ALTERNATIVE CERTIFICATION SCIENCE TEACHERS’ UNDERSTANDING AND IMPLEMENTATION OF INQUIRY-BASED INSTRUCTION IN THEIR BEGINNING YEARS OF TEACHING

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Dedicated to my mother and father, who devoted their lives for their children’s success.
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The purpose of this phenomenographic study was to: (a) understand how beginning science teachers recruited from various science disciplines and prepared in an Alternative Teacher Certification Program (ATCP) implemented inquiry during their initial years of teaching; (b) describe constraints and needs that these beginning science teachers perceived in implementing inquiry-based science instruction; and (c) understand the relation between what they learned in their ATCP and their practice of teaching science through inquiry. The participants of this study consisted of four ATCP teachers who are in their beginning years of teaching. Semi-structured interviews, classroom observation, field notes, and artifacts used as source of data collection.

The beginning science teachers in this study held incomplete views of inquiry. These views of inquiry did not reflect inquiry as described in NRC (2000) - essential features of inquiry, - nor did they reflect views of faculty members involved in teaching science methods courses. Although the participants described themselves as reform-oriented, there were inconsistencies between their views and practices. Their practice of inquiry did not reflect inquiry either as outlined by essential features of inquiry (NRC, 2000) or inquiry as modeled in activities used in their ATCP.
The research participants’ perceived constraints and needs in their implementation of inquiry-based activities. Their perceived constraints included logistical and student constraints and school culture. The perceived needs included classroom management, pedagogical skills, practical knowledge, discipline, successful grade-specific models of inquiry, and access to a strong support system. Prior professional work experience, models and activities used in the ATCP, and benefits of inquiry to student learning were the declared factors that facilitated the research participants’ practice of inquiry-based teaching.
CHAPTER ONE

Purpose of the Study

The purpose of this study is to: (a) gain an understanding of how beginning science teachers recruited through an ATCP from various science disciplines implement inquiry during their initial years of teaching; (b) describe constraints and needs that they perceive in implementing inquiry-based science instruction; and (c) understand the relation between what they learn in their ATCP and their practice of teaching science through inquiry.

Introduction

Similar to many other countries, the United States (U.S.) is facing a growing demand for science teachers. Attempts have been made to address this deficit (Bradshaw, 1998; Darling-Hammond, 2000a; Patterson & Luft, 2002; Webber, 1996). In the U.S., there is also a rising concern about teacher preparation and the quality of the teaching force. The nation is facing a growing demand for qualified teachers. A number of studies have estimated that at least two million new teachers will be needed by 2010 for a variety of reasons, including aging of the current teaching force, class-size reduction initiatives, and teacher attrition (Feistritzer, 1999; Haberman, 2001; Hussar, 1999; Schaefer, 1999; U.S. Department of Education, 2001). This means a great number of new teachers must be hired (Schaefer). Of course, the anticipated teacher need is greater than the number of teachers being prepared to teach in traditional teacher education programs (Johnson, Birkeland, & Peske, 2003).

Alarms have also sounded due to the following demographics in current teaching force. First, researchers concur that there are nationwide shortages of teachers in mathematics, science, foreign language, and special education, although the exact numbers may be debated (The Abell Foundation, 2001; National Association
of State Boards of Education, 1998; National Commission on Teaching and America’s Future, 1996; Ruhland & Bremer, 2002; Zeichner, 2003). Nationally, in the area of science, 18-21% of public secondary school science teachers lack state certification in their field (Ingersoll, 1999). Second, there are higher attrition rates in these fields (Ingersoll, 2002). Third, the shortage is most severe in certain geographical areas, such as urban and remote rural districts (Ingersoll, 1999, 2002; Ruhland & Bremer; Stoddart & Floden, 1995). Last, there is a growing inconsistency between the ethnicity of students attending public schools in the U.S. and their teachers (Brennan & Bliss, 1998; Zeichner). Few minority teachers are coming through traditional teacher education programs and, consequently, we see a declining diversity in the teaching workforce that is minority (Feistritzer, 1998). According to the U.S. Digest of Education Statistics (2003), in 2000, in traditional public and public charter elementary and secondary schools, less than 15% of the teaching force was minority, contrasted with a growing minority student population of 32%.

Securing a sufficient force of highly-qualified teachers to staff U.S. public schools has become a critical concern in education communities across the country. Thus, interest in teacher preparation and qualifications has increased on the national agenda during the past two decades as never before (Rice & Brent, 2002; Ruhland & Bremer, 2002; Wise, 2000). As growing consciousness of the importance of teacher quality linked with teacher shortage brought ATCPs to the forefront of U.S. educational policy agendas (Feistritzer, 1999; Rice & Brent).

I am a former teacher of general science, grades six through eight, and biology, grades 9 through 11, in Batman, Turkey, with three years of experience. I also have two years experience working as a biology teaching assistant at a college preparation organization. I often met with secondary science teachers who said that
they were having difficulty conveying the material to their students. The teachers were frustrated by this. Beginning teachers especially felt they were facing a daunting task. The frustrations they experienced made them feel incompetent.

I had my first teaching experience when I was a junior in college majoring in biology teaching, a couple months from becoming a senior. I taught a biology topic, energy in cells, to senior high school students and high school graduates. Right after this teaching experience, I realized that I had never been taught to emphasize the important ideas, only the facts, even though the teachers college I graduated from is a nationally recognized teachers colleges and Turkey’s first college of education. Subsequent to my first experience in the classroom and prior to my entry into the teaching field, the real world where teaching takes place, I searched for information that would help me be a better teacher.

In Turkey, as in the rest of the world, there were and presently are teacher shortages in certain regions, provinces, and schools, and a specific need for teachers of certain subjects. In the same year that I started my teaching career, to compensate for the shortage of teachers, the Turkish government recruited graduates (other than education majors) of 4-year colleges to become teachers. After this, tens of thousands were recruited and assigned to teaching positions where they were needed, without being provided with formal training before entering the classroom. The idea was that these people would be provided with necessary training to compensate their teaching expertise deficits while working as teachers, a kind of on-the-job training. Many of these recruited graduates believed that they already had sufficient knowledge to be teachers and viewed learning the practice of teaching as trivial.

Aware of my own deficiencies as a beginning science teacher, I met with some of these recently recruited teachers assigned to teaching positions at the school where
I was employed as a middle school science teacher. I witnessed the transition of these beginning teachers and the difficulties they faced. My interest in ATCPs stems from my experiences during my first year of teaching.

Research Questions

An overarching question and five sub-questions guided the design, implementation, and analysis of the study.

*Overarching Question*

How do alternative certification science teachers in the Alternative Science Teacher Education Program (A-STEP) understand and implement inquiry-based instruction in their beginning years of teaching?

*Sub-Questions*

1. What do alternatively certified beginning science teachers mean by classroom inquiry?
2. How do alternatively certified beginning science teachers implement inquiry-based instruction in their teaching?
3. What do alternatively certified beginning science teachers perceive as constraints, challenges, and needs for implementing inquiry-based instruction?
4. What do alternatively certified beginning science teachers perceive as factors that facilitate their implementation of inquiry-based instruction?
5. How are alternatively certified beginning teachers’ experiences of teaching science through inquiry related to what they learn in their ATCP?
Conceptual Framework

One key concept, inquiry, framed this study. Following, I explain the concept in relation to the context of the study.

