluminum foil to create a boat that they thought would hold the most weight and still float in a container of water. They needed to apply the knowledge they had about boats, floating, the difference weight distribution makes and eventually density as they noted the difference in results in tap water and salt water. They demonstrated what they knew and were using their prior knowledge as well as refining and constructing scientific explanations of the natural world (Strand 1).

Designing this experiment was an illustration of Strand 2, as they worked to generate and evaluate scientific evidence and explain their findings. After their initial voyage (trial) they redesigned the boat and could employ new strategies in weight distribution. Again data was compared across the class. What the participants did not know was that one container of water was really salt water. All of the water had been colored blue so that this was not apparent; so one group clearly had some discrepant data.

Like good scientists they tried to understand how this was possible and worked to revise their predictions and explanations based on this new evidence, which is an example of Strand 3's emphasis on considering possible points of view worthy of investigation.

Someone finally figured out the difference, and the discussion began anew. New questions began to emerge, motivation resurged, and the participants all tried their boat designs in the salt water. The cycle then repeated itself, as they demonstrated their participation in scientific practice and discourse, as described in Strand 4.

The activities were selected partially because of their strong nature of science component (Strand 3), the high level of engagement and motivation they incur (Strand 4), the possibilities for the participants scientific explanations of the world to be built upon, possibly even challenged (Strand 1), and the rich opportunities for students to design and modify investigations using empirical evidence (Strand 2)

The following table is a summary of the interpretation of the activities by strand.

Table 5.2

Summary of Interpretation of Activities by Strand

Activity	Strands Evident	How evident
Paper Folding	Strand 1	Making connections to prior learning (folding paper) and applying to new situation
	Strand 2	Generating (design experiment) predicting and evaluating; using evidence (folding different papers)
	Strand 3	Students knew to make multiple trials, and about variable
	Strand 4	Working as a team to discuss evidence; cross-talk between groups
Film Canisters	Strand 1	Using senses and prior knowledge to determine what is inside
	Strand 2	Creating a new trial for other groups
	Strand 3	Students understood the need for testing hypotheses
	Strand 4	Using observation data, working in groups, defending results, whole group debate
Apple Activity	Strand 1	Some groups listing what known about apples. Other groups used what they knew about tools to make observations
	Strand 2	Some groups cutting open apples and making detailed observations

	Strand 3	Explaining observations and new knowledge with evidence
	Strand 4	Making observations, recording data, working as a team, debating evidence
M & M's Get Wet	Strand 1	Using prior knowledge about M & M's and factors affecting the color coating coming off in water
	Strand 2	Designing experiment, making and revising predictions
	Strand 3	Students knew to collect and compare data, supporting conclusion with data
	Strand 4	Discussing discrepancies, possible reasons for discrepancies, and new questions for future experiments
Fake snow	Strand 1	Using senses and background knowledge to determine identity of powder
	Strand 2	Designing and carrying out investigation
	Strand 3	Students understood the need to develop multiple interpretations of what powder is based on senses
	Strand 4	Working as a team discussing evidence, cross-talking between groups, developing future questions for investigation
Oobleck	Strand 1	Make connections to prior learning of states of matter, adding new understanding
	Strand 2	Following directions of a lab and analyzing errors
	Strand 3	Noting chemical change, following procedures

	Strand 4	Working as a team, discussing product and differences in product, cross-talking between groups
ADHD's	Strand 1	Using senses and prior knowledge to predict change in falling of paper heli-device
	Strand 2	Designing an investigation to change fall rate
	Strand 3	Students knew to make multiple trials, and about variables
	Strand 4	Using observation data, working in groups, defending results, whole group debate
Pen and Paper Sports	Strand 1	Not evident
	Strand 2	Designing and analyzing investigation on factors affecting movement of pencil with eyes closed
	Strand 3	Students knew to make multiple trials, and about variables, multiple interpretations by individual participants
	Strand 4	Making observations, recording data, debating evidence
Floating Pennies	Strand 1	Using prior knowledge about how to make something float, and density
	Strand 2	Designing experiment, making and revising predictions
	Strand 3	Student understood the need for collecting and comparing data, supporting conclusion with data

	Strand 4	Discussing conclusions and evidence, possible reasons for discrepancies, and new questions for future experiments

Interpretation of the Interviews in Terms of the Strands of Science Proficiency

In analyzing the participant interviews by strand, the goal was to find out if anything in their comments showed evidence of the strands. Although the class was not designed using the four proficiencies (strands), I was curious to see if the participants showed that they understood the reform-based ideas related to the strands more than six months after the course. The following interpretation is presented by strand, with participant comments added to show their apparent understanding.

Strand 1: *Know, use, and interpret scientific explanations of the natural world.* The discussion of Strand 1 in *Taking Science to School* (NRC, 2007) emphasizes the identification and use of knowledge that students bring to the science classroom. If prior knowledge was accessed and the concepts were build upon or if knowledge was applied to a new situation, I considered the comment to be evidence of Strand 1.

Participant 1, when reflecting on the lesson plan that he had used to teach science for Assignment 4, reflected that if he were in his own classroom, he would do the lesson in a different way. He stated:

> Hmm, well one thing I also think I would change is I would first have the students look at patterns in nature. I am not sure how I would do this – maybe find some really good images, or, real things, like a honeycomb,

> and anyway just give them some examples and have them talk about what they see. Then we could look at some man-made kinds of tessellations, like brick walls, or chain link fences and talk about them. Why do they think they are that way – what are the advantages? I kinda think that would help them before they had to create their own.

This relates to Strand 1 because Participant 1 would help the students make connections to their prior knowledge by bringing in things that are examples of tessellations, both natural and man made. He would have them interact with the artifacts and question the students about them. He thinks that by using things they know about, and having them evaluate the characteristics of those things, he is helping them develop a deeper understanding.

Participant 2 does not offer as much detail as Participant 1, but she has a conceptual understanding that connecting to the students' prior experiences is needed, and she uses the phrase *build on* to show she will help take them to that next step.

> and when I pick a lesson I try to pick a lesson that will be something that relates to the kids' prior experience, both in and outside of school. And when I start out I try to build on kids' previous experiences, prior knowledge. . .

Participant 3 had an interesting experience using a chart commonly referred to as a KWL chart. (What do we **K**now, What do we **W**ant to know, What have we **L**earned) (Ogle, 1986). The students were surprised that the teachers were asking them what they knew and also surprised by their list of prior knowledge. Then she and her mentor teacher used this as a beginning point, asked questions and then referred back to the chart during the unit.

> They hadn't really ever done a KWL chart before and so they were like what do we know? What do you mean what do we know? And like, how can we tell you things – you're supposed to teach us. Once we started taking about water and they're like – oh there's oceans, there's seas and there's this – there's that. We had this huge list, and they all sat there and said – we knew all that? And then with their questions from all different things like where does water come from and where does water go when we're done with it? How big's the biggest???? And that was all the random stuff that came out. I think that was the best way to draw them into it, and just to see what they really know and get them to realize that they know things, and pick from what they want to know what we are actually going to be studying and sort of go back to the chart.

I did not find anything that I considered to exemplify Strand 1 in the analysis of Participant 4's interview.

Participant 5 speaks of accessing the student's prior knowledge when she articulates "she will go one step back." She emphasizes the importance of listening to the students' prior knowledge, or lack thereof, and how it connects with what they will learn.

> I will probably ask them what they know that's relate-able, I will go one step back all the time, what do you know of this? And we are learning this, so could you tell me about what you know. Listening to them about what they know already and its connection to what they are going to learn.

> To find out the basic knowledge that they have, because if you don't have that knowledge, then you will have to teach that (the basics) first.

When students refer back to something they have already learned, and show that they can make connections between that and something they are currently learning Participant 6, is very excited, "and then I am like yes! They get it!"

> Uh, I will know when they can explain it to me and show it to me, or they can explain it to their friend, or when they make connections, like when they are talking to somebody and they say, "oh yeah, it's like when we were doing that!" and then you know they pull something out from something I've tried to build upon and then I am like "Yes! They get it!"

Participant 7's interview did not have anything I considered to exemplify Strand 1.

Strand 2: *Generate and evaluate scientific evidence and explanations.* As noted above, I considered a comment to be evidence of Strand 2 if it involved or incorporated anything about designing and carrying out an investigation and evaluating evidence to draw conclusions and defend them.

Finding things that interest the students, and having them think and investigate those things multiple times is what Participant 1 thinks will facilitate students generating and evaluating scientific evidence and explanations.

> I mean, it is more than just telling the students the information and have them regurgitate it for a test. It is more about finding things to interest the students and then giving them the space to think about things, try things, and then talk about it with their peers. Then they almost always have to try things again, because someone else may have found out something

> they didn't, or found out something differently, or they may feel challenged by what another student did.

Participant 2 gives an example of an investigation she has done with students that began with things they knew about.

> You could do plants, how are these alike, how are they different? For example with third graders, I had them practice with seeds, they each brought in something with seeds from home, they brought in a food with seeds and we counted the seeds and we grouped the seeds and we compared the seeds.

Two examples from the investigations Participant 3's students did with water seem to illustrate Strand 2, and also further exemplify Strand 1.

> So it was fun when we did a sand activity and they drew river in the sand, and made little streams going to it, and then they would pour the water in and see how the streams run into the big river and it was neat because we were able to take something that they didn't understand at all, and then being able to show them and then they could connect to it, and then like later saying oh yeah, streams – they are like little rivers and they all make one big river.

> And my teacher did some cool things too – like took the kids outside with bowls of water with different amounts and they drew lines and came back out an hour later to see the evaporation so they could actually understand evaporation and what it does, which was a little harder.

Participant 4, when asked about how she would plan an investigation, her comments embody the ideas of Strand 2 in the following excerpt.

> I think, umm, the thing I would do first is to look at the standards and figure out what exactly I need to be addressing, because that usually gives me like some ideas. After that I would I think pose things as a question. I think its fun to let the kids just try to figure things out first amongst themselves. Just say like, "Okay today were going to be learning about magnets so what do you think all the pieces on the table mean? Play with them and see what you can find out about magnets from these, from what I have given you." Exploration is the big one.
>
> I think you will see small groups and I will probably jump from group to group to group. When I am with the group I think I see it more as asking questions than helping students by giving directions. I hate, I really don't like the do this – do that, because I want them to be experimenting for themselves, so I am not sure about exactly how that looks but that is how I feel about it.

In describing what will be going on in her classroom during science time, Participant 5 illustrates the ideas of Strand 2.

> We will be working in groups, there will be tables all around, there will be posted for example, hurricanes, tornadoes, whatever they are studying on the walls, their own work posted as well, and working in groups, definitely. And cooperative learning each student will have something to

> do, to report. One is the recorder one is the timekeeper, materials person, whatever.

Participant 6 portrays the many process components her students will need in order to design and analyze empirical investigations.

> They would need I would think like a lot of like process support before actually how step by step, they would need a lot of support, step by step, everything from how you go about formulating your question to, how you actually perform the experiment, to analyzing the data, putting it into the chart and I think they'd need support along every step of the way. Hopefully by then they would know how to make a chart or a graph or how to analyze the data or how to record, how to methodically record, and accurately record your data and then teach them you know about independent and dependent variables, what goes on what axis and if we're using a chart, you know how many times something happens that they would be able to so then they'll have ok now I know this because look, you can't take this away, this happened, you know rather than just "Oh, but I saw it."

Building from a previous investigation, Participant 7 describes the ways in which he would facilitate his students' ability to design and evaluate a new investigation, and enrich their conceptual knowledge.

> I said now we're going to have a contest to see who can design the cheapest propeller car. So I talked to them about you know like when Ford wants to roll out the new Mustang they want to be able to produce it

> first as cheaply as possible for it to still be an effective car. So we were going to design in groups the cheapest propeller car that could still travel 3 feet. And so all of the kids started working, they started shaving off some of the pieces, and so some of the groups only took off like a little piece at a time to make sure it still worked. Some kids took it completely apart and then put it together as cheaply as possible; and in the end it took like what was kind of a boring meaningless lesson on cost and it turned into more of a lesson of they were now designing and they had been using these cars for like a week. They were ready to take that next step and the curriculum didn't plan for that but by enhancing it I was able to make it mean more.

Strand 3: *Understand the nature and development of scientific knowledge***.** I found myself interpreting Strand 3 in two different ways: evidence of understanding the nature and development of scientific knowledge could be if the participants described science as a way of knowing or if they enacted science as a way of knowing. I attributed knowledge of the nature of science to responses that indicate implicit understanding of the nature of science.

Participant 1 describes as aspect of what it means to understand the nature and development of science.

> And I think kids need to learn about how you do science – not like they have to do it step A to Step Z, but that there are certain facets of conducting a science experiment that are important to know and to do.

Again with an aspect of the strand, Participant 3 discusses being able to replicate an investigation, and using multiple trials.

> Maybe the answer was right but the procedure was wrong – I could ask them to replicate it again.

Reflecting on science activities is another component of Strand 3 that Participant 3 mentions. She feels that the use of science journals to find out what was understood and remember would be beneficial to students and to teachers.

> What we did in our science class there was that we had journals and it actually worked pretty well, so on the days that we had science we'd either do it in the form of like centers or like a whole group activity, that they would have to do a journal entry. I think that's really helpful because if they have like a worksheet or something that you wanted them to do while they were doing the activity, they were just regurgitating the information we were telling them or copying what was on the board or whatever, but using the science journals it was easier to tell if they understood it or what they remembered. I know for me I would be looking at younger grades, so this would make it helpful to see what they remember. Even if it was like bell work in the morning or something - they wrote about what they learned in science the day before. So for each project you could do a check up like that to see what they remembered.

Participant 4 refers to reflection on learning as well as incorporating new vocabulary. She believes that drawing and writing can both be used in reflecting.

> I think they need to reflect on what they've learned and then use the new vocabulary, and a lot of drawing too – I am visual, I can look at a picture of what I've learned and I can understand it, so incorporating the writing and the drawing in the technical reflection as well.

For Strand 3, there were no comments by Participant 5 that I perceived as relevant.

Understanding the nature and development of science is illustrated by this quote from Participant 6.

> And if two groups doing an experiment get different results? - Well that's good, that will be good, that's going to happen in every experiment and if they do it a third time we'll get different data again. Just talking about, I think I would bring up the idea of idea of experimental error and uh, just what outside variables affected this experiment other than you know, did the same person water everyday, if were still talking about plants or does it, you know what I mean like if we were measuring – yeah measuring is a good example. Exactly, and if it was the same person do we know for a fact that he did this much and just talking about areas of error that human that we're going to have.

Strand 3 includes "developing a conception of 'doing science' that extends beyond experiment to include modeling, systematic observation, and historical reconstruction" (2007, NRC, p. 39). Participant 7 discusses reflection on science with some reference to history and the need for debate in science.

> We had our journal, where we wrote about science learning every day and that is something that a teacher can bring into the classroom – students can be writing about their learning in science.
>
> Taking the idea of the Earth revolving around the sun or that the Earth is round. There was a period of time where everyone thought the Earth was flat, because if it weren't flat we'd all roll off, or fall off, and how do the oceans stay on? When these things were discovered they had to convince other people. It is very important that you are able to defend your ideas in science, because if other scientists hadn't convinced us, then some discoveries would have just been thrown away and maybe not thought about for several centuries until someone else would have thought about it, and then they would have had to defend it. So defending your ideas is kind of the basis of science.

Strand 4: *Participate productively in scientific practices and discourse.* I considered a comment evidence for Strand 4 if it referred to discussions or to motivation and positive attitudes toward science.

Participant 1's response below seems to demonstrate at least part of what Strand 4 encompasses. Participant 1 expects his students will "participate in scientific debates, adopt a critical stance and be willing to ask questions" (2007, NRC, p. 37).

> I think classroom discussion is very important, especially when you talk about assessments and that was one of them, class discussions. I think it's interesting because this is one of those places where you can have students kinda share what they know, explain to their friends their answers, - and I

was sort of looking at it on the basis of math, so if you say, what answer did you get? And one student says I got this, and another student says I got a different answer, you ask them, you say, "How did you get to that answer?" And I think if students discuss it, they get to hear different ways of getting the answer – they can even back up and look at their own conclusions of how they got there. Whereas whether they got the right answer or the wrong answer, they're still having to explain their methods for getting there – their thinking – and I think that way you can find out, okay that's where you were kind of off track in your thinking or that's where you were right on, but you just missed this one step or you were totally on the right track. And I think the students can start hearing – like- "Oh wow, Billy over here is seeing this other thing and I didn't even think about that, that makes a lot of sense."

So, I would say almost have them defend their conclusions. I guess you could maybe have like groups of kids, or individuals or pairs and maybe find the kids that came to a different conclusion, and then have the two different groups discuss – like why are your conclusions different if we all did the same observations. So that way the kids are sitting there saying the theory is 'everyday the sun is going to shine' and one kid went out when it was raining and one kid came out during an eclipse, and one kid came out in Arizona, so its like – well why are they different? What are the factors? Teaching from the start about these different factors or these different variables in everyday life, observations, and then sort of

> questions and answers. I don't know, like have them think outside the box, like, what if what you observed is different – what if it had been raining during the experiment? Or what if there was an additive or try and change some variable, and have them question themselves about it.

Creatively scaffolding discussion so that all students have a voice in the classroom community is the way Participant 2 envisions her students participating productively in science.

> I think discussion is really important I think it's how they get a chance to learn from one another. Sometimes even in the same group, somebody got something different out of it, so if I am able to hear what my group member has to say – in a small group or in whole class we learn from one another. I really like to make sure that the students who are kind of shy talk up and have a chance to be heard. You might have to scaffold it that at first they just talk with their partner, and then in the small group and then when someone raises their hand to represent the group, I made a comment and I am shy, but maybe the leader of our group shared my idea with the class, I could say wow – my voice is being heard. They might even say oh so and so said this, so I think that is important. Discussion, discussion is important.

Participant 3's comment includes parts of Strand 1 and Strand 4. She discusses how she sees science as a social process, and the need to work together as a community.

> There is more learning in the classroom when the kids share ideas and work together. When they can talk with each other or maybe with other groups who got a different answer, they learn more. Even if they have a debate about it, and they have to explain to each other how they are

> thinking, whether or not the debate is resolved, both sides have learned something. Even sharing their prior knowledge might help them understand a new concept. If I have never been to the ocean and you have and we are studying water, you can tell me that the water from the ocean tastes salty, and I can relate to that. I think really most of our learning is social but in science, in science especially, people are always building off each other's ideas.

Participant 4 finds that students can enhance learning for each other when they are able to share and explain things while participating in scientific discourse.

> I think it's (discussion) important because there have been so many times when I haven't understood what the teacher is saying that then somebody else said something and I totally got it. I feel like more than anything the kids are actually teachers and students of each other and that's how that discussion happens even if its like the quick, turn to your partner and tell each other this and what do you think about this because that's where I feel I would really learn the most is from somebody that wasn't necessarily even the teacher.

Participant 5 emphasizes the idea of teamwork and agrees with Participant 4's comments about students learning from one another.

> They learn better that way, they learn when they talk to each other, they learn when they have an assignment to do. They know they are a part of a team, they are going to accomplish something. That is important to their life and they have to start learning it in science.

> Discussion is that people who know can refresh other people's minds – maybe not only refresh but teach something to others. Some students will be able to enlighten other people's minds. Also it helps so that we can clarify any misconceptions that they have, or to bring up experiences that they have had, to engage them as well.
>
> Discussion can start out whole group and then while we are experimenting they will be discussing in their small group, and I will go to the group and we will have our own discussions there and then at the end we will draw back together for a discussion. Because one kid will say this and another will say, "oh, yeah" – so every group has a different perspective maybe about something. And then they help each other understand about it.

Participating in scientific discourse is an ongoing process according to Participant 6. She sees the students communicating through discussion from the beginning to the end of an investigation.

> The role of discussion. Well, I think it has a lot of roles, like I think it fits in I mean before you start an experiment to get ideas about what you should be hypothesizing brainstorming and then through it to work through what your doing. You have discussions on what you're seeing, your work, like if you had an experiment that was ongoing, like for one week or two weeks so you could talk about, hey what do you think is going on here? Or again at the end definitely so to see if the kids understood, the discussion could serve as an assessment, of ok did they

actually learn anything or where do they still have questions where do we need to build on?

Participant 7 finds that the discussion can be viewed as the "synthesis" of science learning. He gives an example of the importance sharing knowledge, "so we can build off of that knowledge."

> Well whole class discussions are great, but sometimes kids fade into the background with that - they may not feel comfortable speaking in front of the entire group, so I think that sometimes having smaller group discussions, maybe groups of 3 or 4 discuss their learning with each other, kids are much more comfortable and if the can talk about what they learned, their learning is like cemented a little bit more. It's like Bloom's taxonomy, synthesis I think was the part where if they can explain what they did and explain what they would do in other circumstances, learning is a lot more permanent than if it's like a chant and response boring classroom.

Science is definitely a social process. If I go out and do experiments on something and then I don't tell anyone about it, or when you think about stuff like the Earth revolves around the sun, I didn't have to think of that, someone else already did and shared why with the world, so now we can build off of that knowledge. Thinking more of knowledge as something that is shared socially – that's important.

In interpreting the data from the interviews, I extended myself some liberty in the matching of data to the strands. One reason for this is because the strands often overlap, there are not exact delineations among them. Additionally, I could have teased out more of the participants' exact meaning for particular statements during the interviews and had a clearer picture of which strand their comments and thinking most represented. It is often difficult to identify a statement or reference to an activity as only one particular strand. As stated in *Taking Science to School: Learning and Teaching Science in Grades K-8*, (NRC, 2007): "The strands are not independent or separable in the practice of science, nor in the teaching and learning of science. Rather, the strands of scientific proficiency are interwoven, and taken together, are viewed as science as practice" (p. 36-38).

The following table is a summary of the interpretations of the interviews by strand.

Table 5.3

Summary of Interpretations of Interviews by Strand

Strand 1: Know, use and interpret scientific explanations of the natural world.	
Participant	Example
Participant 1	Hmm, well one thing I also think I would change is I would first have the students look at patterns in nature. I am not sure how I would do this – maybe find some really good images, or, real things, like a honeycomb, and anyway just give them some examples and have them talk about what they see. Then we could look at some man-made kinds of tessellations, like brick walls, or chain link fences and talk about them. Why do they think they are that way – what are the advantages? I kinda think that would help them before they had to create their own.
Participant 2	and when I pick a lesson I try to pick a lesson that will be something that

	relates to the kids' prior experience, both in and outside of school. And when I start out I try to build on kids' previous experiences, prior knowledge. .
Participant 3	They hadn't really ever done a KWL chart before and so they were like what do we know? What do you mean what do we know? And like, how can we tell you things – you're supposed to teach us. Once we started taking about water and they're like – oh there's oceans, there's seas and there's this – there's that. We had this huge list, and they all sat there and said – we knew all that? And then with their questions from all different things like where does water come from and where does water go when we're done with it? How big's the biggest???? And that was all the random stuff that came out. I think that was the best way to draw them into it, and just to see what they really know and get them to realize that they know things, and pick from what they want to know what we are actually going to be studying and sort of go back to the chart.
Participant 4	Not evident
Participant 5	I will probably ask them what they know that's relate-able, I will go one step back all the time, what do you know of this? And we are learning this, so could you tell me about what you know. Listening to them about what they know already and its connection to what they are going to learn. To find out the basic knowledge that they have, because if you don't have that knowledge, then you will have to teach that (the basics) first.