Recent science education reform literature (i.e., American Association for the Advancement of Science [AAAS], 1989, 1993) and National Science Education Standards [NSES] (National Research Council [NRC], 1996) emphasizes “teaching science as inquiry” as a core principle for science education. Yet “inquiry” has a persistent history as a central term in science education in the U.S. (Abd-El-Khalick et al., 2004; Anderson, 2002; Bybee, 2000).

In Teaching Science as Inquiry (2000), Bybee provided details on the roots of inquiry. He stated that the history of inquiry goes back to late nineteenth century. Advocates such as Charles W. Eliot, president of Harvard University, articulated the need for science and laboratory approaches in the school curriculum. Louis Agassiz provided an early example of teaching science as inquiry.

From the nineteenth century until today’s reform movement, several people, including Dewey, Schwab, and Rutherford, emphasized the role of inquiry in science teaching and education. Following, I briefly discuss the arguments that John Dewey, Joseph Schwab, and James Rutherford provided regarding inquiry. Then I discuss recent reform documents related inquiry-based science teaching.

John Dewey was the leader of the progressive movement in education during the early part of the 20th century. Dewey is frequently cited by science educators as a pioneer in education who emphasized the role of inquiry in science education. Dewey stated that science teaching overemphasized the “accumulation of ready-made material with which students are to be made familiar, not enough as a method of thinking, an attitude of mind, after the pattern of which mental habits are to be
transformed” (Dewey, 1910, p. 122). He explained, “Knowledge of human affairs couched in personal terms seems more intimately appealing than knowledge of physical things conveyed in impersonal terms” (p. 122). Therefore, inquiry was a central component of Dewey’s educational philosophy. He wrote that developing thinking and reasoning, formulating habits of mind learning science subjects and understanding the process of science were objectives for teaching science through inquiry.

During the 1960s, Joseph Schwab suggested that science should be presented as inquiry and students should carry out inquiry activities (Schwab, 1960). As an alternative to the teaching of science as a presentation of facts already known, Schwab (1960) put forward enquiry (his choice of spelling) as a way of teaching classroom science. He emphasized, “We need to imbue our courses and exposition with the color of science as enquiry. We need to give the student an effective glimpse of the vicissitudes of research” (p. 9). According to Bybee (2000), Schwab laid the foundation for the emergence of inquiry as a prominent theme in curriculum reform of that era. Schwab had a direct influence on the original design of instructional materials for the Biological Sciences Curriculum Study (BSCS).

Also during the 1960s, educator James Rutherford noted that “teaching science as inquiry” needed clarification. He observed that inquiry was being used in at least two general ways. He explained, “Sometimes it is employed in a way which emphasizes that inquiry is really part of content itself” (p. 80), adding that “At other times, the phrase ‘teaching science as inquiry’ is used to refer [to] a particular technique or strategy for bringing about learning of some particular science content” (p. 80). Thus, he made the distinction between inquiry as content and inquiry as technique (Rutherford, 1964). The former in essence refers to studying about the
nature of scientific inquiry while the latter refers to using inquiry as an instructional strategy.

Today’s reform movement in science education began with the publication of Project 2061: *Science for All Americans* (AAAS, 1989) and continued with the publication the *NSES* in 1996. The reform rhetoric in these documents revitalized the concept of inquiry as the essence of science education, placing extensive emphasis on inquiry as the central strategy for teaching science (Abd-El-Khalick et al., 2004).

The *NSES* uses inquiry in three different ways: scientific inquiry, inquiry learning, and inquiry teaching (Anderson, 2002; Bybee, 2004; Flick & Lederman, 2004). “Each one is fairly distinct from the other two, even though each has various nuances,” explained Anderson (p. 2).

The use of “scientific inquiry” in the *NSES* reflects an understanding of “‘science as process,’ in which students learn such skills as observing, inferring, and experimenting” (NRC, 1996, p. 2) and is independent of instructional strategy. “Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work” (NRC, p. 23).

When inquiry is used in the manner of “inquiry learning,” it refers to a learning process wherein students are engaged. This active learning process reflects the nature of scientific inquiry (Anderson, 2002; Flick & Lederman, 2004). The *NSES* (NRC, 1996) rest on the premise that learning science requires students’ involvement both in “Hands-on” and “Minds-on” activities.

Finally, inquiry in the *NSES* (NRC, 1996) viewed as a teaching approach (Anderson, 2002; Bybee, 2004; Flick & Lederman, 2004). However, Anderson affirms that “*NSES* contains no precise operational definition of inquiry teaching” (p.
3). Some of the descriptions of inquiry as teaching as depicted by NSES include: (a) Inquiry as the activities in which students develop knowledge and understandings of scientific ideas, as well as an understanding of how scientists study the natural world; (b) Inquiry as activities that involve students in generating authentic questions from their experiences; (c) Inquiry as activities that provide a basis for observation, data collection, reflection, and analysis of firsthand events and phenomena; (d) Inquiry as activities that encourage the critical analysis of secondary sources—including media, books, and journals in a library.

In addition to these three meanings associated with classroom inquiry, the NRC’s *Inquiry and the National Science Education Standards: A guide for Teaching and Learning* (NRC, 2000) further details a practical guide to teaching inquiry and teaching through inquiry. It describes the components of inquiry-based teaching, essential features of inquiry. According to the NSES, learners (a) are “engaged by scientifically oriented questions,” (b) “give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions,” (c) “formulate explanations from evidence to address scientifically oriented questions,” (d) “evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding,” and (e) “communicate and justify their proposed explanations” (NRC, 2000, p. 25).

Bybee (2004) noted that as “an approach to teaching and learning, the essential features of inquiry should not necessarily be defined as ‘activity-based, hands-on’ or other approaches to teaching” (p. 5). He stated, “Too often, such terms serve as the ends; the goals as though doing activities in themselves were the aim and the defining quality of our inquiry approach to teaching” (p. 5).
In this study, the terms “inquiry,” “inquiry teaching” or “inquiry-oriented activities” are used to refer to pedagogical approaches modeling the general process of investigation that scientists use as they attempt to answer questions about the natural world—scientific inquiry. I use NRC’s (1996) definition of inquiry that reflects on inquiry as “multifaceted activity” (p. 23). According to this definition, in inquiry-oriented activities, learners make observations, pose questions, and examine books and other sources of information to see what is already known. Based on the observations, learners plan investigations, review what is already known in light of experimental evidences, and use tools to gather, analyze, and interpret data. Finally, learners propose answers, explanations and predictions, and communicate the results. This meaning of inquiry reflects on the five essential features of classroom inquiry outlined in “Table 2.6: Essential Features of Classroom Inquiry and Their Variations” (NRC, 2000, p. 29). In the context of this study, to understand and compare the meanings of inquiry held by alternatively certified science teachers from various disciplines, I use the five essential features of inquiry as my operational concept.

Also, to avoid creating confusion to readers, below I provide a brief description of types of inquiry that I refer to elsewhere in this study.