Participant 6	Uh, I will know when they can explain it to me and show it to me, or they can explain it to their friend, or when they make connections, like when they are talking to somebody and they say, "oh yeah, it's like when we were doing that!" and then you know they pull something out from something I've tried to build upon and then I am like "Yes! They get it!"
Participant 7	Not evident
Strand 2: Generate and evaluate scientific evidence and explanations	
Participant 1	I mean, it is more than just telling the students the information and have them regurgitate it for a test. It is more about finding things to interest the students and then giving them the space to think about things, try things, and then talk about it with their peers. Then they almost always have to try things again, because someone else may have found out something they didn't, or found out something differently, or they may feel challenged by what another student did.
Participant 2	You could do plants, how are these alike, how are they different? For example with third graders, I had them practice with seeds, they each brought in something with seeds from home, they brought in a food with seeds and we counted the seeds and we grouped the seeds and we compared the seeds.
Participant 3	So it was fun when we did a sand activity and they drew river in the sand, and made little streams going to it, and then they would pour the water in and see how the streams run into the big river and it was neat because we were able to take something that they didn't understand at all, and then

	being able to show them and then they could connect to it, and then like later saying oh yeah, streams – they are like little rivers and they all make one big river. And my teacher did some cool things too – like took the kids outside with bowls of water with different amounts and they drew lines and came back out an hour later to see the evaporation so they could actually understand evaporation and what it does, which was a little harder.
Participant 4	I think, umm, the thing I would do first is to look at the standards and figure out what exactly I need to be addressing, because that usually gives me like some ideas. After that I would I think pose things as a question. I think its fun to let the kids just try to figure things out first amongst themselves. Just say like, "Okay today were going to be learning about magnets so what do you think all the pieces on the table mean? Play with them and see what you can find out about magnets from these, from what I have given you." Exploration is the big one.
Participant 5	We will be working in groups, there will be tables all around, there will be posted for example, hurricanes, tornadoes, whatever they are studying on the walls, their own work posted as well, and working in groups, definitely. And cooperative learning each student will have something to do, to report. One is the recorder one is the timekeeper, materials person, whatever.
Participant 6	They would need I would think like a lot of like process support before actually how step by step, they would need a lot of support, step by step,

	everything from how you go about formulating your question to, how you actually perform the experiment, to analyzing the data, putting it into the chart and I think they'd need support along every step of the way. Hopefully by then they would know how to make a chart or a graph or how to analyze the data or how to record, how to methodically record, and accurately record your data and then teach them you know about independent and dependent variables, what goes on what axis and if we're using a chart, you know how many times something happens that they would be able to so then they'll have ok now I know this because look, you can't take this away, this happened, you know rather than just "Oh, but I saw it."
Participant 7	I said now we're going to have a contest to see who can design the cheapest propeller car. So I talked to them about you know like when Ford wants to roll out the new Mustang they want to be able to produce it first as cheaply as possible for it to still be an effective car. So we were going to design in groups the cheapest propeller car that could still travel 3 ft. And so all of the kids started working, they started shaving off some of the pieces, and so some of the groups only took off like a little piece at a time to make sure it still worked. Some kids took it completely apart and then put it together as cheaply as possible; and in the end it took like what was kind of a boring meaningless lesson on cost and it turned into more of a lesson of they were now designing and they had been using these cars for like a week. They were ready to take that next step and the

	curriculum didn't plan for that but by enhancing it I was able to make it mean more.
Strand 3: Understand the nature and development of scientific knowledge	
Participant 1	And I think kids need to learn about how you do science – not like they have to do it step A to Step Z, but that there are certain facets of conducting a science experiment that are important to know and to do.
Participant 2	Not evident
Participant 3	And I think kids need to learn about how you do science – not like they have to do it step A to Step Z, but that there are certain facets of conducting a science experiment that are important to know and to do. . . . . Maybe the answer was right but the procedure was wrong – I could ask them to replicate it again.
Participant 4	I think they need to reflect on what they've learned and then use the new vocabulary, and a lot of drawing too – I am visual, I can look at a picture of what I've learned and I can understand it, so incorporating the writing and the drawing in the technical reflection as well.
Participant 5	Not evident
Participant 6	And if two groups doing an experiment get different results? - Well that's good, that will be good, that's going to happen in every experiment and if they do it a third time we'll get different data again. Just talking about, I think I would bring up the idea of idea of experimental error and uh, just what outside variables affected this experiment other than you know, did the same person water everyday, if were still talking about

	plants or does it, you know what I mean like if we were measuring – yeah measuring is a good example. Exactly, and if it was the same person do we know for a fact that he did this much and just talking about areas of error that human that we're going to have.
Participant 7	Taking the idea of the Earth revolving around the sun or that the Earth is round. There was a period of time where everyone thought the Earth was flat, because if it weren't flat we'd all roll off, or fall off, and how do the oceans stay on? When these things were discovered they had to convince other people. It is very important that you are able to defend your ideas in science, because if other scientists hadn't convinced us, then some discoveries would have just been thrown away and maybe not thought about for several centuries until someone else would have thought about it, and then they would have had to defend it. So defending your ideas is kind of the basis of science.
Strand 4: Participate productively in scientific practices and discourse.	
Participant 1	And I think if students discuss it, they get to hear different ways of getting the answer – they can even back up and look at their own conclusions of how they got there. Whereas whether they got the right answer or the wrong answer, they're still having to explain their methods for getting there – their thinking – and I think that way you can find out, okay that's where you were kind of off track in your thinking or that's where you were right on, but you just missed this one step or you were totally on the right track. And I think the students can start hearing –

	like- "Oh wow, Billy over here is seeing this other thing and I didn't even think about that, that makes a lot of sense."
Participant 2	I think discussion is really important I think it's how they get a chance to learn from one another. Sometimes even in the same group, somebody got something different out of it, so if I am able to hear what my group member has to say – in a small group or in whole class we learn from one another. I really like to make sure that the students who are kind of shy talk up and have a chance to be heard. You might have to scaffold it that at first they just talk with their partner, and then in the small group and then when someone raises their hand to represent the group, I made a comment and I am shy, but maybe the leader of our group shared my idea with the class, I could say wow – my voice is being heard. They might even say oh so and so said this, so I think that is important. Discussion, discussion is important.
Participant 3	There is more learning in the classroom when the kids share ideas and work together. When they can talk with each other or maybe with other groups who got a different answer, they learn more. Even if they have a debate about it, and they have to explain to each other how they are thinking, whether or not the debate is resolved, both sides have learned something. Even sharing their prior knowledge might help them understand a new concept. If I have never been to the ocean and you have and we are studying water, you can tell me that the water from the ocean tastes salty, and I can relate to that. I think really most of our

	learning is social but in science, in science especially, people are always building off each other's ideas
Participant 4	I think it's (discussion) important because there have been so many times when I haven't understood what the teacher is saying that then somebody else said something and I totally got it. I feel like more than anything the kids are actually teachers and students of each other and that's how that discussion happens even if its like the quick, turn to your partner and tell each other this and what do you think about this because that's where I feel I would really learn the most is from somebody that wasn't necessarily even the teacher.
Participant 5	They learn better that way, they learn when they talk to each other, they learn when they have an assignment to do. They know they are a part of a team, they are going to accomplish something. That is important to their life and they have to start learning it in science. Discussion is that people who know can refresh other people's minds – maybe not only refresh but teach something to others. Some students will be able to enlighten other people's minds. Also it helps so that we can clarify any misconceptions that they have, or to bring up experiences that they have had, to engage them as well.
Participant 6	The role of discussion. Well, I think it has a lot of roles, like I think it fits in I mean before you start an experiment to get ideas about what you should be hypothesizing brainstorming and then through it to work through what your doing. You have discussions on what you're seeing,

	your work, like if you had an experiment that was ongoing, like for one week or two weeks so you could talk about, hey what do you think is going on here? Or again at the end definitely so to see if the kids understood, the discussion could serve as an assessment, of ok did they actually learn anything or where do they still have questions where do we need to build on?
Participant 7	It's like Bloom's taxonomy, synthesis I think was the part where if they can explain what they did and explain what they would do in other circumstances, learning is a lot more permanent than if it's like a chant and response boring classroom. Science is definitely a social process. If I go out and do experiments on something and then I don't tell anyone about it, or when you think about stuff like the Earth revolves around the sun, I didn't have to think of that, someone else already did and shared why with the world, so now we can build off of that knowledge. Thinking more of knowledge as something that is shared socially – that's important.

CHAPTER SIX

Summary of findings

This chapter summarizes the findings of this study relevant to the four research questions. Also included are comparisons of the science teaching methods course to the goals of the Maryland Collaborative for Teacher Preparation program, to reflection orientations articulated in the literature, to calls for research, and to recommendations for professional development. Following these comparisons is a discussion of the value of methods courses, limitations of the study, implications, and directions for future research.

Summary of Findings: Research Question 1

What educational and professional experiences influenced the instructor's visions of science learning and teaching?

The educational and professional experiences that influenced my visions of science learning and teaching were documented through my written reflections, sole-authored publications, and publications by and with my mentors. These influences are summarized in Table 6.1. Highlights include the following.

I have been fortunate in my educational endeavors to have learned from excellent teachers. My most influential experience occurred in an inquiry-based physics course for prospective teachers at the university (Layman, 1997; Roberts, 2000, 2007; Ukens, Hein, Johnson, & Layman, 2004). There were four key ideas from this class that I found especially meaningful. These are: 1) Every student was made to feel capable through the encouragement, scaffolding and support of the professor. 2) We were told that we were scientists in a community of scientists, carrying out scientific investigations and employing scientific practices. 3) The classroom expectations for our learning were high, but they were clearly expressed by a professor who demonstrated that he valued us as individuals, as learners, and as future fellow teachers of science. 4) The professor engaged us in reflecting on each lesson, and always made connections between what we were doing and how our future classroom practice of a particular concept might look. His high level of care, concern and confidence in us was always evident.

The physics course was part of a new program, the Maryland Collaborative for Teacher Preparation. This program was designed to encourage students to prepare to become elementary science and mathematics specialists (Bell & Denniston, 2002; Gardner & Ayres, 1998; McGinnis, 2002, 2006; McGinnis, Watanabe & McDuffie, 2005). I enrolled in courses that were part of this program, attended some of the seminars and field trips that were modeled in similar ways, and was one the first graduates. The instruction was an excellent model of what reform-based teaching and learning were supposed to look like. This was the vision of science learning and teaching I took with me into the classroom.

There were others who influenced me on this journey. My undergraduate methods instructor modeled reform-based science, with an intentional focus on reflection. Taking the time to reflect upon science learning and teaching, both my own and my students, was powerful to me. Weekly journal reflections more often than not led to as many questions as understanding. My undergraduate methods course introduced a further way to use reflection, which was called teacher research. This was a new addition to the set of influential experiences (van Zee, 1998; van Zee & Roberts, 2001; van Zee, Lay &

Roberts, 2003) and one that I believe kept me in the field of education (Roberts, 1999, 2000, 2007).

The theme of reform-based teaching and learning with an instructor who demonstrated care and concern, with high expectations, was repeated in a Master's level science teaching methods course. Reflection and critical thinking were foundational components of this course, modeled by a professor with a deep interest in diversity and socio-cultural issues (McGinnis, 1995, 2000, 2003; McGinnis & Simmons, 1999). This professor, and the others have continued to offer encouragement and support to me for almost twenty years. I have greatly benefited from this model of providing on-going support to teachers in the field, a practice widely recommended (Loucks-Horsley, Stiles, Mundry, Love & Hewson, 1998; Garet et al., 2001).

(add something about teaching in Title 1 schools)

From the classroom teacher position, I moved on to become the elementary science specialist for the county. This meant providing monthly professional development for elementary teachers. Again, reform-based practices and reflection were the core components. We did investigations for half of the meeting time, and then discussed how that investigation and process would translate into classroom practice. Another responsibility of this position was a two-week intensive professional experience for a cohort of about twenty to thirty teachers in the summer, followed up by two years of once a month meetings. Again this was a series of highly interactive inquiry-based investigations, in small groups, with lots of collaboration, discussion and debate around science concepts from the curriculum.

One of the requirements for participating in this program was that the teachers have their students do science investigations of their own, and share them at a Science Inquiry Conference during the school year. This was modeled after the Elementary Science Inquiry Project of Wendy Saul (http://www.esiponline.org/about/index.html). An additional aspect of this program was for the teachers to write up and present their findings and reflections at the National Science Teacher Association's annual meeting. Some of the experiences I had had as a teacher researcher I believed were valuable, so I shared them with these teachers. Several of those teachers joined our teacher research group.

As a member of the Carnegie Academy for the Scholarship of Teaching and Learning, my understanding about education was profoundly affected. Shulman's (1999) ideas of pedagogical content knowledge affirmed and deepened my understanding of science teaching and learning. Interacting with other teachers who were part of this group, listening and sharing ideas and research, was an experience that continues to inform my practice today. The Carnegie Foundation's KEEP TOOLkit is free software for multi-media representation of teacher research on the Internet, now available through www.merlot.org as the "content builder." Research projects can be easily translated into a web-based snapshot of practice. I have used this software in professional development, in my methods courses, and with my elementary students in my classroom (van Zee & Roberts, 2006).

I was invited to be a part of the committee for the National Research Council. This committee was responsible for creating a publication that developed a framework for teaching and learning science. This framework, published in *Taking Science to*

School: Learning and teaching science in grades K-8 (NRC, 2007), identified four interrelated strands of science proficiency. One of my university professors invited me to collaborate in providing examples of the four strands of scientific proficiencies as identified by this committee (McGinnis & Roberts, 2009).

These experiences have provided the foundation for the ideas and practices I put into place as a methods course instructor. I wanted a classroom that became a community of learners, with students and instructor engaged, held accountable and encouraged by each other. I wanted to provide the students with authentic experience in an environment where they could work together to solve problems, and think and act as scientists. I took time to get to know my students so that I could provide appropriate scaffolding or challenges, and modeling the kind of teaching and pedagogical approaches I envisioned them using in their classrooms.

The following table is a summary of the influences of prior experiences on the methods course.

Table 6.1

Summary of Prior Experiences

Prior Experience	Description	Influence on Design of Methods Course
Undergraduate physics course	My initial experience with inquiry based learning and teaching.	This was the way I wanted to teach! My model for reform-based teaching practices with both children and adults

Maryland Collaborative for Teacher Preparation	I was a participant in this program that was designed to prepare science and mathematics teacher specialists through courses that modeled reform-based practices.	Commitment to reform-based practices
Undergraduate science teaching methods course	Another inquiry-based teaching and learning experience	Emphasis on reflection
Graduate science teaching methods course	This was yet another inquiry-based teaching and learning experience.	A first attempt at creating a methods course syllabus.
Science Inquiry Group	I was a member of this teacher research group during my first and subsequent years of teaching.	Commitment to requiring collaborative reflective practices such as peer observation while teaching a lesson in field placement
Connections to the university as a beginning teacher	As a first year teacher, I brought my first grade students to the physics lab where they were successful in interpreting motion	Commitment to recognizing the capabilities of even young children in learning science

	graphs they had made themselves with motion detectors connected to computers	
Teacher in diverse Title 1 schools	Ability to speak Spanish facilitated relationships with students and their families.	Commitment to nurturing culturally responsive teaching
County elementary science specialist	I provided professional development for teachers consistent with inquiry/reform-based practices	Repertoire of inquiry-based activities suitable for professional development with adults
Carnegie Academy for the Scholarship of Teaching and Learning	Became a member of this community of reflective practitioners and learned to use the KEEP TOOLkit software for creating multi-media "snapshots of practice."	Use of multi-media portfolio final
State elementary science specialist	Assisted with development of the state assessment for science and development of the Governor's Academy	Knowledge of curriculum and assessment issues

	summer program for HS biology teachers	
National Research Council committee	Served on the committee that developed the publication *Taking Science to School,* (NRC, 2007).	Knowledge of current reform document
Elementary science methods course instructor at the University of Maryland	First experiences in trying to nurture reform-based practices, culturally responsive teaching, integration of other disciplines, multi-media final assessment, and reflective practice	Basic plan for the course and confidence to teach it

Summary of Findings: Research Question 2

What visions of science learning and teaching were promoted in the participants' science teaching methods course?

Abell and Bryan (1997) suggest that methods instructors need to model beliefs and attitudes about reform-based science teaching and learning and to discuss them explicitly. In addition, prospective teachers need to see science being taught in ways they are expected to teach. Furthermore, the philosophical framework methods instructors espouse and their actions must be consistent while providing support as pre-service teachers refine their beliefs. I perceive myself as enacting these recommendations in the science teaching methods course I taught. As summarized next, my interpretations of participants' responses to assignments, reflections, final, and the interviews provide evidence of the visions of science learning and teaching promoted in the course.

Interpretation of Assignments

There were four major assignments spaced several weeks apart during the course. The commentary below briefly describes each assignment, states the assertions that emerged from interpretation of participants' responses, summarizes the evidence, and makes connections to relevant literature. All of the assertions have been listed earlier in Table 4.26.

Assignment One. Eliciting prospective teachers' perceptions of science and science learning is a way to pre-assess issues they might need to examine and refine with support. The first assignment, *What is Science?* gave me insight into what the participants' initial beliefs, attitudes and understandings were about science. For this assignment the students first reflected on their own ideas about what science is. Then they read Chapters 2 and 3 of the text *Teaching Science as Inquiry* (Bass, Contant & Carin, 2009) and an article by William Harwood (2004), *A New Model for Inquiry: Is the Scientific Method Dead?*

Five assertions emerged from interpretation of participants' responses to this assignment: Participants had many different attitudes and beliefs about science. The participants described science as they had experienced it at school, usually in the context of “traditional” instruction. Participants sometimes expressed negative attitudes towards their ability to do science, or their experiences with science. Participants’ visions of science and science teaching sometimes reflected current views of the nature of science. Readings seemed to have influenced some participants to see science in a different way.

The diversity and complexity of the participants’ beliefs and attitudes about science as they entered my classroom were similar to those documented in other studies (Davis, Smithey & Petish, 2006; Tosun, 2000; Abell & Bryan, 1997; Bryan and Abell, 1999; Crawford, 2007). Many of these attitudes came from their experiences as students, an outcome that has been described as the *apprenticeship of observation* (Lortie, 1975). Like the pre-service elementary teachers interviewed by Tosun (2000), some had negative attitudes toward science based, for example, on learning science from “boring textbooks.” Others were more positive. Some of their ideas also came from their experiences outside of classrooms. For example, Participant 7 said, as noted in Table 4.2, “The key to science is curiosity; it is what drives us to first engage in science as children - we pick up a stone to see what is underneath of it.” This is similar to a description of science learning in informal settings as “scrutinizing bugs in the backyard” (NRC, 2009, p. 97).

An important aspect of the nature of science is its tentativeness (Lederman, 2007). As noted in Table 4.4, Participant 11 commented on this, “There still is ample opportunity for established laws of science to be modified or disproved. This is the beauty of being scientific. Science continues to evolve and progress.” After reading about current ideas in science and in science education, seeing the teaching and learning of science through a new lens was also noted. Table 4.6 provides evidence for the role of reading in supporting pre-service teachers as they refine their ideas.

In summary, having the participants describe their ideas about what science is was a way for them to acknowledge their perspectives on science and for me to get a glimpse into their thinking. Some negative attitudes were expressed, for example, the idea that science was for an elite group of people who were smart enough to do it. But there were also those who expressed some understanding of aspects of the nature of science, as noted above. Descriptions of traditional classrooms, with the teacher in the front, and students reading chapters from a textbook and answering questions, were not uncommon. The reflections on the readings showed that the participants noted a difference between approaches they had seen or experienced and what was possible through an inquiry-based approach.

Assignment Two. The second assignment, *The Status of Science*, occurred after the prospective teachers had been in their placements for three to four weeks. As a class, we brainstormed a list of questions to think about and analyze to assess the status of science in their particular settings. This assignment provided a vehicle through which the participants could ask candid questions, search for materials and resources on a school and district level, and create an awareness of the status of science in their placement settings. This also would give them valuable information to use for Assignment Four, when they had to teach a science lesson in the placement classroom.

Seven assertions emerged from interpretation of the participants' responses for this assignment. These are: There were a variety of attitudes about science amongst those interviewed on school staffs. Interviewees commented on the influence of standardized testing on science instruction. Participants perceived inconsistencies in the way the role of science is espoused by administrators and districts - and the reality of the classroom. Participants reported that school staff perceived a variety of ways science is being integrated, or could be integrated, into the curriculum. They reported that time for science varied among schools and teachers. There were some aspects of inquiry-based science reported. Participants perceived many challenges to science teaching and learning in elementary classrooms.

It has been my experience, as well as that of the participants, that there are a variety of attitudes about science amongst school staff. Two of the participants noted that the teachers interviewed did not feel prepared to teach science because they did not know enough science, professional development opportunities were of poor quality, or did not exist. This may have been the case, as many teachers at the elementary level are not prepared to teach science in terms of content knowledge and teaching practices (Loucks-Horsley et al. 1998).

In addition to teachers feeling ill prepared, the participants reported other influences that impact science instruction, such as standardized testing, which focuses on math and reading, a finding also evident in the literature. Smolleck (2007), for example, noted that testing pressures had made science a low priority. Currently, during her visits to schools, she found that if science was taught at all it was relegated to the last few minutes of the day. Lee and Luykx (2005) also found that an emphasis on basic literacy and mathematics skills, especially in diverse schools, reduces or eliminates time for teaching science.

The participants identified some inconsistencies in information from district websites and school administrators and what the teachers revealed about science in the classroom. As recorded in Table 4.9, Participant 5 gives a clear example of this:

> The principal and the teachers I interviewed think science is important because it is part of everyday life, that can be applied in real situations, and it helps developing higher order thinking skills. The principal asserted that reading and math scores had gone up by consistently teaching science. However, I found inconsistencies on the school's point of view and the reality of the classroom. Science wasn't taught.

Olson, (2008) offers one solution to "making time," for science as "overlapping" the disciplines. This is similar to the common theme summarized in Assertion 4, of integrating science content with other disciplines. However, the time dedicated to science was an issue in most schools. All of the participants were placed in Title 1 schools and their experience of the lack of time devoted to science is similar to that reported by Lee and Luykx (2005). However, the participants reported that if and when they saw science, it was sometimes done in an inquiry-based way, similar to descriptions in the *National Science Education Standards* (NRC, 1996).

In thinking about the challenges, Participant 6, as recorded in Table 4.13, began to wonder:

> As I am spending more time in the classroom, it is becoming evident that there are lots of demands that come with being a teacher; and perhaps doing science regularly creates too big of a demand, especially when you don't have the time or materials.

The participants also commented on the school staff's perception of lack of materials, lack of support for working with students who are learning English and other nonmainstream learners, which are challenges also well documented in the literature (Lee et al., 2009; Davis, et al., 2006; McGinnis, 2003).

In summary, the information and ideas the participants encountered while interviewing school personnel seem to be typical of the status of science instruction in many schools. Teachers seemed to be feeling pressures of the implementation of NCLB, with a decreased emphasis on science instruction in schools and classrooms. The challenges recognized by the participants and their teachers are real, and they are many, and ways to provide better support are needed.

Assignment Three. This assignment was an opportunity for participants to evaluate science lessons of their choice from the curricula that were being used in their placement classrooms. The intention was for the prospective teachers to think about the lessons in terms of the students with whom they were working. Each was to choose a lesson for implementation at the appropriate grade level of science and other content. The next step in this process was for each prospective teacher to re-write a lesson using the 5E format (engage, explore, explain, elaborate, evaluate) developed by the Biological Sciences Curriculum Study (Bybee, 2009) and recommended in their textbook (Bass, Contant & Carin, 2009) and then to make changes to the lesson in order to address the challenges identified. Once the prospective teachers had completed the analysis and rewriting, they were to create valid assessments for their lessons.

The participants' responses, as interpreted from this assignment, illustrated four assertions. These are: Participants' initial impressions demonstrated some awareness of inquiry-based instruction in evaluating a lesson plan. Participants' modifications reflected a growing understanding of reform-based instruction. The participants identified inquiry-based ways to motivate student learning. In evaluating lesson plans, the participants seemed to focus more on assumptions about content than other areas, such as physical ability, special needs, giftedness, race/ethnicity/culture, gender or socio-economic status.

Some participants acknowledged having experienced at least some science as inquiry as students. For others, the idea of inquiry-based instruction was new. Their sources for information about inquiry-based instruction, in addition to their experiences in class, were their textbook *Teaching Science as Inquiry* (Bass, Contant & Carin, 2009), the *National Science Education Standards* (NRC, 1996), *Inquiry and the National Science Education Standards* (NRC, 2000), *Nurturing Inquiry* (Pearce, 1999), and a variety of handouts. This assignment occurred about halfway through the class, so for them to evaluate lessons to ascertain the degree to which the lessons were inquiry-based was feasible.

The assignment provided additional information about the participants' beliefs and understandings of inquiry at this point in the course. As noted in Table 4.14, Participant 15's comment exemplifies initial understandings of pedagogy typical of inquiry approaches:

> The lesson seems student centered and interactive. I like that the students work in groups and make predictions through collaboration and discussions. Students are able to share ideas and help one another elaborate on observations.

The participants showed they had expectations and intentions that affirmed the use of interactive, student-centered activities through their reflections on ways they would modify the lesson by using hands-on activities, having students write about what they observed and summarize what they had learned, and making connections to student learning. This is similar to what Forbes and Davis (2010) found that "pre-service elementary teachers' generally positive orientations toward active, hands-on, investigation-based science can serve as a productive foundation upon which to support their developing understanding of scientific inquiry" (p. 822).

Additionally, the participants seemed highly focused on engagement and motivation. As Davis, Petish and Smithey (2006) found, "at least at the elementary level, pre-service teachers seem initially to want mainly to engage, interest, motivate, or manage their students" (p.620). The participants used engagement and thought about it in ways that were similar to *Taking Science to School's* (NRC, 2007) description of engagement, to motivate students to be involved with the activity at hand and to construct their own knowledge, sustaining their involvement for a period of time.

When evaluating the lesson plan using the framework of questions provided, the participants often noted the lesson plan made assumptions about different disciplines such as science, reading, and math but only one participant made a comment about a cultural assumption. Only one participant made a comment about a special needs assumption. As noted in Table 4.17, Participant 14 claimed there were no assumptions at all:

> Additionally, factors such as physical ability, special needs, giftedness, race, ethnicity, culture, gender, and socioeconomic status do not play a

role in the activity. One student will not have an advantage over another and therefore everyone will be able to participate in the activity and explore nature at the same pace.

As discussed in Chapter 4, Participant 14's comment was a surprise to me. It seemed as though the participants were unable to see the diversity of the students in their classrooms. As the participants were placed in Title l, urban schools, I found it hard to believe that there existed a lesson plan so perfect that no modifications needed to be made. It seemed to be more of an issue of one-size fits all instruction and a limited understanding of the individual needs of students. This occurred even though in class we had read and discussed articles about differentiation, considered video case studies of teachers collaborating to work with special needs students, and also discussed a video about English Language Learners and the kinds of supports they might need. In other methods courses issues of equity and diversity were discussed as well, because the students sometimes shared comments from their other classes. This is an issue new teachers seem to have to face and often have difficulty with – how to recognize that all students' science learning and development might be different and that in each classroom there are learners with diverse range of ideas, backgrounds, abilities, needs, and science experiences that influence their learning (Davis et al., 2006, Lee et al. 2009: Nieto, 2000). As Cho and DeCastro-Ambrosetti (2005) noted in a study entitled "Is Ignorance Bliss?" "Many of those entering the field of teaching have a lack of knowledge of the experiences, needs, and resources of culturally and linguistically diverse student populations" (p. 24). This is a possible explanation of the participants' limited attention to issues of individual students' needs and differences.

In summary, after having many weeks of doing inquiry-based activities and reading about reform-based science, the participants had a base of information that they employed in evaluating the science lessons they chose. Motivation was a factor they saw as important. When the participants spoke of motivation and engagement it was in relation to aspects of inquiry-based science. The participants' thinking about assumptions surprised me. The majority of their comments were focused on assumptions that were made about the content areas, (reading science, math) but physical ability, giftedness, ethnicity, gender, and socioeconomic status were never mentioned even though requested. It seemed that the content of the lesson was predominant in importance and that knowing the learner was often ignored.

Assignment Four. Assignment Four was multi-faceted. It combined developing a lesson, teaching the lesson, being observed by a peer, and reflecting individually and with the peer. There was synthesis of key concepts of the course. Participants were required to use a "driving question" (Krajcik et al., 2003, p.81) about teaching and learning that they were exploring in the context of planning and implementing their lesson. They could choose to teach only to a small group of students to make differentiation a little more manageable. They were required to identify benchmarks and standards for the district they were in, as well as to identify the national standards the lesson addressed. In addition to finding ways to integrate other content areas and technology if possible, they also needed to create an assessment. They shared their driving question (focus of inquiry) in a pre-observation conference with the peer observer of their choice. The peer observer watched the lesson and took notes focusing only on the issues relating to the driving question. This lesson was videotaped so that the participant doing the teaching could review the tape prior to the post-discussion. Afterward, the "teacher" and the observer reflected individually. For the post-observation, the peer observer went first, without interruption from the teacher. Then the teacher shared reflections with the peer observer and was able to ask questions. This process was an example of collaborative inquiry situated in the context of classroom practice in a science lesson and had the potential to "contribute significantly to teachers' professional growth" (Little, 2002). A framework of questions guided the summary the participants had to write. The process was involved, but the idea of reflecting on one's own teaching, peer observation, driving questions, integration of other content and/or technology, and helping <u>all</u> students reach their potential were all repeated themes in the course. This assignment built on the lesson analysis completed for Assignment Three and some participants chose to use the same lesson for Assignment Four.

There were seven themes that seemed apparent when I reviewed these data: The driving questions the participants chose were often about student engagement. Participants found ways to integrate their science lessons with other content areas. They used different types of assessment in the lessons they taught. In general, participants felt they were successful in teaching the lesson. They were able to look critically at their experience and reflect on ways to improve. The participants were able to identify pertinent challenges they encountered when teaching their lesson. Their reflections were thoughtful and meaningful regarding themselves, their peer observations and students.

None of the other methods instructors required or requested the students to teach a lesson in the context of their courses, even though the participants were all in placement classrooms at this time. Believing that the participants would learn a lot more about teaching by actually teaching than by coursework, however, I created this assignment to provide such experience. I was aware, as Forbes and Davis (2010) found, that prospective teachers often do not have enough opportunities to actually try out inquiry-based science lessons in the classroom. I believed that field experiences should be a significant part of teacher education programs because these afford prospective teachers opportunities to develop a basis of understanding upon which future teaching and learning can be expanded. As Dewey stated, "[The teacher] has to see on his own behalf and in his own way the relation between means and methods employed and results achieved. Nobody else can do that for him" (Dewey, reported in Schön, 1983, p. 17).

The driving questions the participants formulated for this teaching/reflection assignment could have been about the science content or about their teaching but were often about engagement. These are only two examples from Table 4.18: Participant 3 asked, "What is the level of student engagement?" Participant 14's question was "Are the students engaged at all times?" Like the prospective teachers in Abell, Bryan and Anderson's study (1998), these participants were focused on engaging and maintaining student interest.

The participants found ways to integrate their science lessons with other content areas in response to a need to provide students more experience in reading expository texts, particularly given that standardized tests often include such texts (Anderson & Guthrie, 1999). Adding a writing or reading component to lessons that did not include them was also a response to the influence of high stakes testing. If the use of literacy was included, teachers could defend their use of time for science, otherwise, science probably would not take place. Adding a math component was a response to reform-based science calls to integrate math and science (Gardner & Ayers, 1998; McGinnis, McDuffie, &

Graeber, 2006). Several of the students made math connections to science or, in reflecting on the teaching of their lesson, found ways that those connections could have been made or improved upon.

Assessing science in different ways was apparent in the participants' design and reflection on their lessons. As Abell and Volkmann (2006) recommend, the participants provided opportunities for students to "reflect on and demonstrate what they know" (p. 13). Some of the participants required a writing piece as assessment, some used teacher observation as the main assessment, and still others used questioning to assess learning, none included a "test."

In their reflections on the lesson, the participants' perceptions of success in teaching primarily were determined by whether or not they were able to implement the focus chosen through their driving question (Krajcik, et al., 2002) based on their own reflections and that of their peer observer. Even though their experience in teaching was limited and was still influenced by their experiences as science learners, it also was influenced by their desire to provide more student-focused learning, to help students enjoy learning science. This finding was documented in other studies as well (Abell & Bryan, 1997; Davis, 2006;). Student focused learning in the perception of the participants was important, and for some was reflected by how engaged the students were in the lesson. It was important to the participants to facilitate and question during the lesson they implemented in their field placements rather than use direct instruction.

The challenges identified in the teaching and learning from these experiences were many. From the participants' comments, the bulk of their challenges seemed to come from classroom management struggles. This is not unusual for new teachers, for teachers who are guests in another teacher's classroom, or in some cases for students who had not been engaged in science activities in that classroom, or were in novel situations such as being pulled from the class to a conference room to do a lesson (Windschitl, 2003). For example, as recorded in Table 4.23, Participant 4 expressed some frustration, "The students are very energetic which can be wonderful but in this class' case, where there is no discipline, it is horrible."

The participants reflected on their lessons, on their peer observations and on the students with whom they worked. The peer observation was included to promote, as Harford and MacRuairc (2008) recommend, "a culture of observation and critical dialogue in a profession which has traditionally been characterized by isolation, while at the same time fostering and validating the voice and experience of the student teacher" (p.1884).

This assignment was a synthesis of many pieces of science teaching and learning. The prospective teachers worked to include and implement reform-based strategies. As in Abell and Bryan's study (1997), these prospective teachers struggled, at times, with letting go of some of their ideas about teaching that came from their prior and often didactic experiences and moving to teaching and learning that was student-focused. For example, Participant 13, as noted in Table 4.23, believed she should have given more explanation on how to read and fill in a chart, an aspect reflecting a more traditional approach, rather than possibly inviting the students to create a chart of their own for collecting data, an aspect that could have reflected movement toward a more inquiry-based approach:

> I then jumped right into the lesson plan by explaining that we were going to make and record observations, predictions and outcomes, instead of explaining, in detail, how to read the chart and fill it in. This minor hurdle did not prevent further development in the lesson.

The participants seemed to find the peer observation and reflection useful. They indicated the value of discussing the teaching and learning that took place and how ongoing conversations helped them to see a bigger picture, and have a more in-depth understanding of their lesson. This was similar to findings of Gardiner and Shipley-Robinson, (2009) when they placed student teachers in pairs during a field placement and the student teachers shared the value of the collaboration. As noted in Table 4.24, Participant 2 gives an example of this, "I feel like I had a superficial understanding of how the lesson went and my colleague provided with more in depth details since she was an outsider looking in."

In summary, the participants were challenged to plan, prepare, implement, assess, reflect, and critique their own lesson. For many of them, this was the first time they had taught a lesson in their placements. Student engagement seemed to be a focus for their driving question and for their evaluation of their own success. If the students were engaged, they considered their lesson a success. The participants had experienced the lack of or limited time dedicated to science in their field placements, and understood that only through integration would they be able to justify the teaching of science. Reform-based instruction calls for the meaningful integration of mathematics, but the reality of the classroom places a high priority on literacy as well. Although reading and writing are most often required in any science investigation, bringing attention to their inclusion, in some sense, gives the teacher permission to do the rest of the lesson. The participants found value in the peer observation experience, and recognized that another set of eyes can provide the teacher with data that may have otherwise gone unnoticed. Identifying challenges through thoughtful reflection on their lessons was something they all accomplished.

Summary of Findings for Assignments

The four assignments in this course were designed as a progression of learning (NRC, 2007; Roth 2009) in terms of the nature of science and science pedagogy. Initially the students were asked to describe their understandings of science. It was through this assignment that some of their beliefs and attitudes about science were brought to light. Their beliefs demonstrated a range of understandings and experiences, from those who seemed to understand some aspects of the nature of science, to those who believed science was only for the best and the brightest. They also reflected on the first readings in this assignment, and found the inquiry based science they were reading about sounded like a better way for science learning and teaching to take place than the didactic ways in which they had experienced science as students. After examining their own personal attitudes about science, the students researched the status of science in their field placements. Their findings reflect many of the same findings that have been documented in the research. These ideas were: there is little to no time for science, limited resources available, literacy and numeracy skill practice takes priority over everything else, cooperating teachers were uncomfortable teaching science, school faculty believed there were ways to integrate science, but it was not often done, there were inconsistencies between perceived attitudes of science from administrators to teachers and classroom practice. There were a few positive anomalies; the participants found those teachers who like to teach science and try to find ways to include it in their schedules, had inquiry-based teaching strategies.

After evaluating their field placements, the participants were asked to evaluate a science lesson of their choice, so we are moving from a broader perspective of schools and classrooms to a more specific focus on curriculum. They were encouraged to choose a lesson from science curriculum at their schools, but because some placements classrooms did not include science in their curriculum, participants also chose lessons from other sources. In their evaluations of curriculum, the participants seemed to focus on how engaging or enjoyable the lesson seemed to be, and when discussing modifications, finding ways to make the lesson more motivating was important. The participants also found other ways to modify the lessons that demonstrated their growing understanding of reform-based science practices. However, in evaluating the lessons, issues relating to knowing the students, or differing students' needs like ethnicity, diversity, socio-economic status, or language, did not seem to be considered, but issues relating to the content were. The last assignment was the next step in the learning progression, and that was the combining of all of the aspects of the course and assignments. The participants used their evolving framework of beliefs and attitudes and understanding of reform-based science with a lesson plan they had modified for the students in their placement settings. They implemented this lesson in their placement sites. Working in tandem with a peer observer, they reflected on the lessons they taught and provided a written reflection of their experience as well. The participants demonstrated that they could implement reform-based science teaching strategies and that their beliefs were changing. They were able to identify challenges and successes, and to suggest additional modifications to the lesson. The participants demonstrated that in one experience of planning and teaching a science lesson, they were able to incorporate many aspects of reform-based science practices. Understanding the learner, and the diverse needs of learners, was an area that needed more attention. However, in a one-time experience their focus on content and engagement is reasonable. Further experiences would have helped to bring these important issues to the forefront.

The following table is a summary of the findings from interpretation of responses to assignments.

Table 6.2

Summary of Findings from Assignments

Assignment	Finding
Assignment 1	Range of beliefs and attitudes: science for the best and brightest, to showing understanding of aspects of the nature of science; Readings about inquiry science influenced their thinking about science learning and teaching
Assignment 2	Field placement interviews revealed constraints (time, materials, comfort level of staff to teach science, integration possible but not often done and inconsistencies about science amongst staff members) - and exceptions to constraints (a few staff reported teaching science through inquiry)
Assignment 3	Evaluation of curriculum focused on engagement and motivation. Ways to implement and or modify the lesson using reform practices showed growing understanding of reform-based science instruction. Limited

	attention to issues of diversity
Assignment 4	Implemented lessons that incorporated aspects of reform-based teaching/learning, changes in attitude sometimes apparent, identified challenges and successes

Interpretation of Reflections

The weekly reflections were either free choice or focused. The assigned foci included: *Describe your own experience of learning science and how it's different in elementary classrooms today*, *What reading so far was the most meaningful or thought provoking*? *Eye openers from schools*, *your understanding of the current status/politics of science at elementary levels*, and *envisioning yourself as a science teacher*.

My purpose in emphasizing reflection in this course was two-fold. First, I wanted to better understand how the participants were thinking about teaching and thinking about their own learning, and second, to look for changes or issues related to reform-based science learning and teaching. There were often conflicting ideas the participants struggled with in my study, similar to those reported by others (Abell & Bryan, 1997; Bryan & Abell, 1999). For example, one participant struggled with the idea of everybody "getting" a concept before moving on and the idea of re-teaching until all the students "got it." For the participants, having to reflect on their science teaching and learning gave them a beginning place to look at their own their practices, and ask questions about aspects that puzzled them.

I chose Participant 16 as representing a "typical" (Stake, 2000) student in the methods course for a case study. This is a typical case because it is being examined to provide insight into the thinking and understanding developed by a student who was representative of others in the class. The case was developed in depth and the contexts were examined in detail.

In her reflections, Participant 16's thinking about science teaching and learning from her own experiences began as tentative, almost wishful, and grew to be much more emphatic and determined. As noted in Chapter 4 (p. 221), in her first reflection, she describes learning science as "just a lot of memorizing and boring reading" and commented, "I believe that if my teachers used a more hands-on approach with me then maybe I would have enjoyed it more and perhaps retained more information." In her final reflection she admits to having a changed view, "I envision a classroom where the students want to learn even more then I give them and who take the learning outside of my classroom and seek out more information on their own." She even leans towards being an agent of change for science reform; "I have been able to think beyond the way I was taught science and set new expectations for my science classroom." As noted in Chapter 4 (p. 243), however, when I sent Participant 16 my interpretations of her reflections and final and asked her to make sure that I had not misrepresented any of her ideas, in a personal email she shared, "Wow! I seemed much more insightful than I am now. I loved reading this because it made me think about a lot of things that I am (sadly!) not doing in science right now. Thank you!" This was two years after the methods course. This comment seems to indicate that the change in understanding has not necessarily become a change in practice. A follow-up study would be helpful to explore this topic more thoroughly. As Davis et al. (2006) recommend, "Teacher educators need to consider how to build on new teachers' strengths and devise instructional opportunities that could promote growth in areas of weakness, such as translating some productive ideas into practice" (p. 620).

Interpretation of Multi-Media Portfolio Final Assessment.

The final assessment was to be a synthesis or a showcase of learning about science and science teaching for the semester. The prospective teachers were encouraged to review assignments, reflections, activities, and readings to identify examples of their learning. They were to use the Carnegie Foundation's free software for building websites, the KEEP TOOLkit (now available at www.merlot.org). Being in the computer lab made learning how to use this Internet-based tool an easy job. In one class period, the prospective teachers practiced uploading pictures and text and manipulating the web page components. I shared previous finals with them from other methods courses I had taught. I showed both exemplary finals and less than exemplary finals to give them a perspective about creating their own multimedia portfolio as their assessment.

The KEEP TOOLkit was designed to help teachers and students create "snapshots of practice" easily on the web. It was an easy way for the user to analyze and reflect on any given situation, and "transform their materials and reflections into visually appealing and intellectually engaging representations" (http://www.cfkeep.org/static/about/about.html). Using portfolios as a form of assessment provides opportunities for students "to make public a variety of evidence of their individual strengths" (Glasson & McKenzie, 1999, p. 327). Such multi-media portfolios could tell the story of their learning in a greatly enhanced way.

Participant 16 created a portfolio that was both visually appealing and intellectually engaging. My choice of using this program to assess the students was because of how powerful a tool it became for demonstrating what had been learned. There was not much of a learning curve – I have even used it successfully, in a first grade class. Through her final Participant 16 showed an awareness of the change in her thinking from the beginning to the end of the course. She used both visual and textual aids to illustrate her learning and beliefs. She used the analogy of a teacher's toolbox to synthesize her understandings of reform-based science learning and teaching. Her final product was a detailed representation of her learning, reflection and visions for teaching.

The following table is a summary of the findings from interpretation of the weekly reflections and multi-media portfolio final assessment.

Table 6.3

Summary of Findings from Interpretation of Weekly Reflections and Multi-Media Portfolio Final Assessment

Weekly Reflections	Began with negative attitudes - "science is just a lot of memorizing and boring reading" to a complete change in perspective about science for her own classroom "I have been able to think beyond the way I was taught science and set new expectations for my science classroom"
Multi-Media Portfolio Final Assessment	Visually appealing and intellectually engaging Used analogy of teachers toolbox to illustrate synthesis of learning and understanding of reform based science practice

Summary of Research Question 2

In summary, *what visions of science learning and teaching were promoted in the participants' science teaching methods course*? I have described the findings from the four assignments. The first assignment showed the participants' initial ideas and beliefs about science; the second assignment helped them learn about the status of science in their field placement schools; the third assignment provided an opportunity for the students to evaluate a science lesson; the fourth brought all of these components together in planning and implementing a reform based science lesson at their field placement site.

I chose Participant 16 as a typical student, and used a case study to interpret her weekly reflections and the final. Through her reflections Participant 16 recognized her changes in thinking and her new attitudes about reform-based science. Her multi-media portfolio final highlights the learning and the changing she did during the course and provides a detailed illustration of her visions of science learning and teaching.

Summary of Findings: Research Question 3

What visions of science learning and teaching did the newly qualified teachers bring with them as they graduated from the teacher preparation program?

A set of semi-structured interviews documented the visions of science learning and teaching that the newly qualified teachers brought with them as they graduated from the teacher preparation program. When I first interpreted the data from the interviews, I organized the data into sections. Those sections are: visions of science teaching, visions of science learning, visions of science practice, lesson plan reflections, and the methods course: participant reflections. These data are discussed in detail in Chapter Five (pages 1-122).

Visions of Teaching and Learning.