**Types of Inquiry**


*Open Inquiry*

This refers to student-centered activities that require the presence of all five features of inquiry (NRC, 2000) to be attained by students. It requires higher-order thinking and students working directly with the material, concept, equipment, and so forth. In many ways, it is comparable doing science. The key to inquiry here is
students asking the questions that guide their own investigation (Colburn, 2000; Martin-Hansen, 2002).

*Guided Inquiry*

During these types of activities, teachers help students initiate inquiry-oriented activities. While students involve in guided inquiry, they do not necessarily have to attain all features of inquiry on their own. For instance, the teacher can provide a scientifically-oriented question and data for students to use in inquiry. Martin-Hansen (2002) wrote that, “Teachers find that this is a time when specific skills needed for future open-inquiry investigations can be taught within context. Guided inquiry is a natural lead-in to open-inquiry” (p. 35).

*Coupled Inquiry or Learning Cycle*

This approach incorporates two types of inquiry: guided inquiry and open inquiry. Using this approach the teacher begins the activity with an invitation to inquiry along with guided inquiry that leads to open inquiry (Colburn, 2000; Martin-Hansen, 2002). Martin-Hansen described the cycle as follows: “1) an invitation to inquiry, 2) teacher-initiated ‘guided inquiry,’ 3) student-initiated ‘open inquiry,’ 4) inquiry resolution, and 5) assessment” (p. 35).

*Structured Inquiry*

Martin-Hansen (2002) stated that structured inquiry is guided inquiry directed by the teacher. Both Colburn (2000) and Martin-Hansen described this type of inquiry as similar to “cookbook” style activities which provide more direction to students than structured inquiry does. Colburn explained, “The teacher provides students with a hands-on problem to investigate, as well as the procedures, and materials, but does not inform them of expected outcomes. Students are to discover relationships between variables or otherwise generalize from data collected,” (p. 42).
These views of inquiry guided the study to analyze participants’ views and practice of inquiry-based teaching.

Significance of the Study

Reforming science education at any level and phase depends on teachers (Committee on Science and Mathematics Teacher Preparation, 2001). However, alternatively certified beginning science teachers’ understanding and use of classroom inquiry has not been studied. I aim to begin to address this gap in the literature through the present study. Understanding the beginning years of teaching will help inform teacher preparation programs, both traditional and alternative. Improved ATCPs will strengthen teachers’ knowledge and produce highly-qualified science teachers. So, recognizing common concerns and gaps in understanding classroom inquiry is critical to improving the design and implementation of ATCPs. Understanding alternatively certified beginning science teachers’ practice of inquiry in the beginning years of science teaching is thus significant.

Organization of the Dissertation

This research study is organized in six chapters. Subsequently, I provide a brief description of the upcoming chapters.

Chapter Two

In Chapter Two, I elaborate on the concepts introduced in Chapter One, focusing on how they have been discussed within the research literature.

Chapter Three

Chapter Three outlines description of the guiding research tradition and the design of the study. I also provide detailed information on the ATCP program, the research participants, methodological issues (i.e., data collection and analysis),
anticipated limitations of the study, and actions I took to increase the credibility of the study.

\textit{Chapter Four}

This chapter consists of two sections. The first section summarizes two ATCP program faculty members’ formal understanding of inquiry as implemented in science method courses they taught to the research participants. This section also elaborates on their intended teaching goals and summary. The second section includes four individual teacher profiles. Each profile is divided into the following sections: background, teaching context, meaning of inquiry, constraints and needs, and factors that promote inquiry-based activities, including the relation between a teacher’s education in the ATCP program and how it influenced their teaching styles. A summary concludes each profile.

\textit{Chapter Five}

Based on the full data set and the profiles presented in Chapter Four, I present findings in forms of assertions. The assertions emerged from cross-case analysis of four profiles. In discussing each of the assertions, relevant data from participant interviews and from interviews with the ATCP program faculty members, where appropriate, are utilized in order to answer research question.

\textit{Chapter Six}

In this final chapter, I discuss the research findings in relation to the literature reviewed in Chapter Two. I then conclude with implications for practice and recommendations for future research.
CHAPTER TWO: LITERATURE REVIEW

This chapter is arranged around four research areas that guided this research. These research areas, in order of presentation, are: a) defining teacher quality; b) alternative certification as one vehicle to producing more highly qualified teachers; c) inquiry and science teaching; and d) beginning science teachers. In closing the chapter, I provide a summary of the gaps found in the literature that this study is aiming to address.

What is Teacher Quality?

The need to strengthen science education in the United States has been widely recognized in numerous education policy documents of the 1980s (AAAS, 1989), and has resulted in documents declaring the priorities and agendas for reforming K-12 science education (e.g., AAAS, 1989, 1993; NRC, 1996). One of the recognized priorities is the preparation of highly-qualified science teachers, so that scientific literacy goals can be reached.

As of December 1, 2002, the No Child Left Behind (NCLB) Act of 2001 set requirements for teachers to be “highly qualified” when they teach core academic subjects (U.S. Department of Education, 2002). These academic core subjects are English, reading or language arts, mathematics, science, foreign languages, civics and government, economics, arts, history, and geography (Bassett, Campbell, Hirsch, Hupfeld, & Reichardt, 2004). The federal NCLB required that all teachers in core academic subjects be highly qualified by the end of the 2005-2006 school year and provided some resources to help states and districts meet this goal.

According to NCLB, to be deemed highly qualified, teachers must be fully licensed, demonstrate content knowledge, and have a bachelor’s degree (U.S. Department of Education, 2002). In the state of Missouri, for example, ATCP teachers
are considered “highly qualified” while teaching during their alternative preparation program because they hold a certification, albeit a temporary one (Missouri Department of Elementary and Secondary Education, 1999).

Zumwalt and Craig (2005) reviewed the research literature on teacher’s characteristics in terms of research on the indicators of quality. They examined teacher quality as assessed by such proxy college entrance tests (SAT and ACT), college GPA, college major, status of college attended, and teacher and state tests in relation to demographic variables of in- and pre-service teachers. In particular, they concentrated on the connections between academic ability and achievement. They argued that the studies conducted on teacher quality in the past focused on personal qualities and behavioral performance as compared to the current emphasis on intellectual competence and their students’ performance. Zumwalt and Craig discussed the findings from the last two decades that teachers who were academically able were not drawn to teaching and that those who were in teaching were less academically able than those in other careers. They considered the data from these studies as flawed because the data relied on high school students’ responses to SAT or ACT questions on intentions to teach.

“The dismal picture of lower academic ability and achievement of prospective teachers appears modified in the recent research literature” (Zumwalt & Craig 2005, p. 160). They explained that the raised requirements for entry into teacher education and state certification processes have increased the quality profile of teachers as measured by SAT, ACT, and GPA. They noted that the current research shows that those who go into teaching have GPAs comparable to those in other fields, and their standardized test scores are at or above the national average. In regard to the SAT and ACT, the studies Zumwalt and Craig reviewed revealed that researchers typically
presented scores in terms of quartile. Studies discovered that a large number of those in the lower quartiles dropped out along the teacher education pipeline. Interestingly, it was the same for the lower portion of the top quartile of those who took a job in the teaching profession. Zumwalt and Craig also drew attention to the connection between teacher quality and student outcomes. Although some studies demonstrate a positive relationship between teacher verbal ability and student achievement, it is not clear what level of teacher verbal ability makes a difference or what other teacher quality indicators might contribute to that relationship.