Although these newly qualified teachers had not yet begun to teach, their visions of science teaching and learning describe a range of reform-based instructional approaches. Because the ideas described for both teaching and learning were similar, I grouped them together. These approaches to teaching and learning included students taking the lead in identifying the problem, generating questions, designing investigations, making and recording observations, interpreting data, creating explanations, and developing models and argument, processes similar to those articulated in the *National Science Education Standards* (NRC, 1996). These teachers were able to describe a promising understanding of teaching science as inquiry and claimed that they believed they would implement reform-based science practices in their new classrooms. These findings about the beliefs of new teachers are similar to those recorded by Crawford (2007) who noted that more research is needed on how teacher beliefs about inquiry and reform translate to practice. Bryan (2003) and Luft (2007) also found that there can be many different factors that influence and affect how beginning teachers' practices of teaching science will be translated into their new school site.

My hope was that these newly qualified teachers would not encounter school cultures that would inhibit or constrain their ability to follow through, although there is research that documents the difficulties some new teachers experience in implementing inquiry approaches in their own classrooms (McGinnis, Parker, & Graeber, 2004). From my own experience in teaching (almost 15 years), with a strong commitment to reform-based teaching, the difficulties I encountered in trying to implement teaching science as inquiry were overwhelming at times. Anderson (2002) claims that the research does not provide a clear vision of the complexities of this endeavor.

Some participants seemed to have taken on the challenge of becoming an agent of change for science in their comments. As noted in Chapter 5 (p. 25), Participant 1 in response to the question "how would you maximize student learning?" claims "by at least setting aside time everyday for it, at least having time like where I would have to get to it – as opposed to "well – we are out of time for the day – oh well, no science." As noted in Chapter 4 (p. 229), Participant 16 explains her commitment to teaching science, "I realize that it is apparently very easy to avoid teaching science…I have the power to make a difference in the education of my students. I can continue the way things are going or I can make a change." As Crawford, (2007) explains, we need to encourage newly qualified teachers to join the effort to implement reform-based practices. Their philosophy of teaching should be such that new teachers can articulate and defend why an inquiry-based approach is better for science instruction.

Visions of Practice

In interpreting the newly qualified teachers' visions of practice, there were several predominant themes. One was assessment; another was discussion and its benefits. Abell (2006) and Krajcik et al. (2003) argue that if instruction is going to be effective, then teachers need to develop meaningful understandings of their students' prior knowledge. The participants seemed to have absorbed this imperative, indicating that pre-assessment of student knowledge was important before starting an investigation.

Some thought that pre-assessment could happen as a discussion. Participants noted that daily discussion could be used as an assessment tool. The importance of discussion as a tool for teachers to understand student thinking is noted in current reform documents as well (NRC, 2007). The participants explained that when their students had to share their ideas orally, their content knowledge, process skills and science thinking became apparent, that discussion also pushes elementary students into putting their ideas into words, which would help develop an understanding about their students' thinking. They seemed aware that discussions provide teachers with a "rich array of information," as has been reported by Krajcik et al. (p.339). The participants talked about using informal assessment during instruction. Most of what was described was not planned but "on the fly" (NRC, 2007, p. 281). Often descriptions of informal assessment were observations, or discussion. According to Krajcik, et al., (2003) engaging in "thinking about, analyzing and mentally debating what should be done to most effectively teach" (p. 314) is being reflective about practice, and that is what the participants were attempting to implement, during the lesson they taught.

The participants also envisioned discussion as a tool to help students explain and defend the conclusions of an investigation. They described examples of students collecting data, forming conclusions and using those data as a vehicle to demonstrate what they know in their future classrooms. They claimed that they would have a class discussion to follow an investigation. If in that discussion, several different conclusions were reached, they predicted a debate might ensue. As noted in Chapter 5 (p. 292), Participant 6 explained that if this happened, it might be a good time to talk about variables, and human error (in measurement perhaps) as a way to understand differences in conclusion. Discussion at the conclusion of an activity was a goal of the MCTP program as well as a way to summarize student learning (Gardiner & Ayers, 1998, p. 25). The participants viewed discussion as an assessment tool as well and explained that they found the discussion approach to be effective, more authentic than formal assessment. As noted in Chapter 4, Table 4.20, Participant 3 stated, "I think that a more accurate assessment was done when I talked with each group individually. I did this as they finished the activity, and then with the whole class." The participants suggested that they would develop authentic assessments by using assessments that are closely related to what happened during instruction. This thinking was similar to the reform-prepared teachers in the study by Marbach-Ad and McGinnis (2008).

Building a community that provides a safe and collaborative environment so that the elementary students can participate in discussion freely was a vision frequently mentioned by the participants. This idea was discussed in the textbook as an important aspect of science learning and teaching (Krajcik, et. al, 2003). One vision of the importance of this was expressed by Participant 1, as noted in Chapter 5 (p. 72), "And you have to set up that environment, that classroom family environment, where everyone feels comfortable, and everyone is good at sharing."

In summary, the participants in looking forward to their new classrooms and to the teaching of science expressed visions that were similar to ideas espoused in reform-documents (NRC, 1996; NRC, 2007). In discussing their visions of practice, they highlighted ideas related to assessment and discussion. They emphasized that assessment could be done in ways other than tests and quizzes, and that discussion would facilitate student learning and their understanding of student learning.

Interpretation of Lesson Plan Reflections

After having designed and implemented a science lesson in their placements, and having written a formal reflection for the class, the seven participants interviewed were asked to look at and think about their lesson plan again. This was about six months after the course had ended but before they began to teach. Data from their original reflections are presented in Tables 18-24 of Chapter Four. The participants interviewed remembered that science was not emphasized in their schools, just as Smolleck (2007) found, "elementary school science has become almost nonexistent within our elementary school classrooms" (p. 1) Because science was rarely, if ever, taught, their experiences teaching science were sometimes unique. The students in their placement classes were excited to do science. The participants also sensed they were different from the teachers at their sites, because they were being encouraged to teach science in a way that emphasized connecting to and integrating other content areas, as were the reformed-based teachers in the McGinnis, Parker, & Graeber study (2004). Participant 1 commented on the fact that he could have integrated his lesson more, and that it would have been improved if he had made connections to the real world through the use of models. Participant 5 thought that she could have shown the students how classifying is a strategy of many disciplines such as math, reading, and social studies. Participant 4 found that classroom management was a particular challenge for her, attributing this situation to the students' lack of science experiences and the mentor teachers' management style. Just as in the Forbes & Davis (2010) study, the participants not only carried out their lesson plan, but also had a peer observer. The participants in this course afterwards considered sharing the reflections between the observer and the observed beneficial. Missing from this reflection was any discussion of the students, or of learning that occurred, or may have been improved, and or any reference to working with diverse groups of students, which brings up the same question asked by Davis, et al. (2006), how do newly qualified teachers learn to understand how to meet the needs of all learners with diverse backgrounds and experiences?

Participants' Reflections on the Methods Course.

When interviewed about the course, the participants discussed what best practices they saw employed, how the course was similar or different to other methods courses, what the key ideas were they believed they would take into their own classrooms and what could have been improved in the course. These reflections are discussed in detail in Chapter 5, pages 316-344 and are summarized below.

The participants described the approach as student-focused, inquiry-based teaching, with the instructor taking on the role of facilitator. These descriptions are characteristic of reform-based teaching (Bell & Denniston, 2002; Crawford, 2007; Gardner & Ayres, 1998, NRC, 1996). They indicated that they felt respected as adult learners and felt viewed as being able to teach and to learn to teach science. They commented on the fact that I made them curious and that I asked them to reflect on their learning and teaching, a practice evident in descriptions by other methods course instructors (Abell & Bryan, 1997; Forbes & Davis, 2010; Gardner & Ayers, 1998). Another aspect of the course they mentioned as a best practice was when I brought in things from my own classroom (student work, etc) for them to see.

Participants claimed that the course was different from other courses because they were required to conduct assignments in their field placements and to evaluate lesson plans. Even though field experiences provide important opportunities for future learning

(Zembal-Saul, Blumenfeld, & Krajcik, 2000), the other methods instructors did not choose to incorporate these settings in their assignments. The participants thought science methods was similar to their social studies methods course “a little” because that course had them do group projects; and similar somewhat to math, because in math they used manipulatives as well.

As previously noted, there were changes in attitude about science and about the teaching and learning of science, similar to those documented by other researchers (Abell & Bryan, 1997; Davis, Smithey & Petish 2006; McGinnis, Parker, & Graeber, 2004; Windschitl, 2003). The newly qualified teachers were committed to reform-based teaching and indicated they were prepared to teach science. There were participants who claimed they would push for science time in their classrooms and schools and make sure that it would get taught. Crawford (2007) explained that we need to encourage new teachers to join the reform efforts and become agents of change for science education. The participants shared that they were willing to be advocates and proponents of change. Whether or not that will be sustained is yet to be seen. Integration was a major theme throughout the interpretation of all data. They saw the enhancement of all content areas through the teaching of science and the necessity to integrate in order to get science into their daily curriculum. They explained that the classroom community they experienced in this course was an environment they would try to create in their own classrooms.

Because they had not yet begun teaching, the responses about what could have been better were basically that they did not know yet, and that they would like to know about where they would be teaching. There is very little research on how new teachers make long-term plans for instruction (Forbes & Davis, 2010). As noted in Chapter 5, page 344, Participant 6 wished we would have addressed this need and had this constructive criticism about planning:

> I wish we would have done a little more curriculum planning, like your entire, like here's your standards and content that you have to teach, so how are you going to do it? Because like now it's like go and my school honestly they just here you go honestly just that, no text books- nothing. So now I am like, yeah that's the only thing I think I felt I really needed.
>
> More like curriculum design?
>
> Exactly how am I going to plan my unit? How am I going to go effectively go beyond one lesson, oh yea like that's the thing – like even a long extended lesson, more than just a one day lesson?

This is a problem that Forbes & Davis (2010) addressed in their study of prospective teachers and curriculum design. The process of curriculum planning is an important aspect of teachers' practice, and often not emphasized in education programs. Their findings show that if prospective teachers are given the opportunity to evaluate curriculum and lesson plans, they often adapt those materials to provide for better inquiry-based science instruction. This is yet another component to be included in the design of a methods course.

The participants remembered things that related to reform based instruction that demonstrates that those experiences were meaningful to them. They liked the inclusion of authentic student work and examples from my own classroom, and found the field experience to be meaningful. What they were often focused on was procuring their future job, which is a logical focus. In thinking about her next job, Participant 6 realized that we had not discussed any long-term curricular planning, or actual planning beyond one lesson. This is a valid concern, however, one semester is not enough time to do it all, and careful consideration of all of the aspects needed in a methods course is necessary. Or perhaps as Luft et al. (2003) pointed out, having more than one methods course, or a continuance of support into the induction years of a teacher may be a better way to provide a more in-depth spectrum of knowledge to prospective and beginning teachers.

The following table is a summary of newly qualified teachers visions of science teaching and learning.

Table 6.4

Summary of Newly Qualified Teachers Visions of Science Teaching and Learning

Topic	Example
Visions of Teaching and Learning	Describe a range of reform-based instructional approaches, such as: identifying the problem, generating questions, designing investigations, making and recording observations, interpreting data, creating explanations, and developing models and argument; Recognize constraints such as influences of standardized testing (no time for science), some express a desire to become agents of change and make time for science
Visions of Practice	Focus on assessment; pre-assessment of prior knowledge important to learning, informal assessment during lesson, assessment through discussion, wanted to develop authentic assessments that were closely related to what happened during instruction

	Focus on benefits and uses of discussion, daily discussion, students sharing ideas to articulate thinking, students defending conclusions with evidence through discussion
	Reflection on practice
	Building a safe environment - where a community of learners "feels comfortable."
Lesson Plan Reflections	Lesson plan reflections included making connections to real world through models, showing connections to other disciplines, need for better classroom management, found peer observations valuable No comments made regarding changes regarding issues of diversity
Methods Course Reflections	Described class as student-focused, inquiry-based teaching, instructor as facilitator and felt respected, capable Noted being asked to reflect on their own practice was different Appreciated seeing student work from my own classroom Only methods course that required assignments that were connected to field placement Enjoyed group learning in class Wanted to replicate classroom community "feel" into their new classrooms Wished we had spent some time on long term curricular planning

Summary of Findings: Research Question 4

How do these visions compare with those advocated by reform documents?

The newly qualified teachers' visions of science learning and teaching seemed to reflect the strands of science proficiency articulated in *Taking Science to School: Learning and Teaching Science in Grades K-8* (NRC, 2007). I believe that the strands of scientific proficiency can enrich the work of science educators at all levels, pre-service, induction, and experienced teachers as well as college faculty. In using this framework to look back at the methods course, I hope to provide a look forward into one way in which reform-based teaching efforts can be enacted; also, a look forward into what could be improved upon, and how the strands could be used as a tool for planning, teaching and implementation into and beyond the methods course classroom. The strands could be used as a framework to provide elementary and middle school classrooms with richer and more in-depth science opportunities for all students. In using the strands as an interpretive framework, I found that the nature, duration and distribution of the strands varied in the participants' responses in the assignments and interviews. The examples quoted below all have been presented previously in Chapter 5.

Interpretation of Strands of Science Proficiency in Responses to Assignments

Evidence of the four strands of science proficiency seemed to depend upon the nature of the assignment. As discussed below, I did not perceive Strands 1 and 2 to be represented in responses to Assignment One and Strands 2, 3, and 4 in Assignment Two. However, all four strands seemed to be evident in responses to Assignments Three and

Four. The examples provided are not meant to be all-inclusive but represent data interpreted in more detail in Chapter 5 of this study on pages 347-374.

Assignment One. This assignment was a pre-assessment of the prospective teachers' ideas, attitudes and beliefs about science. Strands 1 and 2 did not seem to be represented in responses to this assignment because the prospective teachers were not accessing or using their prior science knowledge nor generating new science knowledge. They were, however, accessing their prior knowledge in regard to their experiences as learners of science. As reported in Chapter 5 (pages 347-349), the participants' comments are most relevant to Strand 3, *understand the nature and development of scientific knowledge* and to Strand 4, *participate productively in scientific practices and discourse* (NRC, 2007, p. 37), particularly aspects relating to motivation, attitudes, and identity.

Strand 3. The following quote from Participant 11 (Chapter 5, page 349) is representative of comments relevant to Strand 3, about the nature of scientific knowledge: "Although there are certain areas of science that have continued to be proven and supported, there still is ample opportunity for established laws of science to be modified or disproved. This is the beauty of being scientific. Science continues to evolve and progress." This comment demonstrates that some of the participants had ideas about science as a way of knowing, and the tentative nature of science knowledge, as they began the course. The students commented on science as a way of knowing. They described science as their relationship with the world around them, science as a means to explain natural phenomena, and as a process. They expressed ideas that science is a certain type of knowledge and has its own uncertainties and explanations. (NRC, 2007, p. 37). These are all aspects of Strand 3.

Strand 4. Several comments demonstrated that the participants had some understanding of what it means to participate in scientific practices and discourse as described in Strand 4. As noted in Chapter 5, page 350, Participant 8, for example, stated that as teachers they should, "Give priority to evidence to generate explanations and engage in "critical discourse" instead of not requiring any response at all." Strand 4 also relates to "*motivation, attitudes, and identity"* (NRC, 2007, p. 195). As noted in Chapter 5, page 351, Participant 7, for example, described science in a positive way: "The key to science is curiosity; it is what drives us to first engage in science as children. We pick up a stone to see what is underneath of it. We have to satiate our curiosity." She went on to identify children's actions with those of adult scientists: "The same curiosity that drove us to pick up that stone in our backyard is the same curiosity that drive adult scientists to continue their path of inquiry throughout their lives and careers." Not all of the participants expressed such sentiments toward science, however. As noted in Chapter 5, page 352, Participant 12 had this comment: "Science was indistinguishable from the mess of general information we learned from boring textbooks and strict teachers who never gave us a chance to do any hands-on learning."

The responses of the participants for the first assignment show that they have had a variety of science learning experiences, which have influenced how they think about science. Both positive and negative attitudes are described, along with some aspects of the nature of science and the development of scientific knowledge.

Assignment Two. In Assignment Two, the participants were to assess the resources, attitudes and practices of science, as they existed in their placement classrooms. The participants were to do this by interviewing the principal, their mentor teacher, and one other teacher at the school. As in Assignment One, this assignment did not lend itself to evidence of Strand 1 because it did not involve the students making connections to prior knowledge or other science ideas, but rather was a way for the participants to get a picture of the status of science in their placement schools. The participants reported a wide variety of practices, attitudes, beliefs and motivations about science.

Strand 2. This strand was evident when faculty members responded to students and described classroom science investigations with a student-centered emphasis and students working independently.

Strand 3. Strand 3 is evident in this assignment in the sense that the participants are trying to understand the *schools' understanding* of the nature and development of scientific knowledge, how science would be enacted. "This strand includes developing a conception of doing science" (NRC, p. 39). As stated in Chapter 5, page 356, Participant 4, for example, described her mentor teacher as having the students keep journals in which "they write about what they are thinking." Other participants noted that a member of the faculty at the placement site described having students record information as a way to generate an explanation or evidence for an investigation, and having students enact science as scientists would.

Strand 4. Participant 15 thought that teachers in her school were incorporating ways of questioning that would nurture the students' development of scientific knowledge. This is evidence of Strand 4, participating productively in scientific discourse. As noted in Chapter 5, page 358, she wrote, "I also like how the teachers ask students questions to get them thinking." She remembered this when she taught her lesson, and tried to implement the same strategy: "My teacher corrected me when a student asked me a question and I answered. The teacher told me, the next time ask them 'Well, what do you think will happen?'" She also watched how her teacher elicited student thinking: "I also heard him asking, "How do you know that?" to encourage the students to explain their thought process." In contrast, Participant 9 found the principal at her site to be straightforward about science and standardized testing: "It is unfortunate, but "science (test results) will not make or break the school."

The participants learned about how teachers engage their students in the nature and development of scientific knowledge (Strand 3), and the attitudes and beliefs that exist. In addition they learned about the motivation and lack of motivation towards participation in scientific practices (Strand 4). This made them aware of the potential issues and struggles they might possibly have to face as science teachers and facilitated the examination of their personal beliefs in comparison to beliefs of faculty at their sites.

Assignment Three. In Assignment Three, the participants chose a lesson to evaluate and rewrite using the 5 E's (engage, explore, explain, elaborate, evaluate). The students had a framework of questions to use when evaluating the lesson. Because I wanted the participants to begin to develop "capacity in pedagogical design" (Forbes & Davis, 2010), I thought that an initial look at curriculum and its possible constraints would help prepare them for the next assignment when they would be choosing and adapting a lesson to teach. Minogue et al. (2010) suggests that illuminating the strands may be helpful to teachers in the design and implementation of science instruction. According to Forbes and Davis (2010), there is not much research on how prospective teachers learn to use science curriculum and materials. In my attempts to identify how the strands were evident in these assignments, I have learned and gained insights on ways to improve my practice and possibly the practice of future teachers of science I may teach. The strands evident in Assignment Three were Strands 1, 2, 3 and 4.

Strand 1. The analysis of a lesson required the participants to be familiar with or learn about the conceptual ideas in the lesson. They needed to know something about their students in order to build on those concepts, or to scaffold those concepts their for elementary students. They also had to use their understanding of the students' science knowledge in order to evaluate the lesson. They had to first understand the "big ideas…to enable learners to construct explanations of natural phenomena" (2007, NRC, p. 39). Participant 6 provides the best example of thinking about a lesson in order to build on student knowledge and make connections to other content areas. As noted in Chapter 4, Table 4.17, she writes, "There is a major assumption that after a brief, 3 paragraph explanation (included with the lesson), that the students will be able to visualize a tsunami." She notes, "Even more, this lesson supposes that children have the previous experience of either being to the ocean and having firsthand experience with the characteristics of a wave." Then she exclaims, "We do, however, live in a state without any coastline!" In addition, she was aware of issues with mathematics knowledge, " There is also an assumption that students will be able to create ratios with regards to the buildings and land area. The assumption is that their math skills are at a high enough level to make those ratios with regards to the buildings and land area." She realizes in her analysis, that if she is to use that lesson she will have to do some adapting and goes to the internet to find a YouTube video of tsunamis.

Strand 2. The participants' comments on ways they will design, modify, or use the investigations with their elementary students show their thinking about designing and carrying out investigations and the many components that are needed to execute that design effectively (NRC, 2007, p.39). This is not a small task. As Crawford (2007) notes, even if pre-service teachers have developed good understandings of reform-based teaching and learning, it is still a challenge to convert that understanding into science teaching practice. Participant 4 believes investigating live specimens will be a motivating opportunity for the students:

> Students will love this activity to observe real ants.

Strand 3. As interpreted in Chapter 4, Table 4.15, Participant 4, for example, discusses student observations and how she will scaffold data collection: "After the students are done observing the ants, as a class we will fill out the I Notice- I Wonder chart on the whiteboard at the front of the class." She envisions further her students' conversations: "They can share what they wrote in their journals with the class, and learn from each other, and at the same time, make sure what they journaled is accurate and complete. They can even add as we go along. "

Str*and 4.* As an example of evidence of Strand 4, (and also Strand 2) Participant 13 notes that some of the practices that are needed to participate in a scientific community will be a part of her lesson. She will adapt the lesson by engaging students in collecting data, analyzing and explaining findings, using data to draw a reasonable conclusion, and sharing results. As noted in Chapter 4, Table 4.15, she writes, "I would add these steps: They will record attempts in a chart. Students will analyze and explain their findings with other students." She also specifies a particular graphic organizer: "Students will be required to make a Venn diagram to compare and contrast with one other salad dressing, and utilize their data charts to draw a reasonable conclusion." She acknowledges the importance of discourse by continuing: "Students will share their ideas with the class."

Although the importance of providing an equitable learning environment for diverse groups of students is not specifically mentioned in the description of the strands, it was a topic of importance to the committee. The strands hope to provide a framework for science education that can be used to teach science to all. The committee in Conclusion 6 make clear that students from diverse backgrounds (cultural, linguistic, socio-economic) have both strengths and needs that must be attended to in the science classroom (NRC, 2007, p. 340). In the framework of questions provided for this assignment (Chapter 4, p. 156) the students were asked to evaluate the lesson for assumptions about their lesson. Their focus seemed to be on Strand 1, the conceptual ideas of the lesson, and understanding the learner largely ignored.

Assignment 4. Assignment 4 involved the synthesis of the other three assignments. This assignment is discussed in detail on pages 179-214 of Chapter 4.   The participants had to design and implement a science lesson of their choosing in their science placement. Opportunities for prospective teachers to practice teaching in placement classrooms is a critical aspect of their learning to teach in reform based ways. In addition to the fact that these opportunities are not inherent in all methods courses, even when the opportunities are presented, there are obstacles to their successful execution. Forbes & Davis (2010) and Abell & Bryan (1997) have noted that prospective teachers often do not have substantial opportunities to implement and practice science lessons in elementary classrooms. Forbes and Davis (2010) also noted that often when prospective teachers do attempt to enact science as inquiry lessons they face resistance to it. McGinnis, Parker and Graeber (2004) found that sometimes school cultures present obstacles to new teachers, even those trained in reform-based practices. Windschitl (2003) reported that often for pre-service teachers, there are constraints that are related to being in another teacher's classroom or in novel situations. This was true for the participants in this study. Two of the participants had to conduct their lesson at recess time and another had to conduct her lesson in a conference room in the office of the school.

During the teaching of this lesson, the participants were observed by a peer, and then reflected on the lesson individually, and later with the peer observer. It is not unusual for all of the strands to be evident in this assignment because it included the actual teaching of the lesson.

Strand 1. Participant 5 shares a wonderful example of students applying something they learned to a new situation. This is evidence of Strand 1: "know, use and interpret scientific explanations of the natural world," (NRC, 2007). As noted in Chapter 4, Table 4.20, she writes: "I wanted to assess the students' prior knowledge, so I encouraged them to talk about what they knew about fingerprints." Next she provides some specifics: "I did this by listening to their comments on the shapes they saw on their fingertips and later by reading the journal entry they wrote when identifying their own pattern." Then she assessed what happened: "Students were successful in learning this lesson; they told me fingerprints are used in everyday life to identify people." Finally she comments on an unanticipated application: “They believed that maybe animals would have different prints too.”

Strand 2. Strand 2 includes a “wide range of practices involved in designing and carrying out a scientific investigation” (2007, NRC, p. 39). The participants created “driving questions” (Krajcik et al., 2003) for their lesson and designed methods to study their question by collecting and analyzing of data. Participants 5 and 11 had driving questions related to the content of their lessons as the focus of their inquiries into their own practices. Participant 5, for example, as noted in Chapter 5, page 368, asked, “Would students be able to identify their ridge patterns by themselves?” Participant 11, in Chapter 4, Table 4.18, questioned: “Will this inquiry experience lead to a solid grasp on the basic physical traits of Earth?” In addition, the experiences the participants designed for their students included practices in carrying out experiments, including collecting data, making systematic observations, and using the data to explain their results. An issue with their teaching experience was that it was a one-time occurrence, and often a very limited amount of time, so that their ability to fully explore the topic of the investigations with the elementary students was limited.

Strand 3. Strand 3 goes beyond understanding only the nature of science to “a conception of doing science that extends beyond the experiment” (2007, NRC, p. 39). Strand 3 involves thinking about thinking. Participant 15 demonstrated Strand 3 as shown in Chapter 4, Table 4.24, when she began to question her results and ask about alternate explanations: ” I don’t know if my questions really promote higher order thinking though. I know I asked plenty of questions but I’m having a hard time deciding if that is really what I was going for or not." She then pondered, "Is there another way to think about it?"

Strand 4. The participants' reflections on their lessons showed evidence of Strand 4, participating productively in scientific practices, or thinking about how to improve upon it, and generating new questions to ask. They reflected in collaboration with their peers. Participant 2 notes, as shown in Chapter 5 page 371, that she could have improved in her lesson with respect to modeling the scientific practices involving classification: "I could have been more thorough in explaining why scientists classify things and how they (the children) are scientists themselves." She suggests ways to engage the children more: "I could have also encouraged the students to get up and walk around to see how other students classified their buttons instead of going around the table and explaining (seated)." She also recognizes the importance of writing, as shown in Chapter 4, Table 4.23: "I could have incorporated a writing component by asking the students to list all the ways there are to classify buttons but I do not know if time would have allowed this."

One would hope that during a science learning experience that all four strands of scientific proficiency would be evident. This was in fact the case, although for each participant the strands were evident in varying degrees. The nature of the investigation and the limitations imposed by the school setting were factors that influenced their activities. All of the participants considered lessons that could be conducted and understood at least in part in one lesson. None of them found science instruction to be a consistent practice in their placement classrooms so there was not a unit, or series of lessons that they could plug into for this practice lesson. All of the participants incorporated reform-based strategies and approaches into the teaching of this lesson despite other impediments they encountered.

Summary of Interpretation of Strands of Scientific Proficiency in Assignments

Throughout these four assignments, the strands were evident but not equally in every assignment. Partly this is due to the nature of the assignments and partly due to the way in which I interpreted the strands. Another researcher might interpret these data in different ways. The interconnectedness of the strands does make it difficult to ascribe specific criteria to each one. My results were similar to those of Minogue (2010) in that "the nature, duration, and distribution" of the strands varied, although the application was different.

The following table is a summary of the interpretation of strands of science proficiency in responses to assignments.

Table 6.5

Interpretation of Strands of Science Proficiency in Responses to Assignments

Assignment	Strand	Evidence
Assignment 1	Strand 3	Some of the participants had ideas about science as a way of knowing; science is a certain type of knowledge and has its own uncertainties and explanations.
	Strand 4	The participants had some understanding of what it means to participate in scientific practices and discourse, both positive and negative attitudes are described

Assignment 2	Strand 2	One faculty member responded with description of his classroom that included the ideas of science investigations, a student-centered emphasis, and students working in small groups.
	Strand 3	Participants noted that a member of the faculty at the placement site described having students record information as a way to generate an explanation or evidence for an investigation, and having students enact science as scientists would.
	Strand 4	One faculty member shared a strategy for having students participate in discourse by not telling the answer but using questioning to facilitate student learning.
Assignment 3	Strand 1	The analysis of a lesson required the participants to be familiar with or learn about the conceptual ideas in the lesson. They needed to know something about their students in order to build on those concepts, or to scaffold those concepts their for elementary students.
	Strand 2	The participants' comments on ways they will design, modify, or use the investigations with their elementary students show their thinking about designing and carrying out investigations.
	Strand 3	Participant 4 envisions her students recording information

		in their journals and using that information to contribute to the discussion in the class. Her students will be generating and evaluating their own and others' evidence.
	Strand 4	Participant 13 will adapt the lesson by engaging students in collecting data, analyzing and explaining findings, using data to draw a reasonable conclusion, and sharing results.
Assignment 4	Strand 1	Participant 5 was excited when her students asked if animal paw prints were as unique as human fingerprints, showing they understood and could apply the concept to a new situation.
	Strand 2	The opportunities the participants designed for their students included carrying out experiments - collecting data, making systematic observations, and using the data to explain their results.
	Strand 3	Participant 15 began to question her results and ask about alternate explanations, when reflecting on her lesson
	Strand 4	The participants believed their students participated productively in science as they did in reflecting in collaboration with their peers on their lessons, and considering ways to improve and new questions to ask.

Interpretation of Interviews by Strand

This summary discusses the participants' responses to interview questions that seemed to show evidence of each strand of science proficiency. The participants were interviewed more than six months after the methods course. I was interested to see what visions or ideas, if any, they retained about reform-based science teaching and learning. Table 5.3 summarized the interpretations of the interviews by strand. Details are provided in Chapter 5, pages 391-416.

Strand 1: ***Know, use, and interpret scientific explanations of the natural world*** (NRC, 2007, p. 37). For evidence of Strand 1, I looked for examples of building upon prior knowledge. Additionally, if there were connections made between concepts and/or prior knowledge, or if concepts were applied to a new situation, I considered the comment to be related to Strand 1. Participant 5, for example, emphasizes the importance of accessing prior knowledge to use as a foundation for new learning. As shown in Chapter 5, page 393 she says: "I will probably ask them what they know that's relate-able, I will go one step back all the time, what do you know of this? And we are learning this, so could you tell me about what you know." She is aware of the need for more than asking, that listening is important: "Listening to them about what they know already and its connection to what they are going to learn. To find out the basic knowledge that they have, because if you don't have that knowledge, then you will have to teach that (the basics) first."

In *Taking Science to School* (NRC, 2007), research documented that prior knowledge is an important influence on many areas of science learning. Participant 5 recognizes that as a teacher understanding what her students “bring to the table,” will influence both her approach to teaching (where to start) and their learning. The understanding that a beginning teacher recognizes the need for finding out about the ideas and background knowledge is also documented in research by Davis et al. (2006) and Abell, Bryan, and Anderson (1998).

Strand 2: ***Generate and evaluate scientific evidence and explanations.*** This includes: *the knowledge and skills needed to build and refine models based on evidence* (NRC, 2007, p. 37). Participant 7 had the best example of implementing Strand 2. Building from a previous investigation, Participant 7 described how he facilitated his students’ design of a new investigation based on an experiment they had just finished - building a propeller car, and enriched their conceptual knowledge, although the curriculum did not include this extension. This was a lesson he implemented during his student teaching. He described it as rather impromptu, an idea he came up with “on the fly” to put some more “meat” into the lesson. Once the students had built the propeller cars, he asked them to design the cheapest car that would still travel three feet. This showed him that the students in fact did possess the knowledge and skills needed to refine their models, some with more success than others. Other participants discussed the processes involved in generating scientific evidence and evaluations, such as accurate collection of data, and evidence based conclusions.

Strand 3: ***Understand the nature and development of scientific knowledge****.* (NRC, 2007, p. 37). Strand 3, according to *Taking Science to School* (NRC, 2007), includes thinking about science that is not limited to just doing the experiment. Considering other interpretations of data or evidence and viewing one’s own data as possible is emphasized as well. Participant 6 shows understanding of this idea through the following example from Chapter 5, page 400: “And if two groups doing an experiment get different results? Well that’s good, that will be good, that’s going to happen in every experiment and if they do it a third time we’ll get different data again.” She muses about what she would do next, “Just talking about, I think I would bring up the idea of experimental error and uh, just what outside variables affected this experiment” and provides some possibilities “other than you know, did the same person water everyday, if we’re still talking about plants or does it, you know what I mean like if we were measuring – yeah measuring is a good example.” She specifies another example: “Exactly, and if it was the same person do we know for a fact that he did this much and just talking about areas of error that as humans that we’re going to have,” and states the essential question: “Which results ‘count?’”

Strand 4: ***Participate productively in scientific practices and discourse*** (NRC, 2007, p. 37). Participating in science practice and discourse, and being motivated, with a good attitude, or an ability to identify with being part of a scientific community are all components of Stand 4. Krajcik et al. (2003) and Pearce (1999) describe these kinds of communities of learners in the classroom. Students enact science in ways that are representative of scientists. Participant 3 gives a glimpse of this kind of community when she explains that learning in science is related to the building of ideas from discussions in science. She begins with a statement of her beliefs (Chapter 5, p. 276): “There is more learning in the classroom when the kids share ideas and work together. When they can talk with each other or maybe with other groups who got a different answer, they learn more.” She next qualifies this: “Even if they have a debate about it, and they have to explain to each other how they are thinking, whether or not the debate is resolved, both sides have learned something**.”** She describes a least case: **“**Even sharing their prior knowledge might help them understand a new concept” and provides an example: “If I have never been to the ocean and you have and we are studying water, you can tell me that the water from the ocean tastes salty, and I can relate to that.” She then generalizes with a statement of her beliefs (p. 276), “I think really most of our learning is social but in science, in science especially, people are always building off each other’s ideas.”

Summary of Interpretation of Interviews by Strand

The interviews with participants demonstrate that they have remembered key components of reform-based ideas. They articulated visions of science learning and teaching that exemplify reform as described by the strands. Participant 7 was fortunate that in one of his placements science was taught, (although not regularly). As a result of that he was able to engage the students in science learning experiences in addition to the lesson he did for the methods course. In his description of that lesson, he shows that he applied a reform-based approach to a science learning experience. As reported by Crawford (2007) it is possible for prospective and newly qualified teachers to implement reform-based learning opportunities for their students. Looking at the data in relation to the strands of scientific proficiency, as they were evident in interviews about this methods course, has made me think more deeply about my role as a teacher educator and the decisions I make as a facilitator of learning. Duschl (2008) explains that the strands of scientific proficiencies are a shift in focus for science education, going from the “what” of science teaching to the “how and why” of science teaching. I think that I could probably design a more effective methods course using the strands as the framework in the design and delivery of reform-based science instruction. Additionally studies like that of Smith (2009), which gives a case study example of the strands of science proficiencies in a first grade classroom, would provide models to help elucidate how the strands work for prospective teachers and could be used to help teachers begin to design their own lessons.

Comparison with Goals of the Maryland Collaborative for Teacher Preparation Program

As a graduate of the Maryland Collaborative for Teacher Preparation (MCTP) program, it is not a surprise for me to find that I have incorporated many of the goals and practices of the program into my own methods course. In this section, I consider ways in which my intent in the methods course reflects the goals of the MCTP program. Relevant examples of the participants' perceptions of the course are quoted briefly here, drawn from responses reported in the sections interpreting the assignments and the interviews, particularly from the section *The Methods Course: Participant Reflections* in Chapter 5, pages 316-344.

The first aim of MCTP as articulated in the report *Journey of Transformation* (Gardner & Ayers, 1996) "was to help prospective teachers develop a confident understanding of the fundamental concepts, principles and reasoning processes at the heart of science and mathematics, especially those that underlie the school curriculum" (p. 6). The MCTP program included reform-based undergraduate science and mathematics courses that provided the types of intense physics learning experiences that I have described earlier (see Chapter 4, pp. 76-78; this chapter pp. 417-418). Such science and mathematics courses do not seem to have been available to my students. However, I worked hard to create opportunities for them to revel in learning science as I had. Reasoning processes were definitely highlighted, although we did not go into depth in any one area of science. The participants expressed confidence in their own abilities to find the resources necessary to understand the concepts for science lessons they would provide.

The second aim of the MCTP project was to move from a didactic, lecture mode of instruction to "learning environments in which students could actively investigate problems that help them construct personal understanding of key ideas" (Gardner & Ayers, 1996, p. 6). My ultimate goal was to re-create the environment I had experienced. The learning environment in the course was one in which the students investigated problems. As instructor, I facilitated their understanding of the key ideas through questioning. As noted in Chapter 5, page 321, in response to *question 1* in the interviews, for example, Participant 5 described the course as follows:

> In everything we did, in every class, we always started with an experiment, and then you had us think about that and be curious about what we were doing, and about the things that were happening. You picked your materials, all of the students were in teams and we all participated, and you made us very curious, I don't know how to say it – but we had to find out. Inquiry learning. Science as cooperative learning, reflection, teacher walking around, and questioning are the best practices I saw.

This was the most succinct description of the course produced during the interviews although others echoed these aspects if a variety of ways.

In addition to the two general aims described above, the MCTP report identified six program goals. The first was to "Introduce students into standards-based models of mathematics and science instruction" (Gardner & Ayers, 1996, p. 9). In addition to providing information about standards through current documents and expert articles, (AAAS, 1993; NRC, 1996, 2000), I attempted to model such instruction. As noted in Chapter 5, page 319, Participant 2, for example, said, "We had to work in small groups and we had discussions and you asked questions – most of what you did was what we should do when we teach science."

The second MCTP program goal was "To provide courses and field experiences that integrate mathematics and science" (Gardner & Ayers, 1996, p. 9). One of the objectives of the methods course was to make explicit the ideas of integrating other content areas into science. Participant comments about integration in the course are included in Chapter 4, Tables 4.10, 4.14, 4.15, 4.19, and 4.22. For Assignment 4, for example, Participant 3 wrote, "Students can use books or the Internet to research to incorporate reading, and the multiple writing sections of the lesson require the inclusion of that second language arts area. Measurements and observations that take place pull in mathematics skills the students already possess " (see Table 4.19).

The third MCTP program goal was "Provide internships that involve genuine research activities" (Gardner & Ayers, 1996, p. 9). There were no internships connected with the methods course.

The fourth MCTP program goal was "Develop the participants' ability to use computers as standard tools for research and problem solving as well as for imaginative classroom instruction (through training on how to incorporate calculators, microcomputerand calculator-based laboratories and the use Internet into their instructional practices)" (Gardner & Ayers, 1996, p.9). Our class met in a computer lab, where each participant had the use of a laptop. The participants did not use calculators or microcomputer-based laboratories in the course as that equipment was not available to me. However, they used the Internet to find resources, websites, and video clips for the lessons they taught to their students, and each participant created a web-based portfolio as part of the methods experience (van Zee & Roberts, 2006). See also Chapter 4, Tables 4.10, 4.14, 4.15, 4.19, and 4.22. The case study in Chapter 4 (pp. 219-244) presents in detail the experience of one of the participants in constructing her web-based portfolio with the free software the KEEP TOOLkit. In her last reflection, she wrote, "It is amazing how much your thinking can change over the course of a semester. Working on the KEEP TOOLkit has given me a chance to look back over my old reflections and see how my thinking has grown."

The fifth MCTP program goal was "Prepare prospective teachers to deal effectively with the diversity of students in public schools today" (Gardner & Ayers, 1996, p.9). The students read articles about teaching students in diverse communities (McGinnis, 2000; Roberts, 1999) and saw and discussed videotapes that dealt with diversity topics. Comments from some of the students demonstrate that this was not effectively accomplished. See Chapter 4, Table 17. In evaluating a lesson plan for Assignment 3, for example, one participant chose not to comment on the explicitly required factors and wrote, "Additionally, factors such as physical ability, special needs, giftedness, race, ethnicity, culture, gender, and socioeconomic status do not play a role in the activity; one student will not have an advantage over another and therefore everyone will be able to participate in the activity and explore nature at the same pace."

The sixth program MCTP goal was "Provide graduates with placement assistance and sustained support during the critical first years of their teaching careers" (Gardner & Ayers, 1996, p.9). Although I had no responsibility or way to help students with placements into classrooms, I wrote recommendations when asked and have maintained contact with some participants, sharing classroom resources whenever I can.

The following table summarizes this comparison of methods course with the goals of the Maryland collaborative for teacher preparation program.

Table 6.6

Comparison with Goals of the Maryland Collaborative for Teacher Preparation Program

MCTP Program Goals	Methods course example
Introduce students into standards-based models of mathematics and science instruction	As the instructor I used standards based models of science instruction. Students posed questions, worked collaboratively, carried out authentic investigations, generated and evaluated evidence and discussed and debated conclusions.
Provide courses and field experiences that integrate mathematics and science	The concept of integrating science across all of the content areas, in *authentic* ways, was emphasized during this course
Provide internships that involve genuine research activities	No internships were provided
Develop the participants' ability to use computers as standard tools for research	The participants used the Internet to find resources, websites, and video clips for the

and problem solving as well as for imaginative classroom instruction	lesson they taught to their students, and each participant created a web-based portfolio as part of the methods experience, which Participant 3 later described as something she might use with her future students
Prepare prospective teachers to deal effectively with the diversity of students in public schools today	The students read articles about teaching students in diverse communities and saw and discussed videotapes that dealt with diversity topics. Comments from some of the students demonstrate that this was not effectively accomplished.
Provide graduates with placement assistance and sustained support during the critical first years of their teaching careers	Although I had no responsibility or way to help students with placements into classrooms, I wrote recommendations when asked and have maintained contact with some participants, sharing classroom resources whenever I can.

Comparison of Methods Course to Orientations Articulated in the Literature

Abell and Bryan (1997) describe orientations to science teaching and learning as the conceptual map teachers use that incorporates their beliefs and knowledge about teaching and learning. These authors describe four different orientations to science teaching methods courses. A topics orientation addresses a particular topic such as problem solving, or children's ideas each week of class, and moves through the topics, one by one with the goal of addressing comprehensively the teaching of science subject matter. In the process skills orientation, each week's activity addresses one particular process skill, which has as its goal the development of understanding and implementation of this approach to teaching. The third orientation, the activities orientation, is developed for the methods students to experience a different activity every week as if they were elementary students so that they become confident in teaching science and leave with a collection of activities. The fourth orientation is the reflection orientation:

> The reflection orientation is characterized by asking students to describe their ideas, beliefs, and values about science teaching and learning and by offering experiences that help them clarify, confront, and possibly change their personal theories (Abell & Bryan, 1997, p. 154).

According to these authors, pre-service teachers need a variety of opportunities and contexts in which to think about and refine their philosophies of science teaching and learning.

Abell and Bryan (1997) designed their course with the reflection orientation. This design included four contexts for reflection (p. 155). Prospective teachers:

- reflect on others teaching via integrated media cases of conceptual change science teaching;
- reflect on their own teaching via field experiences in a partner school;
- reflect on expert opinions via course readings;

• reflect on themselves as science learners via participation in science learning activities

A cursory glance at the description of the methods course I taught may give the impression that it was designed with the process skill orientation, or the activities orientation, because of the focus on doing science activities every week but my intent and vision embraces the reflection orientation. Although we talked about process skills and the nature of science through the activities, we also discussed content. The class participants were never expected to experience the activities as if they were elementary students but instead as if they were scientists.

Next I look at each of the contexts of the reflection orientation as described above and map them to the design of my course. The first context, "reflecting on others' teaching via integrated media cases of conceptual change science teaching" (Abell & Bryan, 1997, p. 155) was consistent throughout the course with a focus on science teaching for diverse learners. Video case studies included those of an ELL instructor, special educators working in collaboration with science teachers, and elementary science teachers with diverse groups of students. The focus was not to bring about conceptual change in their ideas in science but rather conceptual change in the participants' beliefs and understanding of what it means to teach diverse learners. Classroom discussion and reflection followed each of these case studies and the participants were encouraged to implement the ideas and strategies in their field experiences.

The second context, "reflect on their own teaching via field experiences in a partner school" (Abell & Bryan, 1997, p. 155) was integrated into the course from the very beginning. Although I learned from the participants and the other science teaching methods instructor that utilizing the placement setting for assignments was not a common practice in other methods courses at this institution, I insisted on this. I required the participants to investigate the status of science at their placement sites and to plan and conduct a science investigation with a group of students at their school. They joined with another participant from their class to do peer observations of each other as they conducted the lessons. Both parties reflected on the lesson taught and shared their reflections. Each participant wrote his or her own reflection of the teaching experience as well as of the peer observation experience. Additionally, their final was a multimedia portfolio synthesizing their learning from the class, which is an additional piece of reflecting on the assignments, activities, discussions and experiences they had in the class.

The third context of the reflection orientation is to "reflect on expert opinions via course readings" (Abell & Bryan, 1997, p. 155). Each week, on a rotating basis, participants were responsible for summarizing expert articles they read and the chapter of the text. In addition, they were to develop questions from these texts and facilitate a class discussion. Those not responsible for the readings were expected to read and highlight ideas that were of particular interest or concern to them. Through discussion, and often through the next weekly reflection, their thoughts and ideas were shared and debated with others. Through these discussions and reflections, participants' ideas and beliefs about science teaching and learning were challenged, questioned, and refined.

The fourth context for reflection in this mode is to "reflect on themselves as science learners via participation in science learning activities" (Abell & Bryan, 1997, p. 155). This was evident in their weekly reflections and in their interviews after the course.

Participant 4, in particular, expressed attitudes about science that were not very positive at the beginning of the course. She told me in a personal conversation that she did not really think she was a science person and to please be patient with her, she would try her best. When I interviewed her, after the methods course, she remembered this from the second week of the class as recorded in Chapter 5, page 330.