Finally, Zumwalt and Craig (2005) reported that there has not been much research to determine how teacher quality variables align with a teacher’s actual practice. They stated, “The perceived intellectual inferiority of teachers and education as a field of study helped make standardized test scores the most used indicators of quality,” (p. 183). They acknowledged that other aspects of intellectual competence critical to teaching have not been captured in research. One critical aspect of teacher quality that they highlight is teaching understanding and appreciation of subject matter and pedagogy.

While NCLB associates the term “highly-qualified” with teacher subject matter knowledge or expertise (U.S. Department of Education, 2002), Shulman and his colleagues (Grossman, 1990; Grossman, Wilson, & Shulman, 1989; Shulman, 1986, 1987; Wilson, Shulman, & Richert, 1987) correlate the term with Pedagogical Content Knowledge (PCK), the type of knowledge that distinguishes teachers from subject matter specialists (Shulman, 1986). Ball (2000) defined subject matter knowledge for teaching as a special amalgam of knowledge linking content and pedagogy.
Shulman (1987) defined PCK as “the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented and adapted to the diverse interests and abilities of the learners, and presented for instruction” (p. 8). Volkmann, Arbaugh, Scribner, Lannin, and Abell (2005) claimed the NCLB definition of highly-qualified was a simplistic view of teaching, while identifying PCK as a more complex view of what makes a teacher highly qualified. According to the complex view of teaching which is represented by PCK (Volkmann et al.), teachers need to have certain knowledge—knowledge of inquiry strategies and activities—, dispositions and skills to be considered highly-qualified.

Science education reform documents, on the other hand, connect teacher quality with vision of science teaching as portrayed by national standards. The NSES (NRC, 1996) highlight the importance of teachers in science education and deem that “Teachers must have theoretical and practical knowledge and abilities about science, learning, and science teaching” (p. 28). The standards regard effective teachers of science as those who create an environment wherein they and students work together as active learners. The NSES teaching standards (see Table 1) spell out criteria for making judgments about science teacher quality.
Alternative Certifications as One Way to Make More Highly Qualified Teachers

National need for more high quality teachers has led to new policies and practices regarding alternative paths to teacher certification.

Even though it is clear that there is no agreement about the definition of ATCP (Dill, 1996), in general, the term is used to refer to nontraditional paths into the teaching field (Ruhland & Bremer, 2002). Feistritzer and Chester (2001) described the term as follows:

The term “alternative teacher certification” has been used to refer to every avenue to becoming licensed to teach, from emergency certification to very sophisticated and well-designed programs that address the professional preparation needs of the growing population of individuals who already have at least a baccalaureate degree and considerable life experience and want to become teachers. (p. 3)
ATCPs usually intend to recruit particular groups into the teaching profession or address specific types of teacher shortages (Allen, 2003; Brannan & Reichardt, 2002). For instance, some programs seek out teachers in specific subject areas (e.g., mathematics and science), teachers for specific grade levels (e.g., middle school teachers), teachers for specific settings (e.g., urban schools), or teachers for specific demographic needs (e.g., increased gender or ethnic diversity in the teaching workforce) (Brannan & Reichardt; Haberman, 2000). In general, these alternative routes to certification are designed to allow individuals with significant subject-matter background to complete their teacher preparation in a shorter timeframe than candidates in traditional teacher preparation programs (Bradshaw, 1998; Wright, 2001).

**Historical Perspective**

The state of New Jersey was the first state to enact legislation for initiation of an ATCP in the early 1980s (Bassett et al., 2004; Feistritzer, 1999). Although this alternate route to certification was the outcome of study and discussion that took more than two years, as noted by Cooperman and Klagholz (1985), it had broader connotations reflecting “20 years of thinking about the need to reform teacher education in the U.S.” (p. 692). In 1985, following the state of New Jersey, the state of Texas became the first state to implement a district-level ATCP in the Houston Independent School District, justifying the program based on teacher shortage projections (Feistritzer).

In the two decades since the state of New Jersey launched the first ATCP in the U.S., not only have the number of states with instituted legislation for alternative certification increased, but more and more institutions of higher education have initiated their own ATCPs that lead to teacher licensure. Feistritzer and Chester
reported that 46 states and the District of Columbia had implemented at least one such program by 2003; in 1983, only eight states reported that they had alternative routes to teaching. A great number of researchers indicate that interest in the number of states employing ATCPs has grown significantly (Bassett, et al., 2004; Feistritzer, 1993; Feistritzer & Chester, 2001, 2003; Kwiatkowski, 1999; Wise, 1994).

Kwiatkowski mentioned that between 1983 and 1996, more than 50,000 individuals in the U.S. received alternative certification while Feistritzer and Chester’s (2003) estimation was over 200,000 individuals by 2003—25% of teacher hire.

Finally, as set forth on page one of this chapter, the federal NCLB legislation also has played an important role in increasing the number of ATCPs. In a state of Missouri for example, ATCP teachers are considered “highly qualified” while teaching during their alternative preparation program because they hold a certification, albeit a temporary one.

The Debate between the Professionalization and the Deregulation Agenda

Much of the debate about teacher quality has centered around two agendas for teacher preparation—the professionalization agenda and the deregulation agenda—(Zeichner, 2003). Proponents of these two agendas agree on certain things, such as providing all students with fully qualified and effective teachers, the reality of only some students having access to these teachers, the critical importance of teachers’ subject matter knowledge, and the importance of providing a high-quality education to all students in U.S. public schools (Darling-Hammond, 1992). However, at the same time, they propose very different solutions to reform and improve teacher education programs across the U.S. (Zeichner).
The professionalization agenda is a broad-based attempt to increase successful approaches to teacher education nationwide based on high standards for the initial preparation, licensing, and certification of teachers as well as teacher performance assessments across the professional lifespan (Cochran-Smith & Fries, 2001; Zeichner). The deregulation agenda, on the other hand, is in direct opposition as it attempts to deregulate teacher preparation by dismantling teacher education institutions and breaking up the cartel of colleges and universities that provide initial teacher education programs by encouraging ATCPs (Cochran-Smith & Fries; Kanstroroom & Finn, 1999; Schaefer, 1999).

Among four orientations or paradigms that have dominated the discourse of debate in teacher education—behavioristic, personalistic, traditional-craft, and inquiry-oriented—ATCPs are typically based upon the traditional-craft paradigm. In this paradigm, teacher preparation is viewed primarily as a process of apprenticeship (Cochran-Smith & Fries, 2001; Kanstroroom & Finn, 1999; Schaefer, 1999; Zeichner, 2003). This orientation is based upon a notion of “teaching as a craft and of teachers as craftspersons” (Zeichner, 1983, p. 5).