> But in science, like with the apple one, it was like – what does an apple have to do with anything? But then I learned about it, and it was like cool! The activities that we did were learning, real science learning, and I don't think they were activities I could have just read about.

As noted in Chapter 5, page 340, and a year later, she sent me this note in an email:

> I had a funny moment in one of my orientations the other day when the presenter asked if anyone was interested in teaching science and against all of my prior preconceptions, I raised my hand. I do not know if you know how much you and your class really impacted my life and changed my view about learning AND teaching and using science in the classroom. I now see how it is such an integral and fun part of learning for me and so vital for our students' success. Thank you for opening my eyes to this; your class was the most beneficial to me out of all of my other graduate courses.

In looking back at the methods course, the influences of learning to teach in a reform-based program, and being a reflective practitioner seem to have had am impact on what took place in this course.

The following table is a summary of the comparison of the methods course to the reflection orientation.

Table 6.7

Comparison of Methods Course to Reflection Orientation (Abell & Bryan, 1997)

In Abell and Bryan's course (1997), prospective teachers:	In my methods course, prospective teachers:
Reflected on others teaching via integrated media cases	Watched and discussed video cases of science learning and teaching for diverse learners
Reflected on their own teaching via field experiences	Carried out assignments in their field placements and peer observations of teaching
Reflected on expert opinions via course readings	Took turns facilitating discussions based on course readings through summarizing and questioning
Reflected on themselves as science learners via science learning activities	Some of the participants changed their beliefs about themselves and their abilities as science learners and teachers.

Comparison of the Methods Course with Calls for Research

van Zee, Long & Windschitl, (2009) note that pre-service science teachers have few experiences in learning through an inquiry-based model as described in the *National*

Science Education Standards (NRC, 1996). The science methods course is often the first experience novice teachers have to experience reform-based approaches to learning. These authors state that research on science teaching methods courses is important in order to document ways in which methods course instructors are attempting to implement reform-based approaches. They propose that research on these courses can inform the field in ways that will help methods course instructors improve instruction and enhance students' opportunities to learn science.

Although the van Zee et al. (2009) chapter focused on secondary science teaching methods courses, these same premises should apply to elementary teacher education programs as well. Sharing the ideas, influences, experiences and interpretations of my own methods course is a way to illustrate one such course, albeit a very short-term research project, in a very specific context.

By documenting my own teaching practices, and the decisions made about assignments and structure of the learning during the class, I am making the design of the methods course and the reason for the design choices explicit. According to van Zee et al. (2009), this can provide information to the field, and be helpful to both new and experienced instructors who are interested in improving the teaching and learning of science. Designing methods courses to include ways in which reflection is fostered for prospective teachers is noted. The experiences that influenced my design of the course, including the inclusion of reflection on learning and reflection on practice, come from a reform-based model at the undergraduate level, graduate level courses where the same philosophy was enacted, and includes my experiences as a Carnegie scholar, and as a member of the National Research Council's *Committee on Science Learning,* *Kindergarten through Grade Eight.* This study attempts to make those influences visible.

Looking at research that investigates the learning of prospective teachers so that improvements to instruction can be made is another issue raised by the authors. Important is building capacity in prospective teachers to engage in scientific inquiry themselves, so that they will better understand how to nurture their students through inquiry (van Zee et al., 2009). Through the interpretation of the data from the student assignments, reflections, activities and interview data, I have attempted to share the learning of the participants in the methods course and reform-based ways in which those learning experiences were constructed. I have also included an interpretation of the participants' preconceptions about science and the nature of science, which help document changes in those ideas during the course.

Through the review of data related to Assignment 4, and the teacher interviews, I have also responded for the call for research to document ways in which field experiences link to the methods course. It would have been better if more of those connections had taken place. One teaching experience does not provide sufficient practice for prospective teachers or an abundance of data to examine.

van Zee et al. (2009) also maintain "Research is needed to help methods course instructors envision and model the student-centred instruction advocated in reform documents" (p. 7). The model for teaching this course was intentionally student-centred instruction. My role in the methods course was that of facilitator, poser of questions, and reflective practitioner. I designed activities to engage the prospective teachers to create scientific explanations for those investigations and to debate about the results of investigations, as well as opportunities for them to test and re-test their hypotheses. My intention was to model a shift in teaching approaches from that of lectures, or teacher-directed to a student-centred approach, which includes engaging the students in scientific inquiry. This was a vision of science teaching and learning that I hoped prospective teachers would use in their new classrooms. The data illustrate ways in which they enacted this approach when they planned and taught a lesson in their placement classrooms. A follow up study would be needed to document what has happened in the classrooms where they began to teach.

Describing and interpreting data from assignments the participants completed in their field placements have documented another call for research from the authors of this chapter. There were two assignments and several reflections that the participants undertook at the placement setting. Although this connection between methods and field placement is atypical for methods' courses in this setting, a relationship does exist between the university and the schools in which the students were placed. The students were not required to do any assignments in their placement settings by other methods course instructors not did the other science methods instructor require that of her students. An ideal situation would be for a more formal connection with collaboration from teachers at the school site, prospective teachers, and methods instructors.

The authors claim "Every instructor who teaches a methods course can contribute to the research literature by documenting how and what the prospective teachers are learning" (van Zee et al. 2009, p. 9). This study attempted to give a detailed account of one instructor's efforts to implement reform-based approaches and make those apparent by identifying the participants' views through interpreting data from interviews assignments and reflections, both by theme and by the strands of scientific proficiency articulated in *Taking Science to School: Learning and Teaching Science in Grades K-8* (NRC, 2007).

The following table summarizes comparison of the method course with calls for research.

Table 6.8

Comparison of the Methods Course to Calls for Research

Calls for Research to:	Example from Methods Course:
Document ways in which instructors implement reform-based approaches	Sharing the ideas, influences, experiences and interpretations of my own methods course is a way to illustrate one such course
Frameworks and design of course	Documenting my own teaching practices, decisions made about assignments and structure of the learning during the class, and the influences of prior experience on those decisions, make the design explicit
Investigate prospective teacher learning	Through data from the student assignments, reflections, activities and interview data, I have attempted to share the learning of the participants in the methods course
Document links to field experiences	Participants' assignments related to field placement events and interview data

	document these links
Help methods course instructors envision and model the student-centred instruction advocated in reform documents	My intention was to model a shift in teaching approaches from teacher-directed to student-centred, engaging the students in scientific inquiry

Comparison of Methods Course to Recommendations for Professional Development

In thinking about the methods course as the beginning of the professional development spectrum as Davis et al. (2006) suggested, I compared the methods course from my interpretation and that of the students to recommendations by Garet (2001) and other professional development researchers. The key features of professional development could provide information for methods course instructors to consider, especially if a change in teacher learning is the goal. Garet (2001) analyzed a set of rigorous studies that were conducted to investigate this connection. Many of studies that examine research-based professional development were focused on the areas of elementary mathematics, science, and literacy. Garet (2001) found that there were six key principles that were most often associated with changes in teacher learning. These are listed below:

(1) focus on content and pedagogical knowledge,

(2) reform-type activities,

(3) relevance of activities to teacher needs,

(4) opportunities for active learning,

(5) extensive duration, and

(6) collective participation (p.1196).

Some of these principles I believe were evident in the methods course. The first principle focuses on content and pedagogical knowledge. Loucks-Horsley et al. (1998) and Elmore (2002) found this to be an important criterion as well. First each activity was conducted in a way to demonstrate or model a reform-based pedagogy that is specific to science education (Gardner & Ayers, 1998; McGinnis et. al, 2004). Developing pedagogical content knowledge is important because the teacher must not only understand the content, but as Shulman (1986) stated the teacher must understand, "the ways of representing and formulating the subject that makes it comprehensible to others" (p.7). Each of the activities was related to content. However, there was not a theme or a continuous strand of content that was developed through the activities. Because elementary teachers are generalists in science, it is difficult to follow a particular area of science such as physics or biology. In reflecting on this, however, it would have been better to have had some kind of connection between the activities or perhaps an overarching theme, as van Zee (1998) who develops understandings about the nature of science by having prospective teachers do daily observations of the moon and develop a causal explanation for the moon's phases throughout the course.

The second principle is that reform-based activities contribute to sustaining changes in teacher learning. This is also a recommendation of *Taking Science to School* (NRC, 2007), that university-based science courses for teacher candidates' ongoing professional development opportunities should include all four strands of science proficiencies and give attention to the core ideas in the curriculum. I believe that all of the activities in the course were reform-based. In interpreting the assignments and activities in Chapter 5 (pp. 346-386), I found all of the strands of science proficiencies were evident, in varying degrees in assignments and in classroom activities. The use and consistency of use of the strands, as well as the intertwining of the strands could have done more thoroughly, if I had begun the course using the strands as a framework. Smith, et al. (2009) did a thorough implementation in using the strands to build upon each other, but their unit of study was planned to do just that.

The third principle discusses the relevance of the activities to teacher needs. *Taking Science to School* (NRC, 2007) also recommends this criterion and that focus should be on the strengths and needs of learners in their setting along with evidence about what works drawn from research and clinical experience. In a methods course, prospective teachers' needs are often greater than those of a classroom teacher, especially if practice teaching of science in a field placement is required during this course. As one is beginning to learn what reform-based instruction is, learning the content and pedagogy of science, focusing on strengths and being sensitive to needs is important. This was accomplished through the methods course, although limited in depth, and in duration. A constraint of the methods class was that the participants were in a student teaching assignment, not in their own classrooms, and as Windschitl (2003) also found, their cooperating teachers had some influence over how the participants' teaching of science was enacted. However, these practice teaching experiences provide prospective teachers with what Windschitl refers to as "mental models" (p. 115) of instruction that they can draw upon in envisioning teaching and learning in their own classrooms.

Every class was an opportunity for active learning, as described in the fourth principle. Participants expressed their appreciation of the active learning characteristic of the course. As noted in Chapter 5 (p.330), Participant 5 explains that she looked forward to the class because “what I remember the most, was being excited about going to your class, because it was fun – and we learned science right from the beginning.”

The fifth criteria, extensive duration, was not evident in the methods course. It was a one-semester methods course and there was no plan in place to continue the collaboration through the university. An ideal situation would be to re-envision the methods course as part of a spectrum of teaching and professional development, as Davis et al. (2006) have recommended, and to be able to continue working with and supporting newly qualified teachers as they begin to teach. As a teacher educator, and a classroom teacher, I believe that this kind of support, and continued adherence to these 6 principles, would further the cause of reform-based practices and enhance science education for all students.

Every class was additionally an experience in collaborative participation, as recommended in Principle 6. As noted on page 332 in Chapter 5, Participant 7 refers to this as *community*. “Our class had about twenty people in it, and most of those people were in my other classes, but in science we were a *community* . . . science was more conducive to learning, because of that community. “ Both Loucks-Horsley et al. (1998) *and Taking Science to School* (NRC, 2007) also recommend a collaborative approach and building a community of learners. Abell & Bryan, (1997), Newman, Abell, Hubbard, McDonald, Otaala & Martini (2004), and Davis et al. (2006) all found collaboration and building community an important aspect of teacher learning as well.

As a teacher educator, and a classroom teacher, I believe that this kind of support, and continued adherence to these principles, would further the cause of reform-based practices to enhance the science education for all teachers and for their students. The key ideas from professional development seem to align with reform ideas, and also to be just good teaching strategies. To enact this kind of professional development, starting with the preservice experiences in science content and methods courses and continuing through a teacher's career would be ideal.

The following table provides a summary of the comparison of the methods course to recommendations for professional development.

Table 6.9

Comparison of Methods Course to Recommendations for Professional Development

Principle of Professional Development (Garet, 2001)	Examples from Course
Focus on content and pedagogical knowledge	Each activity was conducted in a way to demonstrate or model a reform-based pedagogy that is specific to science education
Reform-type activities	All of the activities in the course were reform-based. In interpreting the assignments and activities, I found all of the strands of science proficiencies were evident, in varying degrees in assignments and in classroom activities
Relevance of activities to teacher needs	As one is beginning to learn what reform-based instruction is, learning the content and pedagogy of science, there is a need for practice. This occurred in the methods course classroom and in the field placement site, although limited in depth, and in duration.

Opportunities for active learning	Every class was an opportunity for active learning, and again the participants practiced learning through teaching at their placement sites
Extensive duration	Not evident, limited duration
Collective participation	Every class was an experience in collaborative participation.

Potential Value of Methods Courses

Methods courses are sometimes viewed negatively (Grossman, Compton, Igra, Ronfeldt, Shahan, and Williamson, 2009). Some programs, such as The UTeach program at the University of Texas, do not offer courses that are labeled as teaching *methods* at all. However, the UTeach program includes a series of courses that name aspects of reform-based instruction such as "Classroom Interactions" and "Project-Based Instruction" (van Zee, Long & Windschitl, 2009).

According to Davis et al. (2006), however, some studies find there is a relationship between higher teacher self-efficacy and methods classes. Science methods courses can help to promote improved understanding of instruction (McGinnis et al., 2002; van Zee & Roberts, 2001; van Zee, 1998; Zembal-Saul et al., 2000). Methods courses also have documented improved understandings of and attitudes toward science (Abell & Bryan 1997; Bianchini, Johnston, Oram, & Cavazos, 2003; Bryan, 2003, Davis et al., 2006; Luft & Roehrig, 2007; McGinnis, Roth-McDuffie, & Parker, 1999, McGinnis, Kramer, Shama, Graeber, Parker, Watanabe, 2002; Windschitl, 2003). Roehrig and Luft (2006) report that teachers who came from a preservice program that included a second methods course had an improved disposition toward effective science instruction. Concepts and ideas about teaching science that were constructed during the first methods course could be enriched during the second course to foster a deeper understanding of teaching science.

From my perspective, methods courses can provide meaningful learning experiences. Important aspects of learning to teach can be developed through methods courses, as they were in this course. There are key components in a methods course that I believe need to be included. Methods course assignments should be designed in ways that facilitate the prospective teachers envisioning themselves as future teachers of science. Using an inquiry or reform-based approach to teaching the methods course, while at the same time deconstructing the teaching methodology through discussion and reflection can help prospective teachers see how science will look in their future classrooms. Having the prospective teachers pose questions around science activities, work collaboratively in small groups, collect and record data, generate explanations and provide evidence that supports their explanations, and questioning that is used to facilitate learning are necessary for them to develop the vision that will enable them to enact science instruction in a similar way.

Providing prospective teachers with opportunities to teach during the methods course gives them practice in implementing the ideas and theories they are learning about and a safe place to reflect on their experiences. The class needs to foster an environment of a community of learners so that the students can experience a risk-free setting to discuss and try out their ideas. Through this experience they can begin to learn how to create such an environment in their own classrooms. These aspects need to be modeled during the methods course. If the prospective teachers have already experienced reform-based learning and teaching through their content courses, then the learning can be much richer during the methods course.

Methods instructors need to understand their students as learners, just as we ask our prospective teachers to understand the students with whom they will be working. This includes promoting the understanding that not all students are alike. There exist cultural, linguistic, socio-economic, gender, ethnicity, academic and other differences that create opportunities for prospective teachers to learn from their students. The unique strengths and needs of each student need to be considered from the planning and implementation of a lesson all the way to the assessment of the lesson. This is an area that did not seem to be taught well in my methods course, because in evaluating a lesson plan and in their reflections on the teaching of the lesson, only one student made a comment referring to issues of diversity.

Helping prospective teachers to become aware of their beliefs and attitudes about science provides the instructor with valuable information for how to scaffold learning so that they can work through the tensions that sometimes arise when their "old" beliefs and attitudes and their new ideas of learning and teaching conflict. As documented previously in Chapter 4, pages 221-244, in the summary of the reflections and multi-media final of Participant 16, there was a profound change in attitude from the beginning to the end of the course. She was not alone in this change in attitude; others recognized a change in themselves as well. Some of the participants, as Participant 16, describe becoming agents of change and working to ensure that science gets taught in their classrooms.

The integration of other disciplines with science was a way the participants believe will help them ensure that science instruction takes place. They described making sure that science gets taught by using science investigations as motivation for reading and for writing. Incorporating science concepts in mathematics and mathematics during science are also important. Some participants even described ways to integrate art into their science lessons in authentic ways.

Assignments that are designed to build capacity in the prospective teachers can help them develop the confidence they need to teach science. The participants in this course explained that although they may not know all of the science content that will be related to curriculum they may be asked to teach, they felt both competent and capable in their ability to find the resources necessary and to learn the content to provide meaningful learning for their future students.

In this time of rapid growth in technology, instructors in the 21st century need to integrate authentic applications of technology into their methods course. In the methods course that is the focus of this study, both technology and reflection were combined as the students synthesized the learning in the course through the creation of a multi-media portfolio that was their final assessment for the course.

Using a reflective orientation as described by Abell and Bryan (1997) is a framework that facilitates learning to teach in ways that promote reform-based strategies, culturally responsive teaching, an understanding of each learner, integration of technology and other disciplines to enhance learning, and a disposition for inquiry based learning and teaching.

The methods course is a necessary and logical place for these experiences to take place. It is through these kinds of experiences that prospective teachers can be empowered to provide high quality science instruction that results in improving the achievement of students in science.

Limitations

As a reflective practitioner I am constantly aware that the research is never free from my personal purpose and perspective because I am the researcher and as such have particular biases and view points that are a result of my collective experiences and lenses. Recognizing this, I sought feedback from the participants I interviewed, and from the participant whose reflections and final I analyzed as a case study, to ensure they believed that my interpretation of the data was an accurate and equitable portrayal of their voices. Six of the seven interviewees responded, as did the case study participant. Their comments affirmed my interpretations of their work and responses. A methodological limitation is the messiness of exploring teachers' beliefs and knowledge in the context of one setting. I cannot possibly understand all of the variables involved in the participants' experiences during their field placements or in prior educational settings.

The findings of this study are limited to the particular prospective teachers who gave permission for their writings to be interpreted, including those interviewed, and myself, in one course at a particular site. There is a limitation in the number of participants who were available to participate in the interviews.

Another researcher could view differently from my interpretation the ways the strands of science proficiency were related or not related to the data. Although not generalizable, the results may be useful to instructors who are teaching elementary science methods courses or to others interested in teacher education issues. To show a casual relationship between the influences of the reform-based science teaching methods course from what the participants brought to the course or their visions afterwards was not possible. However, I can see from multiple viewpoints the reflections and perceptions of the newly qualified teachers, as they looked to the future and the visions of themselves as potential teachers of science, that some changes in beliefs and attitudes were evident.

Implications of This Study

The following discussion is a reflection on the implications of this research for issues related to methodology, practice, and policy.

Methodology. As an instructor who engages in self-study (Loughran & Northfield, 1998), I believe that the knowledge and understanding that I gain through carefully investigating my teaching and my students' learning will ultimately benefit my students. As Zeichner (2007) argues, however, self-study research also contributes to broader understanding of issues related to teacher education and policy. He affirms that the knowledge that can be accumulated in self-studies is valuable.

Taking a systematic approach to the collection and interpretation of data is a promising way to further understand issues generated in the context of practice. Some researchers, however, question the value of the knowledge gained because the findings are not based on quantitative techniques (Zeichner, 2007). Some question the ethics of teacher research when the teacher is considered to be also the researcher (Cochran-Smith and Lytle, 1999, p.11). For the classroom teacher, lack of time, lack of resources and the perceptions and attitudes of others to the research also may be constraining factors.

Below, I discuss issues of validity, transferability and taking an inquiry stance to teaching and learning.

Issues of Validity. To address issues of quality, Andersen, Herr, and Nihlen (1994) offered a set of criteria for evaluating the validity of qualitative practitioner research. In the following table, I compare their criteria to this study.

Table 6.10

Validity in Qualitative Research

Type of validity	How it relates to this study
Democratic validity multiple perspectives of participants in study are accurately represented	All of the participants in the study were sent my interpretations of their responses and student work for verification. Those who responded felt they were accurately represented
Outcome validity - something learned from the study can be applied to a new situation or study	There was much learned from the study of this methods course that will lead to changes in the next course. One example will be an intensified focus on diversity.
Process validity - study has been conducted in a dependable way	I took multiple approaches to examining the data to increase the trustworthiness of the interpretation. The data were analyzed in a systematic and cohesive manner, and validated by the participants in the study.
Catalytic validity - The participants in the	The participants in this study came to

study are moved to take action	understand and to implement aspects of inquiry learning that differ in many cases from those used in their placement classrooms.
Dialogic validity- having a critical conversation with peers about research findings	Throughout the writing of this study drafts were sent to members of the committee for their insight and critical review. When I received feedback, I reflected on that information, and made appropriate changes to the study.

This study has met all five criteria for validity. The multiple perspectives of all the participants were reflected accurately according to the responses to the member check. Although there was no "problem" to be solved but rather understanding to be gained, the study led me to a deeper understanding of issues related to teaching the science methods course and ideas for how to change the next course to improve learning and teaching.

The study was conducted in a dependable way, with multiple sources of data used and multiple approaches to interpretation. The data were interpreted in a systematic way, with care taken to follow well-accepted qualitative research practices. Ways in which participants responded to assignments showed that they were taking responsibility for their own learning and were incorporating into their own practices aspects of the reform-based teaching that was modeled in this methods course.

Through the interview process many of the participants described a vision that included changing the ways their students would experience science, as compared to ways in which they themselves had learned science. Some participants described changes in attitudes and beliefs that informed their visions of how they wanted science teaching and learning to occur in their own classrooms. As I worked through the writing of this study, I sent drafts to participants and asked them to check the accuracy of my interpretations. I also sent drafts to members of my doctoral committee for critical review and acted on feedback received. In addition, I shared the study with other educational colleagues for their perspectives. This critical review process will continue as parts of this study will be submitted for publication.

Transferability. Transferability in this study was achieved according to Guba's (1981) description. As a qualitative researcher engaging in self-study, I understand that my study is limited to its particular context. My goal was not to construct statements of "truth" that could be generalized to larger populations. Instead I collected extensive data and developed detailed descriptions that will allow comparison of my particular context in the methods course to other methods courses. Additionally I used multiple methods of interpreting data to facilitate the understanding and interpretation of data through a variety of perspectives, including that of the participants through member check. According to Guba (1981) overlapping methods of data interpretation increases the dependability and stability of the data interpretation, therefore, enhancing trustworthiness.

Inquiry Stance. As a teacher and an advocate for taking an inquiry stance to teaching and to learning, I believe that first of all, this approach is based in the issues of practice, and in the ways teachers think about, come to understand, and then change practice in regard to those issues having the best interests of the learning and life chances of students as their goal (Cochran-Smith and Lytle, 2009). This work may provide other methods instructors with a deeper understanding of their own practices and facilitate useful changes in future teaching efforts. This work is also the place where one's own practice and theories collide, and may lead to new theories, new learnings and a broader knowledge base for the instructor. For me, the edges between my inquiry and my practice overlap, because the questions continue to evolve with each "answer" that is reached.