According to this view, knowledge about teaching is accumulated largely by trial and error and is to be found in the “wisdom of the experienced practitioners” (Floden & Lanier, 1979). It is further assumed that much of this accumulated knowledge is tacit and not amenable to the kind of specification that is attempted in behavioristic approaches….The central problem of teacher education from traditional-craft paradigm point of view is to bring to focal awareness the subsidiary knowledge that constitutes good practice. A master-apprentice relationship is seen as the proper vehicle for transmitting the “cultural knowledge” possessed by good teachers to the novice (Zeichner, p. 5).
Many advocates of ATCPs call for the abolition of state certification rules and for the licensing of teachers with bachelor’s degrees who can demonstrate proficiency in the subjects they are to teach. They assert that subject matter knowledge and teachers’ verbal ability are the determining factors of successful teaching. Thus, they believe that much of what is offered in professional education methods and foundations courses can be learned on the job through an apprenticeship (Ballou & Podgursky, 1999, 2000; Cochran-Smith & Fries, 2001; Hawley, 1990; Kanstroroom & Finn, 1999; Schaefer, 1999; Zeichner, 2003). In contrast, supporters of the professionalization agenda believe that reform-minded teaching (including inquiry-based instruction) requires a strong teacher education program to produce highly-qualified teachers (Darling-Hammond, 1992, 1998, 2000b, 2000c; Hewson, Tabachnick, Zeichner, & Lemberger, 1999; National Commission on Teaching and America’s Future [NCTAF], 1996, 1997; Shen, 1997).

Research findings about ATCPs demonstrate little consensus. Zeichner and Schulte (2001) described the current situation of alternative certification as “one of the most controversial and confusing topics in the discourse about U.S. teacher education during the past 20 years” (p. 266). Goldhaber and Brewer (2000) found out that there was no difference between alternatively and traditionally prepared teachers in terms of their performance. Likewise, Cochran-Smith and Zeichner (2005), in their chapter “Studying Teacher Education: The Report of the AERA panel on Research and Teacher Education,” noted that no studies demonstrate a difference between alternative and traditional teachers in terms of teacher efficacy or competency. However, when performance differences were found between these two groups of teachers, researchers attributed the difference to the quality of the teacher preparation.
programs, whether those programs were traditional or alternative (North Central Regional Educational Laboratory, 2002; Zeichner & Schulte).

Proponents of the professionalization and deregulation agendas have been working to convince audiences (policymakers, educators, program directors, researchers, and the public) that their recommended policies are justifiable and warranted by the outcomes. These agendas have some common characteristics, but also some competing and even opposing characteristics (Cochran-Smith, 2001; Zeichner, 2003).

In particular, the evaluation of ATCPs becomes harder as proponents of each agenda attempt to construct the agenda’s own merit while undermining the justification of the other (Cochran-Smith & Fries, 2001). According to Cochran-Smith and Fries, they accomplish this by critiquing each others’ studies in explicit detail. While doing so, each side interrogates the other’s claims by looking at their methodologies, data and logic (e.g., where methodological errors have been made, where the data reported are incorrect or incomplete, and where faulty logic or reasoning have led to inaccuracies and errors about the nature or size of effects) (Cochran-Smith & Fries). Advocates of each agenda build their own case as if they were neutral, apolitical, and value-free, based exclusively on the empirical and certified facts of the subject. Gee (1996) labeled this action “Napoleon’s move” (as cited in Cochran-Smith & Fries, p. 6).

The state of this debate demonstrates that neutrality is virtually absent from the research. Not only has it been difficult to generalize the findings, but it also has been difficult for audiences to evaluate the success of ATCPs. Variation among ATCPs across the country makes it even more difficult to reach sound generalizations (Bassett et al., 2004; Dill, 1996, Darling- Hammond, 1998; Hawley, 1990; Wilson,
Floden, & Ferrini-Mundy, 2001). Neither underestimating nor praising ATCPs will help improve a program that serves the purpose for which it was developed. In the face of these debates, what needs to happen is the development of a constructive approach that would take into account the strengths of both positions while structuring teacher education programs. While in the short run ATCPs may solve the problem of teacher shortages, they must be carefully designed and implemented if they are to produce qualified and competent teachers (Abell, Volkmann, Arbaugh, Lannin, & Boone, 2003). In light of these debates, the goals of science teacher alternative certification programs should be to improve both the quantity and quality of candidates (Abell et al., in press; Gold, 1996; Huling-Austin, 1990, 1992; Luft & Patterson, 2002). This goal requires a vision to design ATCPs that address the needs of beginning science teachers in implementing inquiry-based activities in K-12 science classrooms.

Inquiry and Science Teaching

*What is Inquiry?*

Attempts to engage students in inquiry-based instruction date back to Dewey. Inquiry teaching has been part of educational settings ever since, regardless of the different meanings ascribed to it (Bybee, 2004; DeBoer, 2004). Dewey (1910) noted that developing thinking and reasoning, formulating habits of mind, learning science subjects, and understanding the process of science were the objectives of teaching science through inquiry. The area of “hands-on” science was promoted in 1960s. The idea was to engage students in science as practiced by scientists using “hands-on” activities. The notion that drove the efforts was that students might develop scientific concepts and ideas as a result of their involvement in investigative settings (AAAS, 1967; Rutherford, 1964; Schwab, 1962). Since then, science processes have been a
part of the science curriculum and have added new targets of and procedures for instruction (Holliday, 2004).

Recent reforms in science education emphasize the importance of inquiry experiences for K-12 students (AAAS, 1989, 1993; NRC, 1996, 2000). Project 2061 (AAAS, 1989) and the *NSES* standards (NRC, 1996) defined inquiry as both a pedagogical strategy and a learning goal. Project 2061, for example, defined the goal of inquiry teaching as “help[ing] people in every walk of life to deal sensibly with problems that often involve evidence, quantitative considerations, logical arguments, and uncertainty (p. xiv). Similarly, DeBoer (2004) explained how scientific inquiry as a model for pedagogy can serve many purposes by having students model scientific inquiry either in general or in a more focused way. The purposes include: a) the preparation of future scientists; b) the development of citizens who will be autonomous, independent thinkers; c) as a pedagogical tool; and d) as a motivational power to teaching science.

The *NSES* considers inquiry-based teaching the foundation for the standards. However, the uses of inquiry in *NSES* show variation in terms of meaning: scientific inquiry, inquiry learning, and inquiry teaching (Anderson, 2002; Bybee, 2004; Flick & Lederman, 2004). These authors agreed that each one of these meanings is fairly distinct from the other (for more information see Chapter 1). DeBoer (2004) stressed that science is both process and product whether it is practiced by scientists or studied in classrooms. “It is important to note, however, inquiry teaching does not require students to behave exactly as scientists do. Scientific inquiry is simply a metaphor for what goes on in an inquiry-based classroom (p. 17).”

Current science textbooks and laboratory manuals portray a different image of inquiry from how it is described by recent reform documents (e.g., AAAS, 1989;
NRC, 1996, 2000). Inquiry is often used alongside other terms that represent similar teaching practices. Some of these terms include, but are not limited to, inquiry as: conceptual change, constructivism, hands-on, and generative teaching practice (Hayes, 2002). Of course, as Hayes stressed, there are many differences among these teaching practices, including the roles that students and teachers take.

*Research on Views of Inquiry*

Inquiry-based teaching has a long history in the U.S. education system. Unfortunately, inquiry has not yet become the norm in U.S. science classrooms. Researchers have related the failure with deficiencies in teachers’ understanding of inquiry (Colburn, n/a; Holliday, 2004; DeBoer, 2004). Yet, science teachers demonstrate a wide variety of conceptions of inquiry. While some teachers relate inquiry to learning that is driven by questions coming from the teacher or students, many think of it as including any sort of hands-on activity (e.g., Hayes, 2002). Keys and Bryan (2001) and Llewellyn (2001) stated that these different conceptions and misconceptions influence the ways in which inquiry-based instruction is or is not implemented in classrooms.

“The meaning of the term inquiry-based instruction when applied to classroom practice often becomes muddled, and the integrity of the inquiry-based instruction can be lost,” (Crawford, 2000, p. 918). To illustrate, science teachers may view their teaching as reform-based—holding beliefs that are not consistent with their actions (Brown & Melear, 2006; Simmons et al., 1999); they may believe that inquiry-teaching means activities where there is either no teacher or less teacher intervention (Holliday, 2004).

Holiday (2004) pointed out to the variant views of inquiry that teachers hold. He said that inquiry teaching as pedagogy includes a variety of approaches to
teaching, but rarely encourages explicit, direct explanations instructionally articulated by the teacher. Holliday mentioned, “No one, including teachers, social science researchers and practicing physical scientists can, of course, provide fixed, rigid, cookie-cutter, one-size-fits-all, precise, rule-like algorithms for when teachers should favor more explicit or more implicit science teaching approaches” (p. 204). He suggested that teachers need to be aware of the situation in order to be able to employ a mixture of back-and-forth, non-linear combinations of implicit and explicit teaching depending on their professional judgments.

The need for science teachers to develop views of inquiry reflecting reform documents (AAAS, 1989; 1993; NRC, 1996, 2000) has encouraged researchers to study the meaning of inquiry held by K-16 teachers, including both novice and experts (e.g., Brown, Abell, Demir, & Schmidt, 2006; Harwood, Reiff, & Phillipson; 2002; Hayes, 2002; Keys & Kennedy, 1999; Koballa, Glynn, Upson, &, Coleman, 2005; Luft & Patterson, 2002; Wallace & Kang, 2004).

In higher education, two studies (Brown et al., 2006; Harwood et al., 2002) conducted on the views of inquiry held by science faculty members disclosed the similarity between their participants’ views of inquiry. One of the common findings of these studies was the emphasis that faculty members placed on the role of questions in scientific inquiry. Harwood et al. interviewed 52 science faculty members across nine science departments (life, physical and medical sciences) about their conceptions of scientific inquiry. The researchers found that the scientists depicted questions as one of the key features of scientific inquiry, which drive investigations, moving from the known to the unknown. In their study, Brown et al. investigated 19 college professors’ views of inquiry. The participants of this study represented both life and physical science disciplines from different types of institutions (two-year community college;
small, private non-profit liberal arts college; public master’s granting university; and public doctoral/research extensive university). Brown et al. argued that science faculty members held a “full and open inquiry” view, seeing classroom inquiry as time-consuming, unstructured, and student-directed. Brown et al. drew attention to research participants’ incomplete view of inquiry. This incomplete view emphasized the role of questioning and collecting data, but left out the role of other essential features of inquiry, including explanation, and justification.

Likewise, Wallace and Kang (2004) investigated the views of six experienced high school science teachers’ practice of inquiry after their participation in volunteer summer workshops on inquiry. These teachers’ experiences ranged from 12 to 29 years. The findings of this study illuminated that the teachers held competing belief sets, constraining and promoting. The belief sets that constrained inquiry-based teaching stemmed from school culture and centered on constraining factors that limit inquiry. On the other hand, the belief sets that promoted inquiry were more private and based on the individual teacher’s notion of successful science learning.

In another study, Hubbard and Abell (2005) examined six elementary preservice teachers’ beliefs about science teaching and learning in a science methods course. Researchers compared students who had experienced an inquiry-based science course with those who had not. They found out that elementary preservice teachers who had taken an inquiry-based science course in their teacher preparation programs were more ready to consider inquiry-based instruction. They also noted that students who were concurrently enrolled in the inquiry-oriented science course began to revise their incoming beliefs towards inquiry while preservice teachers who had no experience in the inquiry-based science course “maintained their limited view that science teaching should be “fun,” with the teacher as teller and fun-maker” (p. 5).
After reviewing several elementary teachers’ views of inquiry Keys and Bryan (2001) asserted that these teachers overwhelmingly put inquiry-based instruction into practice in terms of students’ authentic questions. This affirms studies that have been conducted in some other level of education (e.g. Brown et al., 2006; Harwood et al., 2002). In a case study, Keys and Kennedy (1999) examined an experienced fourth grade elementary teacher, Ms. Kennedy, and how understanding of inquiry teaching after involvement in a mathematics and science education reform project for two years. The researchers reported that Ms. Kennedy invented her own approach to inquiry teaching that matched her personal views of the science curriculum and role as teacher.

Koballa et al. (2005) revealed that novice teachers’ conceptions of teaching science did not noticeably change during the time of the study— one academic year and two summers. They found out that because of participants’ different backgrounds, experiences, and conceptions of teaching science, their views were resistant to change and not aligned well with national standards for teaching practice, even in the face of well-intentioned instruction. Similarly, Simmons’ et al. (1999) study of beginning secondary science and mathematics teachers revealed that, for the most part, their beliefs and practices fluctuated between constructivist and didactic style, and that the teachers held beliefs and practices that were often inconsistent with one another.

In a study that Luft and Patterson (2002) conducted with beginning secondary science teachers in an induction program, they reported that 75% of the participating teachers who attended the induction that took place over the course of a 9-month school year felt that the program had significantly challenged their views about teaching science. This study suggested that beginning teachers had pliable beliefs and practices that could be moved toward standards-based ideals, and that both school
district and university personnel influenced the beliefs and practices of beginning teachers.

It is likely there are many causes shaping beginning science teachers’ views of inquiry. Researchers have drawn attention to a number of experiences that can influence their conceptions and views of inquiry, most of which originated from previous science learning situations. These experiences can range from teachers’ past experiences as K-12 students, to their preservice laboratory practice at the undergraduate level, to coursework in teacher education (e.g., Grossman et al, 1989; Hubbard & Abell, 2005; Koballa et al., 2005; Lee & Krapfl, 2002; Lortie, 1975; Luft & Patterson, 2002; Roth, 1999; Windschitl; 2003). Lortie (1975), for example, found that a teacher’s views about teaching are a product of some 30,000 hours in the “apprenticeship of observation” that takes place in K-16 schooling. Both the U.S. Department of Education report (1999) on student work and teacher practices and the Tobin, Tippins and Gallard (1994) study on instructional strategies for teaching science confirm Lortie’s finding. According to the Department of Education’s report, for example, 69% of twelfth graders who participated in the survey indicated that they had “never” or “hardly ever” designed and carried out their own investigation. Tobin and his associates discovered that inquiry was not characteristic of science classrooms in the studies they reviewed. They noted that inquiry taking place in these classrooms was more representation of confirmatory activities and structured inquiries.