It has been the goal of this study to develop and to better articulate knowledge of particular teaching practices as Lee Shulman (1999) described: "A scholarship of teaching that will entail a public account of some or all of the full act of teaching, vision, design, enactment, outcomes, and analysis in a manner susceptible to 'critical review' by the teacher's professional peers, and amenable to productive employment in future work by members of that same community" (p.6). In this study I have described a public account of the full act of the teaching of the methods course. I have shared my visions and the participants' visions of the methods course. The design of the course is described in detail, as is the enactment of the course. The outcomes and interpretation of the course were critically reviewed by participants through member check, by the dissertation committee and other professional colleagues. It is my hope that this work will inform the future work of other teacher educators, as it has informed my own.

Practice. This section discusses aspects of practice that I believe are important. These are: knowing the learner, connecting the methods course to field experiences, facilitating awareness of and attention to issues of diversity and equity, the use of multi-media portfolios, multiple aspects of teaching addressed within the methods course and changes to consider. This is not a comprehensive list, but addresses some of the issues that were evident in this study.

Knowing the learner. The most important aspect of any teaching situation, in my opinion, is to knowing one's students. Finding ways to learn about and understand the individuals in one's classroom provides opportunities for learning to occur for both the teacher and the student. In designing a methods course, providing opportunities for prospective teachers to experience reform-based learning as students and then to implement reform-based learning as a teacher is quintessential. Having authentic science activities that provide both science content and process experiences gives the prospective teachers a model of what inquiry teaching and learning is, as well as scientific problems to explore and ponder.

Connecting the methods course to field experiences. Requiring assignments in the context of field placements is a way to have prospective teachers wrestle with the application of theory to practice. Using peer observation is a tool that is needed as well. Prospective students need opportunities to practice teaching and receiving feedback from those who do not hold an evaluative position. Weekly reflections can help the instructor learn about and understand the individual students, and assess their level of understanding, issues they are struggling with in their placements, and facets of instruction that may need to change during the course.

Facilitating awareness of and attention to issues of diversity and equity. A major goal of the course was for the participants to become culturally responsive teachers. This goes hand in hand with knowing one's learners, but requires openness and a willingness to understand learning from perspectives that may be different from one's own; and then to find ways to include and honor those perspectives in the classroom. The integration of other disciplines into the teaching of science is a way to include the mandated focus on literacy and mathematics while maintaining a place for science in the curriculum.

Multi-media portfolios. Multimedia portfolios can be particularly useful in helping the prospective teachers reflect upon their learning and changes in attitudes and beliefs over the time that they are in a methods course. Synthesizing learning by choosing artifacts and resources from experiences can be beneficial (Glasson and McKenzie, 1999). Documenting the ways in which students learn and the products of their learning is a form of authentic assessment. In having to look through the work for class and to find resources that help portray their own learning, prospective teachers can use technology in meaningful ways related to their learning and their teaching experiences. In a self-study, Zeichner (2007) found e-portfolios to be useful tools for prospective teachers who analyzed artifacts and evidence as a way to document their learning and proficiencies as they worked to meet state licensing standards. The multi-media portfolio becomes an artifact that prospective teachers can use to showcase their learning and their teaching experiences during their field placements in a contemporary way. The portfolio also can demonstrate to prospective teachers that such assessment is possible for elementary students, especially when using free web-building software.

Multiple aspects of teaching addressed within the methods course. I found it necessary to include many aspects of teaching in the science methods course. Learning about reform-based science strategies (the pedagogical content knowledge), science content, diversity, integration, technology and reflecting on practice, are all necessary. Addressing so many aspects of teaching in one course is not typical but these are all aspects of teaching that must be implemented in concert, and it is better to provide an integrated model, rather than have students take separate course in isolation and check them off a list. Making the connections explicit during the methods course will help students see these aspects working together and provide an example they can later employ.

Changes to consider. I would not eliminate any aspect of the methods course as described in this study, but may alter some of those aspects. I still believe strongly in the importance of the weekly activities, the experience of science in action, and the focus on aspects of both the nature of science and content knowledge. I would like to add one overarching semester-long science investigation, like the seeds and eggs unit in Abell and Bryan's (1997) course, or the moon activity from van Zee's (2003) course that students could work on both outside of and during class. I would take a hard look at the four strands of science proficiency and ways to better use them as a guiding framework for the course. I would also make the prospective teachers aware of the four strands of science proficiencies and have them evaluate the science lessons they choose to teach for these four strands. I need to re-evaluate the framework of questions provided for the analysis of a science lesson to ensure that the prospective teachers actually consider issues of equity and diversity in this analysis and in their teaching. I may want to reconsider the focus questions asked on the weekly reflections to emphasize thinking about the unique strengths and differences of elementary students. In the methods course that is the focus of this study, I waited until we were two thirds of the way through to discuss the final in detail. I would like to try introducing the multi-media portfolio sooner to see if that improves the quality and the articulation of learning that occurs. If it were at all possible, I would like to design a second course that follows this course and provides an additional semester of support and learning about the teaching and learning of science, with a teacher research component. The final assessment would be a research conference with each student sharing his/her study with the class and possibly with the students from the first semester (the methods course) class.

Policy. This study has implications for the use of National Research Council documents to guide reform of national, state, and school district standards, the importance of teaching reform-based science content courses early in prospective teachers' college experiences, the need for a coherent, long-term teacher education program, and imperative that science be taught in elementary schools, particularly those serving diverse populations.

Use of national documents to guide reform. For more than two decades, great efforts have been made to review research and to collaborate with multiple stakeholders in order to create documents that advocate reform for the improvement of science learning and teaching (AAAS, 1989, 1993; NRC, 1996, 2007, 2009). These documents have provided frameworks for the planning and development of science and science teacher education courses as well as strategies for practice. Recent documents (NRC, 2007, 2009) articulate reform-based practices in terms of strands of science proficiency: *Strand 1: Know, use and interpret scientific explanations of the natural world; Strand 2: Generate and evaluate scientific evidence and explanations; Strand 3: Understand the* *nature and development of scientific knowledge*; and *Strand 4: Participate productively in scientific practices and discourse.*

Minogue et al. (2010) put the strands of scientific proficiency in a table, with various criteria listed underneath each strand. I appreciate the thoughtful effort put into making the table but this approach is a concern for me because of my experience as a curriculum specialist at the county and state level. Often the deep and complex meanings and understandings of reform get reduced to check lists that schools and districts can use to "validate" their implementation of the reform, when in reality little has changed. In order for these reform-based ideas to make a difference in the science education of students nationally, effort and time need to be put forth to apply this framework holistically. Smith et al. (2010), for example, provide a model that elementary teachers and curriculum specialists could use. However, they invested much time and effort into understanding the research and adapting it to their curricular standards. Detailed documentation of such efforts would facilitate a broader understanding and application of reform-based practices. As school district personnel, teacher educators, and professional organizations attempt to use the strands to guide their programs, they need to share their successes and struggles with others so that all can learn from their process and progress. National and state organizations will need to provide funding in order to ensure that such studies will occur.

Use of reform-based practices in college science courses. Modeling of reform-based practices needs to occur in both science content courses and science methods courses. Instructors of science courses who employ these practices provide a solid, practical foundation that models for prospective teachers the praxis of theory and practice. If prospective teachers have more than one experience, as learners, with reform-based teaching, the implementation of such teaching in their own classes is more readily achieved. Waiting for the last year of a prospective teacher's education program to introduce the idea of inquiry-based science teaching and learning is too little and too late. Bybee, (2000) stated that the evidence shows that inquiry based science teaching as a content or technique is not and has not been enacted in a significant way. Why has this not happened? The modeling of such teaching needs to occur early in the college years, preferably in the freshman year, with continuing opportunities to enroll in reform-based mathematics and science courses during subsequent years. If we as instructors of science courses and methods courses take it upon ourselves to make reform-based teaching the norm rather than the exception, we are more likely to see an increase in reform-based learning and teaching in K-12 schools.

Methods course instructors have noted that there is a noticeable difference between the two groups, prospective teachers who have completed reform-based science and mathematics courses and those who have not (McGinnis, van Zee, personal communications). Prospective teachers who have prior experience with reform -based science teaching and learning in their science and mathematics courses are more likely to understand and value the approach of a reform-based methods class. I was one of the students who learned science in a reform-based course that was part of a program supported by the National Science Foundation, the Maryland Collaborative for Teacher Preparation. This course transformed the way I thought about teaching and learning. I had already decided this was the way I wanted to teach prior to taking the methods course. For me, the methods course was an affirmation of the power of inquiry based learning and teaching. Peers in my undergraduate methods course, however, frequently commented that they did not understand what was going on in class. Although many began to understand by the end of the course, some continued to be puzzled or dismayed. They needed more than a one semester course to understand and value teaching science as inquiry.

Need for coherent long-term teacher education program. There is a need for teacher education programs that include the use of reform-based practices in the science courses, the methods courses and continuing professional development during the induction years. This would provide a solid reform-based foundation for change to occur, not only in the teacher education program but in elementary and middle school classrooms as well.

This kind of coherent long-term program is already being implemented in Japan. Suzuki and van Zee (2003), for example, compared their own teacher education programs, as enacted in Japan and the United States. They found many differences in their respective programs. The collaborative nature of the learning environment in the Japanese program involved the instructor interacting with prospective teachers for all four years of the undergraduate program, while the US instructor was interacting with prospective teachers only during the one semester when they were enrolled in her course. In Japan, the prospective teachers were able to work together in an office near the instructor's lab, but in the US the prospective teachers were not provided a place to collaborate. For the Japanese instructor, there was an increased responsibility for creating and maintaining this learning community. The school experiences also were different for the two programs. The Japanese prospective teachers spent an entire month working full time in a participating school in their junior year, and the US prospective teachers have a full year internship in a cooperating school site as seniors.

Prospective teachers in the United States would benefit from a more collaborative environment and from an extended experience with student teaching and with methods courses, as in the Japanese program. Roehrig and Luft (2006) found in a study of different teacher preparation programs that prospective teachers who participated in a program with an extended student-teaching experience and who also had two science methods courses shared beliefs that were more aligned with student-centered practices and were able to enact more reform-based lessons than did other teachers from more traditional programs. More, however, is not necessarily always better. In this case the extended field placement time, and additional time in methods courses needs to be focused on the modeling and implementation of reform-based practices, and taught by instructors who are committed to this kind of change. Prospective teachers need to be encouraged to collaborate with peers, with the support of the instructor.

Such changes would necessitate a rethinking and restructuring of the teacher education program with consideration being made for the time the instructor would have to dedicate for this model to be successful. With these changes, inquiry-based instruction both in content and technique, could actually occur in classrooms across the country. It is not enough to just call that reform is needed. The quality of a teacher has a direct impact on the learning of the students. There is a need for research and collaboration among professionals and experts in the field to work together to develop a framework, as was developed for reform-based teaching, to change the way teacher education programs in the United States are enacted.

***Imperative to teach science in elementary* schools**. This study provides evidence of the lack of science in schools, particularly those with diverse populations. In reporting upon the status of science in their placement schools, the prospective teachers noted that they rarely saw science being taught. They were placed in Title 1 schools in urban areas with highly diverse and high poverty populations. To do the practice science teaching I required, they had to carve out time from highly scheduled days. Sometimes that time was during recess and they had to convince the elementary students to work with them rather than play with their friends. Other times, the prospective teachers were able to work with a small group of students in another location while their classmates stayed for additional literacy instruction in the classroom. These experiences did not provide the prospective teachers with an authentic environment or situation in which to teach science. Some complained that the students were so excited by the interactive science experiences they were providing that they had difficulty with classroom management. They believed that the students did not know how to behave in a science context because they were not experiencing science regularly in their classrooms. If prospective teachers are unable to find a venue that is favorable to their practice teaching of science, they will not be as well prepared to teach science. Some may find that this environment gives them a way out of teaching science when they have their own classrooms. Still others may find it difficult as beginning teachers to go against the grain or the culture of the school and find ways to include science.

Not teaching science denies the students the opportunity to learn and enjoy science – a form of discrimination with life-long consequences. Most often this happens in school populations that are very diverse and of low-socio-economic status. This seems to be related to the increased pressure to meet standardized test requirements for the No Child Left Behind mandate. Students in these schools often have an entire day structured around literacy and numeracy activities. For students whose first language is not English, the chances of receiving any science or social studies activities are even fewer. With the current emphasis in the United States on recruiting more non-white students into science, and into education, this is an intolerable situation. To take the opportunity of learning science away from these children is an act of discrimination.

Young children come to school already scientists in the making. They are curious about the world and relish experiences that build on that curiosity. If those experiences are not offered, they are being handicapped. As they move into middle school and high school where science is a requirement, they may feel less adequate than other students who have had these opportunities and not be motivated to consider science as a possible career choice. The number of minority candidates for the sciences is decreasing and maintaining status quo. Capitalizing on the natural strengths that students being to science instead of depriving them of the experiences needs to start now.

Future Research

Multitudes of questions occur to me as I draw this project to a close: How do we design methods courses that utilize the four strands of science proficiencies around core concepts from science curriculum, maintaining the complexities of the strands, and their interrelatedness? This framework supports a deeper and more enriched reform-based science experience. In interpreting the data from this course, it was apparent that there is overlap in the application of the strands. It is also apparent that interpretation of a particular strand to a particular activity or task may vary depending on the perspective of the interpreter. How do we avoid the application of strands to curriculum from becoming a checklist? How can methods courses in an education program be designed so that they link to and build on each other to facilitate reform-based efforts in all content areas? How do we as science educators continue to support newly qualified teachers so that reform efforts show up in the classroom? What structures can be put in place? How can the methods course help newly qualified teachers overcome the challenges they will face in their new situations? As newly qualified teachers enter the public education system, how do we provide support for their experienced colleagues who may or may not be aware of reform-based research and practices and are challenged by their implementation? How can we re-conceptualize the methods course as the beginning of a teacher's journey of learning rather than the end of learning? Research is needed on methods instructors who are not university faculty? Who are they? What do they do as compared to faculty who instruct methods courses? How do we as science educators nurture newly qualified teachers as they begin teaching to continue with the reflective practice and scholarship of teaching and learning they began to understand in their methods courses?

APPENDIX A

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EDUCATION:

Current	Doctoral candidate in Teacher Education/Professional Development University of Maryland, College Park, anticipated graduation 2011
2000	Master's in Science Education, University of Maryland, College Park
1996	B.A. in Elementary Education, University of Maryland, College Park

PROFESSIONAL EXPERIENCE:

2006 -2009	Grade 4 and 5 teacher, Desert Mountain ES, Queen Creek, AZ
2005-2006	K-8 Science Specialist, Maryland State Department of Education
1991-2005	Montgomery County Public Schools K-5 Instructional Specialist for Science (2003-2005) Coordinator for Howard Hughes Medical Institute Elementary Teacher Leadership Grant (2003-2006) Fourth grade teacher/ Team Leader (2001- 2003) Oak View Elementary School, Silver Spring, MD Science teacher (2000- 2001) Mathematics teacher (1999 - 2000) Silver Spring International Middle School, Silver Spring, MD Curriculum Developer (consultant) (2000 – 2002) National Aeronautics and Space Administration Mentor Teacher (student teachers and new teachers)(1997–2003) for both Montgomery County Public Schools, and the University of Maryland Program of Assessment and Diagnosis Integration (PADI) Teacher (1997 –2003) First grade/second grade teacher (1996 -1999) Rolling Terrace Elementary School, Takoma Park, MD Chapter 1 instructional assistant (1991- 1996) Instructional System of Mathematics Assistant (1992-1996) Rolling Terrace Elementary School

INSTRUCTIONAL LEADERSHIP:

2007 - 2009	NSTA panel for Position Statement on Research
2006 – 2009	National Science Teachers Association Research Committee
2004 - 2006	Member, Content Connections Committee for the Voluntary State Curriculum, Maryland State Department of Education

2004 - 2007	Member, National Research Council Committee on How Students Learn K-8
2003 - 2005	Member, Grading and Reporting Development Committee, Montgomery County Public Schools
2003 - present	Co-Chair, Teacher Researcher Day at the National Science Teachers Association's National Conference,
2000 - 2005	Co-Chair, Ad Hoc Committee for Practitioner Research, National Association for Research in Science Teaching
2000 - 2001	Co-Chair, School Improvement/Parent Involvement Committee, Silver Spring International Middle School
1999-2000	Chair, School Improvement/Parent Involvement Committee, Silver Spring International Middle School
1997-1999	Science Liaison, Rolling Terrace Elementary School, Takoma Park, MD

PROFESSIONAL DEVELOPMENT LEADERSHIP:

2007 – 2009	District 301 Committee, Queen Creek Unified School District
2006 -2009	Provided professional development for school and district
2004 -2006	Lead teacher for professional development through Howard Hughes Summer Institute for elementary teachers. (Teaching by inquiry, practitioner research, and curriculum development).
2004 - 2006	Coordinated the Student Inquiry Conference for elementary students in Montgomery County
2003 - 2006	On-going professional development for teachers participating in the Howard Hughes Medical Institute grant project
2003 - 2006	On-going professional development for elementary science liaisons
2003 - 2005	Seminar to introduce practitioner research for high school science teachers for Montgomery County Public Schools, VIPK-16 Grant (NSF)
2003	Seminar to introduce practitioner research for elementary school teachers for Montgomery County Public Schools.
	Facilitator of Short Course on Data Analysis, at the National Science Teachers Association's National Conference,
2002 - 2003	Educational Consultant for Spencer Benson, grant coordinator, for a grant from SENCER (Science Education for New Civic Engagements and Responsibilities)
2002	Facilitator of Pre-conference workshop, Inquiring into One's Own Teaching Practices, at the National Science Teachers Association's National Conference
	Facilitator of Practitioner Research Seminar, What is it? How to do it?
	Why Bother? at the National Science Teachers Association's National Conference Facilitator of Looking at Data Seminar at the National Association for Research in Science Teaching, Annual Conference Facilitator of Short Course on Practitioner Research, at

	the National Association for Research in Science Teaching, Annual Conference
	Seminar for teachers on how to conduct teacher research for ASSET, INC, Pittsburgh, Pennsylvania.
1997	Co-taught physics inquiry course with Emily van Zee for teachers at Rolling Terrace Elementary School in Takoma Park, MD.
1997	Co-taught Chemistry courses for teachers with M. J. Morse, Educational Director at the Children's Museum, Washington, D.C.

UNIVERSITY TEACHING:

2008	Elementary Science Methods for graduate students in the Teacher Certification Program, at Arizona State University
2004 -2005	Elementary Science Methods for graduate students in the Teacher Certification Program, at the University of Maryland

PUBLICATIONS:

McGinnis, J. R., & Roberts-Harris, D. (2009, Sept/October). A new vision for teaching science. *Scientific American Mind*, 62-67.

Roberts, D., Bove, C., & van Zee, E.H. (Eds.) (2007). Learning about motion: Fun for all! in *Teacher Research: Stories of Learning and Growing*. Arlington, VA: National Science Teachers Association Press.

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PRESENTATIONS:

van Zee, E.H. & Roberts, D. (December 2009) Science and Literacy. National Science Teachers Association, Phoenix, AZ.

Roberts, D. (March 2008) Co-chair Teacher Researcher Day, National Science Teachers Association Boston, MA

Roberts, D. (April 2007) Co-chair Teacher Researcher Day, National Science Teachers Association St. Louis, MO

Roberts, D. (April 2005). Science and literacy: When did we take literacy out of science? National Science Teachers Association Convention, Dallas, TX

Roberts, D. (April, 2004). Using reflection on practice to enhance teacher and student learning. National Science Teachers Association Convention, Atlanta., GA

Roberts, D. (April, 2004). Learning physics through inquiry: From first graders to teachers, International Conference on Teacher Research, La Jolla, CA.

Roberts, D. (February, 2004). The Science Inquiry Project. Ethnography in Education Research Forum. University of Pennsylvania, Philadelphia.

Roberts, D. (March, 2003). Capturing curiosity and questions in the science classroom. National Science Teachers Association convention, Philadelphia

Roberts, D. (March, 2003)..Taking the Reform movement from Theory into Practice. Ethnography in Education Research Forum. University of Pennsylvania, Philadelphia.

van Zee, E.H. & Roberts, D. (April, 2002). Collaborative inquiry about collecting and interpreting data in one's own classroom. National Association for Research in Science Teaching annual meeting, New Orleans.

Roberts, D. (March, 2002). Fourth grade boys as writers. Ethnography in Education Research Forum. University of Pennsylvania, Philadelphia.

Roberts, D. (March, 2001). The road to reflective research: From science methods to facilitating a research group. National Science Teachers Association, St. Louis.

van Zee, E.H. & Roberts, D. (March, 2001). Collaborative inquiry into the process of researching while teaching. National Association for Research in Science Teaching, St. Louis.

Roberts, D. (March, 2001) Forming a reflective research group. Ethnography in Education Research Forum, University of Pennsylvania, Philadelphia.

van Zee, E.H. & Roberts, D. (April, 2000). Analysis of prospective and practicing teachers' perceptions of inquiry teaching and learning. National Association for Research on Science Teaching, New Orleans.

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Roberts, D. (March, 2000). Learning about Motion: Fun for All! Ethnography in Education Research Forum, University of Pennsylvania, Philadelphia.

Roberts, D. (April, 1999). Teachers and research: New understandings. American Educational Research Association meeting, Montreal.

Roberts, D. (April, 1998). First graders and their families learn about the moon. International Conference on Teacher Research, San Diego.

Roberts, D. (April, 1998). Physics and first graders: What a good match! American Educational Research Association, San Diego.

Roberts, D. (February, 1998). On the move: Microcomputer-based laboratories, prospective teachers, and first graders. American Association for the Advancement of Science, Philadelphia.

Roberts, D. (October, 1997). First grade students and their questions about the world. Maryland Association of Science Teachers Fall Conference, Lusby, Maryland.

HONORS AND AWARDS:

2009	Outstanding Performance, Queen Creek Unified School District
2001- present	K12 Carnegie Foundation Scholar
1990	Governors Outstanding Volunteer Achievement Award
1990	Outstanding Volunteer Award Montgomery County Community Service Partnership, Inc.

APPENDIX B

EED 529 Science in the Elementary School

Semester: Fall 2008
Day and Time: Monday 4:30 - 8:20 pm
Location:
Instructor: Deborah Roberts-Harris
Email: drobertsharris@gmail.com

Office hours: By appointment
Phone: 480 -584 -7588 (cell)
480-629-4236 (home)

Elementary school teachers have a full plate. They are expected to teach a variety of content areas, be able to differentiate instruction for students from diverse backgrounds, and with diverse needs and gifts. They need to be team players, community members, parent and student advocates, and agents of reform. Teachers are learners, reflective practitioners, facilitators, nurturers, motivators, challengers, models and leaders all at the same time. Teaching evolves, practices changes and is shaped by our own personal experiences and by those students, parents, colleagues, and others with whom we interact. Teaching is a journey; it is "creative, intellectually engaging and exceedingly interesting work" (Saul, as quoted in Pearce, 1999, p.vii).