Many of these experiences are more likely to distort beginning science teachers’ views of inquiry than they are to enhance it (Windschitl, 2003). Thus, researchers have recommended integrating more inquiry-oriented experiences both into undergraduate science courses and into teacher preparation courses to help beginning science teachers develop strong understandings of inquiry (e.g, Roth, 1999;
Tamir, 1983; Welch, Klopfer, Aikenhead, & Robinson, 1981; Windschitl, 2003). In addition to integrating more inquiry, Koballa et al. (2005) also suggested that teacher educators should attend to the conceptions of teaching held by beginning science teachers. Brown et al. (2006) proposed a two dimensional “Inquiry Continuum” in order to promote inquiry-based instruction in undergraduate science courses (see figure 1 in Brown et al. for more information). They noted how different classroom inquiry possibilities including all essential features of inquiry (NRC, 2000) can fall in different locations on the Inquiry Continuum.

The studies that I present illuminate the views of inquiry held by teachers of all levels, from elementary to undergraduate. One of the common findings of all the studies is the incomplete meaning of inquiry held by teachers whether they were preservice teachers, faculty members involved in teaching undergraduate science courses, or inservice teachers.

**How Is Inquiry Practiced?**

As beginning science teachers enter the profession of teaching, they are expected to implement inquiry-oriented teaching in their classrooms following the guiding principles of the reform documents (e.g., AAAS, 1989, 1993; NRC, 1996, 2000). However, teaching through inquiry calls on a lot of strategies that many expert teachers do not have (Volkmann, Abell, & Zgagacz, 2005). Thus, efforts to implement inquiry in science classrooms have been confronted by a great number of barriers.

A number of studies have looked at factors that impact science teachers’ capability and motivation to implement inquiry as a teaching approach in their classrooms (e.g., Brown & Melear, 2006; Crawford, 1999, 2000; Crawford, Zembal-Saul, Munford, & Friedrichsen, 2005; Eick & Reed, 2002; Koballa et al. 2005; Luft &
Luft and Patterson (2002), in a study conducted with beginning science teachers in an induction program, reported that not only did over 90% of the participants’ ability to use inquiry in the science classroom greatly improve, but also that the participants felt more confident teaching science. Luft and Patterson linked the increase in the participants’ skill in implementing inquiry with specific methods such as managing the “science as inquiry” classroom (p. 274) and activities pertaining to inquiry instruction that were provided throughout the induction program, as well as the on-going support from program staff who encouraged their use of inquiry in the classroom.

Roehrig and Luft (2006), in another study, examined the impact of a science-focused induction program on secondary science teachers’ teaching beliefs, instructional practices, and experiences in the classroom. In this study, there were 16 first-year secondary science teachers who had graduated the previous year from four different teacher preparation programs. Researchers learned that there was a correlation between reform-oriented student-centered practices, the number of science methods courses, and the extended-teaching experience that teachers had in their preservice teacher education program. They claimed that preservice teachers need direct experiences with inquiry-based instruction. They asserted that one science methods course cannot provide the in-depth knowledge about inquiry as a teaching approach needed by beginning teacher. Thus, they argued that implementation of inquiry can be reinforced through a second science methods course. In support of this assertion, Lumpe, Haney and Czerniak (2000) linked teacher dispositions toward effective science instruction with science methods courses taken.
Unfortunately, one science method course, however well designed, as a part of general certification program is probably insufficient for preservice teachers to develop an orientation toward inquiry-based teaching…. A second science methods course is one mechanism to provide teachers with an in-depth knowledge of inquiry-based teaching and underlying philosophies. (Roehrig & Luft, 2006, p. 982)

To immerse students in exploring authentic problems grounded in scientific phenomena, making accessible rich and complex data and/or powerful analytical tools for interpretation, Crawford et al. (2005) employed interactive software, *The Galapagos Finches*. They reported that not only were they able to teach aspects of scientific inquiry using the software, but that they also discovered benefits to the preservice teachers. These benefits included: a) context to enhance subject-matter understandings; b) a rich environment for the discussion of aspects of scientific inquiry; c) opportunity for assessment as well as a reform-based pedagogical model; and d) opportunity for self-evaluation, growth and change.

Furtak (2006) examined three teachers and their practice of guided inquiry after participating in training specific to implementing an inquiry-based interdisciplinary program curriculum for middle school students. This study explored the different ways that the three teachers described and managed an activity in a middle school physical science investigation— the Liquids and Vials activity where sinking and floating anomalies were presented. The results of this study indicated that the teachers had difficulty with withholding answers from their students during guided inquiry-oriented activities. The researchers stated that neither curriculum nor the models of guided inquiry teaching provided the teachers how to manage the situation once problems arose. While one teacher managed the problem by treating the investigation as a game, another teacher accepted his students’ ideas without
evaluation, and the third spent considerable time rationalizing his teaching strategies to students.

Eick and Dias (2005) studied secondary science methods students’ thinking on co-teaching practice for the development of practical teacher knowledge supporting the use of structured inquiry. The researchers reported that the co-teaching experiences influenced the preservice teachers’ practice of inquiry. Therefore, they argued that preservice teachers are likely to gain more practical knowledge needed for teaching inquiry through supportive cooperating teachers who not only value this approach, but also co-teach this approach.

After studying the case of Ms. Kennedy, a fourth grade teacher, Keys and Kennedy (1999) argued that inquiry-based teaching needs to be worked out in context—depending on the characteristics of the learners, the school culture, and the science topics. Ms. Kennedy invented her own approach to inquiry teaching that fit with her personal views of the science curriculum and the role of teacher. She did not let student interest completely drive the curriculum, but sought ways to integrate what the students wanted to explore with the curriculum objective. She did not view inquiry as the posing and refinement of student investigation questions about a science topic. She blended inquiry questions arising in context with ongoing lesson plans designed to teach or explore science concepts. When student questions arose, she let the students’ actions guide subsequent lessons until the questions or problems were solved. She used inquiry to produce class data from which scientific explanations could be constructed, and to provide hands-on activities that fostered connections between science knowledge, language, data, and the real world. Thus she developed inquiry skills with the entire class including observations, communication,
measurement, inferring, predicting, and formulating models. Crawford’s (2000) assertion that inquiry is situated in a context supports Keys and Kennedy’s claim.

Several studies that looked at preservice teachers’ practice of inquiry-based instruction affirm that teachers’ inquiry role identities either facilitated or hampered their practice of inquiry (i.e., Crawford, 1999, 2000; Eick & Dias, 2005; Eick & Reed, 2002; Kagan, 1992; Windschitl, 2003). To illustrate, Windschitl’s study with six preservice secondary teachers revealed that the participants who employed guided and open inquiry during their student teaching were not those who had more authentic views of inquiry or reflected most deeply their own inquiry projects; rather they were those who had significant undergraduate or professional experiences with strong science research.

After close examination of the case of Denise, a preservice teacher, Crawford (1999) stated that it is realistic to expect preservice teachers to implement inquiry-oriented activities. Crawford’s study contributes to Windschitl’s findings because Denise had worked for ten years as a professional in horticulture research in university and commercial labs, in addition to working as a volunteer teacher’s aide.