> *Every child is a scientist. Children think in ways that scientists think, say things that scientists say, and do things that scientists do. What pure science it is when a child touches and feels, tastes and senses, examines and manipulates. Children are driven to fully experience all they can in their surroundings. As a result, the students with whom we teach possess rich backgrounds of experience and vast databases of information ....*
>
> *What an awesome task it is, then, to be called upon to teach science. What can teachers in our schools give experienced scientists who have spent their lifetimes acquiring knowledge through their own investigations and discoveries? How can we nurture their curiosity without inhibiting its growth? What experiences can we provide that might enhance the development of the scientist within each of the children we teach (Pearce, 1999, p.3)?*

These questions are some of the questions we will try to address through this course. Together we will learn, teach and grow from our shared experiences and interactions.

Description: EED 529 is a course consisting of instructional strategies, curriculum selection and development, student learning, assessment, and classroom management for teaching inquiry-based science in grades K-8. Content from various science disciplines will be used as vehicles for learning about teaching science to diverse groups of elementary students. This course aims to develop prospective teachers' personal teaching philosophies about science learning and teaching, and how students learn science best according to educational research. This course also emphasizes a practical and reflective approach in how to develop a community of active learners, use and design inquiry based curricula and evaluate one's own instructional practices.

Principles: Awareness of Self and Students, Active Learning and Inquiry, and Practical Application of Theory

Essential Question: What factors are involved in inquiry-based science education in the elementary classroom?

Aspects of this question include:

1. Experiences and attitudes towards K-8 science education, how can a teacher's beliefs and perceptions affect their science instruction?

2. Teaching and learning science with inquiry-based methods.

3. What is, and isn't, science and the nature of science,

4. Relevant science instruction, how do we provide meaningful science experiences for students?

5. How educational standards, learning principles, and content knowledge affect instructional planning.

General Class Information

- All students are expected to adhere to the *ASU Student Code of Conduct.*
- Please turn cell phones off or to vibrate and wait until the break or end of class to accept/return non-emergency text messages or calls.

- Attendance to each class and for the whole class is expected. Any special situations need to be brought to the attention of the instructor.
- **If you need special accommodations during the course please see me after the first class, or as soon as possible.**

Required Textbook:

Teaching Science as Inquiry, (2009) by Bass, Contant, Carin, (11th Edition)
Published by Pearson Prentice Hall

Other Useful Sources:

General Science Education

Inquiry: Thoughts, Views, and Strategies for the K-5 classroom, NSF Foundation Series, Vol 2 (1999). This is a free, downloadable monograph at: www.nsf.gov/pubs/2000/nsf99148/htmstart.htm

Arizona State Science Standards & Performance Objectives (2004). For your on-going reference and design of your science lesson you will need to print the AZ State Science content standards for your placement grade level for the summer session, http://www.ade,state.az.us/standards/sciene/artculated.asp

National Science Teachers Association (NSTA). For $32 you can get a pre-service/new teacher I-year membership to NSTA and 8 issues of Science & Children at hltp://www.nsta.org. Lots of practical lessons, activities, and strategies that you can use in your own classroom,

National Science Education Standards (1996) at
http://www.nap.edu/readingroom/books/nses
The national standards are not a curriculum, but rather a guide for selecting content and designing lessons, Most states use the NSES as a base for their articulated state science standards.

(AAAS) Benchmarks for Scientific Literacy (1993) The NSES are incorporated this document and its predecessor, and visionary mission statement, Science for All Americans (1989), The benchmarks can be found at
http://www.project206I.org/publicationslbsl/onlil1e!bchin.htm

Annenberg Media: A Private Universe, Minds of Our Own. You can download videos of student misconceptions AND science content on many science topics at htlp://www.1earner.ondindex.html
* Free registration to download and watch videos,

Earth & Space Science

(DLESE) Digital Library for Earth System Education at http://www,dlese,onr/dds/index,jsp THE clearinghouse for Earth (and space) systems science educational resources,

University Corporation for Atmospheric Research (UCAR), Windows to the Universe at http://www.windows.ucar.edu/ Multi-level and bilingual science content and activities for students and teachers, Co-sponsored with NCAR, NASA, and NSF,

Mars & Space Education

ASU Mars Education Program at hltp://marsed.asu.edu

Satellite images of Mars by ASU Research Group: Mars Odyssey I THEMIS http://themis.asu.edu
NASA Education at http://education.nasa.gov/home/index.html

Specifically for K-8 students: http://www.nasa.gov/audience/forkids/home/index/html
U.S. Geological Survey, Education Division at http://education.usgs.gov

More resources to come!!!!

Class assignments
Grades will be based on:

	Percentage
Class participation	10%
Reflection Journal	10%
Assignment I: What is science?	5%
Assignment 2: Evaluating science at your school	15%

Assignment 3: Analysis of current curriculum	15%
Assignment 4: Creating and Reflecting On an Inquiry Experience	20%
Final: Snapshot of Teaching, Learning and Reflecting	25%

Grading Scale

90-100 A
80-89 B
70-79 C
60-69 D
Below 60 F

Class Participation:

You will be expected to attend all scheduled classes and participate actively in discussions and small group activities. You are expected to be a collaborative participant of all the work in class. Your participation in our class activities and discussions is important not only for your own learning but also for the learning of others. You are expected to participate thoughtfully, responsibly, and constructively in discussion on a regular basis. Our discussions can serve as a forum in which you sharpen your thinking, share your ideas, ask questions, exchange insights and perceptions with the instructor and each other and contribute towards each other's ideas.

Written Assignments:

All written assignments should be double spaced, 12-point font, in APA format. Please make sure that your work is complete. The length of various assignments is an estimate not a hard and fast rule. Please carefully proofread your work. Grammar, spelling, punctuation, etc should be correct. If you complete an assignment early, or would like me to look at a first draft before you "officially" turn it in, I will be happy to do so if it is given to me with adequate time to provide feedback.

Reflection journal:

This will be turned in weekly. This can be a hard copy or electronic version turned in by the beginning of the next class. For example, the journal entry from our August 25 class is due no later than class on September 8; the journal entry for the September 8 class will be due at the beginning of class on the 15th, etc. The purpose of the journal is for you to reflect on science teaching and learning. Some times I will give you a topic to address, other times, it will be an open entry. If I have not given you a specific topic, it is assumed that you will choose the topic for your entry. The length of the entry is up to you - as long as you fully address the topic, you will fulfill the requirement. If you desire feedback on a specific part of your entry, please note that, and I will be glad to respond. In addition to your reflections there are two items I would like you to record during the semester. I would like you to write down "science quotes" from students. These could be funny, or serious, show how well the student made connections to the science concepts, or a misconception they hold, any quote that is of interest to you. The second item I would like you to keep track of are science questions. What are the questions that the students ask during science? These could be questions they ask you, ask each other, or ask during whole group discussion. There are not a specific number of these you need to have. Try to be aware of what the children are saying and asking.

Due September 15

Assignment I: What is science? For this assignment, first think about yourself, and your experiences. What is science to you? Then do the assigned readings for class, and look back at what you have written about science means to you. Describe how the readings are similar to or different than your ideas. This should be about two pages.

Due September 29

Assignment 2: The status of science

What curriculum is being used in your classroom? What is the science addressed by this curriculum? How often and for how long is science instruction?

Using the interview questions we designed in class, interview your mentor teacher, the principal, the science resource teacher, and a teacher from another grade level. Summarize the results of the interview.

What is the schools perspective on teaching science?

Review the websites for the district in which you are working. Is there information about the district perspective on teaching science?

What are your thoughts, ideas, and feelings about science at the elementary level? This should be about five pages.

Due October 13

Assignment 3: Interpreting Curriculum

Photocopy a lesson that has not yet been taught from a science curriculum guide being used in your classroom. Analyze the lesson using the following questions.

What is your first impression of the lesson?

If you were to implement this lesson as is, what do you anticipate would happen with students in the classroom you are in?

What things in the lesson would motivate the students? What would they like about it? How are other content areas integrated into this lesson? What parts of this lesson would be challenging for the students? Why?

Does this lesson make any assumptions about students in regard to:

- Math or reading ability?
- Physical ability?
- Special needs?
- Giftedness?
- Race/ ethnicity / culture?
- Gender?
- Socio-economic status?

Rewrite the lesson in a 5 E format. Try to address the challenges you identified. When you modify the lesson based on a particular challenge, please identify the challenge that you are addressing. Please underline any parts of the lesson that you modify or add. How would you assess student achievement for this lesson? How are you meeting the needs of the students in your placement setting?

Due by November 10*

Assignment 4: Inquiring about Inquiry

Create a meaningful inquiry experience for a small group of students in your classroom. This lesson does not have to be directly related to the science curriculum that is currently being taught. If there is something you are interested in, or you have heard students talk about, and you would like to design your lesson to fit those interests, feel free.

Choose a driving question for yourself to research when you implement this lesson. Use the 5E format to write up you lesson. Make three copies of this lesson. One to turn in ~ 'is, one for your peer to see prior to the peer observation, and one to mark up after you have taught the lesson and analyzed it. Include differentiation strategies that you plan to use based on the students you will be working with. Give a brief description of each of the students in your small group. If there is a particular reason why you chose these students, please share that information. What are the scientific concepts that the teacher needs to understand before teaching this lesson? What resources are readily available?

What are the process skills and concepts that this lesson addresses? What are the connections to the national standards? What other content areas are integrated into this lesson? What is the role of discourse or discussion in this lesson? Have you integrated the use of technology into this lesson? How? What diversity issues are being addressed either intentionally or unintentionally? In what ways will you be assessing the students? How will you know if they have been successful in learning your lesson? What is the real world application of this science lesson for the students? What unit of study would your lesson best fit into? Would it occur at the beginning, middle or end of the unit?

Have a peer (someone from the class who works at your site) or other trusted individual observe the lesson when you teach it. Prior to the lesson, describe your driving question to your peer so that they c look for evidence to help you answer that question. If there are any other items you would like to have them look for, describe those. Set up a time after the lesson that you can debrief with your observer. Before getting together it is important that each of you reflect individually. We will discuss peer observations in some detail in class before you do this.

*Teach and videotape this lesson.

Take your time and analyze your video. Write up a summary that includes answers to these questions, and discusses how your driving question was answered.

What were your successes? What were your frustrations?

What were the student successes and frustrations?

What did you see in the video that you did not notice during the time you were teaching the lesson?

How would you assess yourself?

How did the observations of your colleague match your perceptions about the lesson? What would your next steps be? What questions do you have now?

What did you learn about yourself, your students, and teaching from this experience? Take the third copy of the original lesson, and mark it to show what changes you would make. (You can actually do this electronically, as long as the changes are obvious for me, you can add post-its or write on a hard copy, etc - as long as the changes are easy for me to recognize).

Final:

Rough draft due November 24

Create a “snapshot” which is a web-based portfolio of your learning using the Keep Toolkit. This will be explained in detail in class. You will be using parts of the other assignments you have done for this class, that best synthesize your learning. You may use excerpts or sections of assignments, readings, reflections, observations in classrooms, class discussions, etc. to demonstrate what you believe are the key elements you learned in this course, We will work on the rubric for it's evaluation together from a brief outline I have.

Final version due no later than December 8. We will spend two sessions on presenting our web-based portfolios to the class. Those who choose to present the week of December first may make changes, if desired, based on feedback from the class.

Course Outline of Readings

Date Due		Readings Journal reflection
9/8/08	Chapter 1 and Handout(s)	Your own experience of learning science, and how it is different in elementary classrooms today
9/15	Chapters 2, 4 and Handout(s)	Free choice
9/22	Chapter 3 and Handout(s)	What reading so far was most meaningful/thought provoking?
9/29	Chapter 5 and Handout(s)	Free Choice
10/6	Chapter 6 and Handout(s)	Eye openers from schools
10/13	Chapter 7 and Handout(s)	Free choice
10/20	Chapter 10 and Handout(s)	Free choice
10/27	Chapter 9 and Handout(s)	Your understanding of current status/politics of science at elementary levels
11/3	Video From MCPS on ELL Chapter 8 and Handout(s)	Free choice
11/10	Handouts - and book excerpt of choice	No journal entry due
11/17	Handouts - and book excerpt of choice Annenberg Video Working with diverse learners	Envisioning yourself as a science teacher

11/24	Handouts - and book excerpt of choice	Free choice
	Annenberg Video Working with special needs	
12/1	TBA	No journal entry due Final presentations
12/8	TBA	No journal entry due Final presentations

APPENDIX C

Snapshots of websites referenced in study

THE CARNEGIE FOUNDATION for the ADVANCEMENT of TEACHING

Newsroom | FAQs | Contact Us

Search

HOME ABOUT US PROBLEM SOLVING R&D CONVERSATIONS RESOURCES ONGOING WORK CLASSIFICATIONS PREVIOUS WORK

PROFESSORS OF THE YEAR BUSINESS EDUCATION SCHOLARSHIP OF TEACHING & LEARNING EDUCATION DOCTORATE MEDICAL EDUCATION NURSING EDUCATION

Carnegie Academy for the Scholarship of Teaching and Learning (CASTL)

Printer-friendly version

CASTL represents a major initiative of The Carnegie Foundation. Launched in 1998, the program builds on a conception of teaching as scholarly work proposed in the 1990 report, *Scholarship Reconsidered*, by former Carnegie Foundation President Ernest Boyer, and on the 1997 follow-up publication, *Scholarship Assessed*, by Charles Glassick, Mary Taylor Huber, and Gene Maeroff.

The CASTL Program seeks to support the development of a scholarship of teaching and learning that: fosters significant, long-lasting learning for all students; enhances the practice and profession of teaching, and; brings to faculty members' work as teachers the recognition and reward afforded to other forms of scholarly work.

Achieving these goals involves significant shifts in thought and practice. For faculty in most settings, teaching is a private act, limited to the teacher and students; it is rarely evaluated by professional peers. "The result," writes former Carnegie Foundation President Lee S. Shulman, "is that those who engage in innovative acts of teaching rarely build upon the work of others; nor can others build upon theirs." Thus, CASTL seeks to render teaching public, subject to critical evaluation, and usable by others in both the scholarly and the general community.

Currently, the CASTL Program is working with a wide variety of institutions (campuses, collaborative centers and organizations, scholarly societies, etc.) to broaden the reach and depth of the scholarship of teaching and learning. These efforts are focused on the CASTL Institutional Leadership Program and the CASTL Affiliates Program.

SHARE

Additional Information

CASTL HOME

- Institutional Leadership Program
  - Themes and Participants
- Affiliates Program
- Previous Work
  - Campus Program
  - Carnegie Scholars
  - Scholarly and Professional Societies Program
- Resources

Statistics Pathway

Spotlight

Webinar: Introducing Carnegie's Work in Developmental Mathematics

ESSAY - Getting Ideas Into Action: Building Networked Improvement Communities in Education

Webinar: Bryk, Gomez on Building Networked Improvement Communities in Education

Updated Carnegie Classifications Show Increase in For-Profits, Change in Traditional Landscape

View Spotlight Archive

Get Connected

Subscribe RSS Twitter Facebook

Home About Us Problem Solving R&D Conversations Resources Ongoing Work Classifications Previous Work

Contact

search Go

Featured Work

Learning in Community Colleges
Windows on Learning features sites from community college educators wishing to share their practices, insights and materials for improving collegiate learning.

Curriculum Reform
Carnegie Initiative on the Doctorate (CID) Collection displays the work of over 30 departments involved in rethinking doctoral education across six disciplines.

Teaching & Teaching Preparation
The Inside Teaching collection provides multiple lenses on teaching, learning and learning about teaching.

Subject Areas

- Arts
- Business
- Humanities
- Mathematics & Statistics
- Science & Technology
- Social Sciences

Carnegie Collections

- CID
- CASTL HE
- CASTL K-12
- Inside Teaching
- Integrative Learning Project
- Windows on Learning
- Inside Writing Workshop

Welcome to the Gallery

The Gallery of Teaching and Learning provides premier, digital representations of knowledge related to teaching and learning. The carefully crafted and vetted work of numerous participants of Carnegie Foundation programs and partners provides examples for individuals, projects, departments, institutions, communities of practice, and for the simply curious.

Browse, Learn, Reflect, and Get Inspired!

Archives

- Exhibitions
- KEEP Case Studies
- Partnerships

ESIP People

Wendy Saul

Dr. Wendy Saul serves as the Shopmaker Professor of Education at the University of Missouri-St. Louis. She is editor-in-chief of *Thinking Classroom: An International Journal of Reading Writing and Critical Reflection* published by the International Reading Association and author/editor of a number of books about the science-literacy connection, including *Vital Connections: Children, Science, and Books* (Heinemann 1991), *Beyond the Science Kit* (Heinemann 1996), *Science Workshop: Reading, Writing, and Thinking Like a Scientist* (Heinemann 2002) and *Crossing Borders in Literacy and Science Instruction: Perspectives on Theory and Practice (IRA/NSTA 2003)* . As director of the National Science Foundation-supported "Elementary Science Integration Projects," she has a special interest in helping educators create reading and writing activities that inform and are informed by science She is also the originator of *Search It! Science The Books: You Need at Lightning Speed* (searchit.heinemann.com), a web database program that suggests appropriate science titles for young readers, their teachers, and librarians.

Donna Dieckman

Donna Dieckman, Program Director for the Elementary Science Integration Projects at UMBC, works with classroom teachers, administrators and university researchers on programs designed to support science and literacy connections. During her nine years as a classroom teacher, she became a strong advocate of using children's literature in the classroom. She has served as a member of the Children's Book Council-National Science Teacher's Association joint panel that selects the Outstanding Science Trade Book Awards in children's literature. She is a co-author of *Science Workshop: Reading, Writing and Thinking Like a Scientist* and a contributor to *Beyond the Science Kit: Inquiry in Action*, published by Heinemann, as well as the user's guide for Search It! Science, a database of over 4,000 outstanding children's science books. She is pursuing her research interests in science-literacy connections as a student in the Language, Literacy and Culture Ph.D. program.

Megan Dieckmann

Megan Dieckman is a student at Juniata College in Huntingdon, Pennsylvania. She is majoring in chemistry. Megan is an ESIP administrative assistant. She works on the Search It! Science Database and is actively involved in the Kids' Inquiry Conference. Megan was a participant in KIC as a 4th grader and she hosts the "Ask Meg" section of the KIC website. She enjoys pottery, quilting, and travel.

Holly Buck

A 2002 graduate of UMBC, Holly Buck has also spent time at Arizona State University and the University of New Orleans. She graduated with a degree in English, and enjoys studying contemporary American literature. While her work as a research assistant at ESIP primarily involves writing and compiling material for the Search It! database of children's science trade books, her passion is creative writing, and she is pursuing her M.F.A in Writing & Poetics at Naropa University in Boulder, Colorado.

** This page is unpublished **

multi media portfolio

Teaching Science
English Language Learners
Always Engaging
Creating Connections
Home Involvement
Inquiry Based
No one learns the same
Guess the mystery substance

Teaching Science

My thoughts on Science in the beginning...

When I think back to my experience with science, the thing I think of first is textbooks. It felt like most of what we did in science was read from the textbook, maybe see something on the chalkboard that we copied down in our notebooks and then be prepared to take a test. There wasn't much about science that was all that interesting to me. It was just a lot of memorizing and boring reading.

How I hope to teach science...

My goal as a science teacher is to get students excited about science. I want them to enjoy science and I want them to be truly engaged in our lessons. I hope that I can instill a love of learning in my students and show them science in a new and exciting way. I don't want my students to leave school feeling the same way I do about science. I think that history keeps repeating itself because we learned science from textbooks and then if that is all we know we go on to teach it that way and the cycle continues. I know I have the power to break the cycle.

"If we want our science students to develop skills in problem solving and decision making, we need to ask them questions that will stimulate higher-order thinking.

--How to Ask the Right Questions

Beyond the textbook...

Children are authentically motivated to do science for one basic reason: to find out! The focus of science teaching today is giving students the chance to think critically and guide their learning rather than providing

Making a New Song About Science

Deborah Smith, Michigan State University
with Desiree Pointer, Thomas Hatch, and Toru Iiyoshi, The Carnegie Foundation

This website explores the difficulties and the joys of my work helping science-phobic preservice teachers find their voices and create their music in singing a song about science, both for themselves and with the children they teach.

-Deborah Smith, Michigan State University

"Yes, we have no bananas..."

Students come to the course with little or no conceptual understanding of the science they will be teaching. They know this; it's painful and scary for them, and getting it on the table and building a community around that problem is an important first step. We have to move beyond this, to an acceptance that we weren't stupid, we just didn't have teachers who knew how to teach science well, because almost nobody knew how, at the time we went through schooling, and most teachers still don't today.

more about the website

Note: While many of the resources below are online, not all of these timeline resources are currently available. More may be added, but the entire course timeline is listed here so that site visitors can see the entirety of the work for the course.

Scroll right in your browser window->

Rationale for Course Design | Course Syllabus | Bibliography of Related Research

COURSE TIMELINE

Questionnaire about school experiences | Autobiographies of Learning in Science – examples | commentary | Auto-biography assignment Student Work | Reading Sheila Tobias' article "What makes science hard?" and students' responses | Watching Private Universe videotape, showing Harvard graduates who are wrong in their scientific explanations.

UTeach
THE UNIVERSITY OF TEXAS AT AUSTIN

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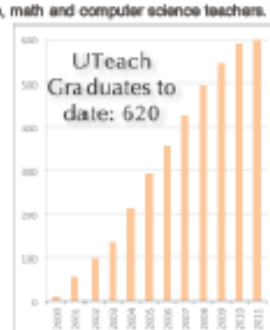
February 21 - April 18: Advising for Summer and Fall 2011 Regist

Welcome to UTeach Natural Sciences

UTeach started at The University of Texas at Austin in 1997 as a new way to prepare secondary science, math and computer science teachers. Its strength lies in the unique collaboration between the Colleges of Natural Sciences and Education. If you are an undergraduate who wants to teach, a college graduate who wants to return for certification, a new teacher who wants a supportive community, or an experienced teacher who wants an advanced degree, then UTeach is for you.



UTeach has proven to be so effective that it is now being replicated at universities across the United States. Read more about the replication efforts of The UTeach Institute.

All students enrolled in the UTeach Natural Sciences Program have the opportunity to participate in a paid internship. Find more information about our programs for current UTeach students including course schedules and degree plans.

Because of the support from UTeach and the nourishment of UTeach Master Program, I continue to improve my teaching and gain insights on students' learning. UTeach also helps me to sustain my deep passion and dedication in chemistry teaching. All of these have made a huge difference in my life and my students' lives. I would like to thank all of you and the entire UTeach faculty for your support over the years! Thank you! - William Chen, UTeach Alumn

Interested in learning more about replication or the UTeach Institute? If so, please click here.

THE UTEACH INSTITUTE

UTeach in the News

Obama Launches Initiative to Train 100,000 New STEM Teachers

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