In a year-long study of Jake, a high school biology teacher with 12 years of experience, Crawford (2000) reported that in an inquiry-based classroom the roles of teacher are not limited to “teacher as facilitator” or “teacher as guide.” Crawford’s study suggested that a teacher’s work in an inquiry-based classroom requires a myriad of teacher roles demanding a high level of expertise. Crawford stated that science teachers need additional roles beyond those illustrated by Jake (i.e., model, mentor, collaborator, and learner). These roles are similar to those suggested by Osbourne and Freyberg (1983) (i.e., motivator, diagnostician, guide, innovator, experimenter, and researcher).
It is also important to note that regardless of the teacher initial utilization of inquiry-based instruction or the emphasis and opportunities that teacher education programs provide to beginning science teachers, a great number of studies has provided evidence that teachers tend to revisit their prior teaching experiences as they begin teaching (i.e., Brown & Melear, 2006; Eick & Dias, 2005; Koballa et al., 2005; Salish I Research Collaborative, 1997; Simmons et al, 1999). Simmons et al., for example, studied 116 beginning teachers, 98 who taught secondary science, 17 who taught secondary mathematics, and one who taught both science and mathematics. They ascertained that 90% percent of beginning teachers oriented themselves toward a more teacher-centered mode with a focus on learning during their practice. Brown and Melear reported inconsistency between teacher interviews and observational data. Their participants described themselves as student-centered during their interviews; however their practice revealed teacher-centered orientations.

The research findings in the area of science teachers’ practice of inquiry are inconclusive (e.g., Brown & Melear, 2006; Crawford, 1999, 2000; Crawford et al., 2005; Eick & Reed, 2002; Koballa et al. 2005; Luft & Paterson, 2002; Roehrig & Luft, 2004, 2006; Simmons et al., 1999; Wallace & Kang, 2004; Windschitl, 2003). The research reveals that it is not science teacher education alone that makes an inquiry-oriented teacher, but that a teacher’s supportive background, life experiences, and induction experiences also contribute.

Research on Beginning Science Teachers

*General Constraints and Needs of Beginning Teachers*

Understanding the first years of teaching is a complex task. A number of researchers who have examined traditional teacher education programs found that beginning teachers have problems with teaching toward meaningful learning (Borko
& Putnam, 1996; Feiman-Nemser & Buchmann, 1986, 1987). Other researchers (Brickhouse & Bodner, 1992; Brookhart & Freeman, 1992; Veenman, 1984) have investigated challenges facing beginning science teachers as they step into a teaching career. Researchers have pointed to lack of content and pedagogical knowledge as the major impediments to implementing effective teaching strategies (Brickhouse, 1990; Roehrig & Luft, 2004). Another study by Fuller and Bown (1975) indicated that beginning teachers were typically concerned with the following critical issues: presentation of information, what information to present, classroom control, and classroom management (as cited in Adams & Krockover, 1997).

These constraints and needs also cited as main contributing factors that increase teacher dropout. Ingersoll (2001) examined data from the Teacher Follow-up Survey of a national sample of 6,733 teachers conducted by the National Center for Education Statistics (NCES) in 1999 as part of the Schools and Staffing Survey, and found that there was a turnover rate of 13.2% in beginning teachers. Teachers who left the profession reported the following reasons: a) lack of student motivation; b) inadequate administrative support; c) student discipline problems; and d) inadequate preparation time.

The studies reviewed about ATCP teachers in their first years of teaching found almost without exception that procedural concerns of time management, lesson planning and classroom management were their most important teaching needs (Chesley, Wood, & Zepeda, 1997; Guyton, Fox, & Sisk, 1991; Houston, Marshall, & McDavid, 1993; Marchant, 1990; Miller, McKenna, & McKenna, 1998). However, the findings on the needs and quality of teachers recruited and trained in alternative certification research, like most areas of educational research, are mixed (Bassett et
For example, a study conducted on beginning teachers with two months of teaching experience, Houston et al. (1993) found that the problems of alternatively certified teachers were greater than those of traditionally certified teachers in six areas: student motivation, teacher time management, amount of paperwork, school administration, lack of personal time, and grading students. However, after eight months of teaching, Houston et al. found no differences between the alternatively certified and traditionally prepared teachers included in the study. On the other hand, studies conducted by Goldhaber and Brewer (2000), Guyton et al. (1991) and Miller et al. (1998) respectively found no difference between the new teachers alternatively certified and traditionally prepared teachers in terms of difficulties encountered. They concluded that the teachers were similar in almost all measures.

Contrary to these findings, Sandlin, Young and Karge (1992) reported that traditionally certified teachers were rated significantly lower on classroom observations than the alternatively certified teacher teachers on five of 16 items in the fall. By midyear, they were rated significantly lower on two of the 16 items. At the end of the year, there were no significant differences between the groups. Demir and Abell’s (2005) pilot study with preservice teachers in an ATCP confirms some of these results. They found that lesson planning and class management were the biggest perceived needs of prospective science teachers in the ATCP.

**Perceived Constraints and Needs of Beginning Science Teachers to Implementing Inquiry**

Historically, inquiry-based teaching has been described as difficult to implement and limited in its applicability because of constraints (Furtak, 2006). For
example, in the 1970s, inquiry curricula were developed to emphasize the cognitive rigor of the scientific enterprise—scientific process skills, the nature of science, and the general cannons of inquiry. After 10 years of program development, in a study which examined the role of inquiry in science education, Welch et al. (1981) reported that teachers perceived constraints with inquiry teaching, including lack of experiment, time and support, safety issues, classroom management, and the need to teach basics.

From the time that those curriculum reforms took place until today, including appearance of the standards (NRC, 1996) researchers have examined the classroom practice of science teachers as they attempt to implement inquiry. From a growing number of classroom-based studies, it can be concluded that science teachers, in general, have difficulties translating guiding principles of reform documents to their own classrooms and perceived needs (e.g., Crawford, 1999; Crawford et al., 2005; Hayes, 2002; Keys & Kennedy, 1999, Wallace & Kang, 2004).

Researchers, for instance, have explored the constraints that face secondary science teachers as they attempt to implement inquiry. Logistical constraints (e.g., class size, physical facilities, and time) (Adams & Krockover, 1997; Loughran, 1994; Trautmann, MaKinster, & Avery, 2004; Wallace & Kang, 2004) and lack of administrative support (Brickhouse & Bodner, 1992; Loughran) are frequently cited as barriers to inquiry-based instruction. Other researchers have claimed that teacher content knowledge, pedagogical knowledge, or knowledge of the nature of science, are major impediments to implementing inquiry (Brickhouse, 1990; Roehrig & Luft, 2004). For example, Loucks-Horsley, Love, Stiles, Hewson & Mundry (2003) claimed that teachers’ tendency to use the methods through which they were taught, reliance
on textbooks, lectures, and use of cookbook laboratories are challenges to implementing inquiry-based instruction.

Quite a few scholars (Kennedy, 1997; Singer, Marx, & Krajcik, 2000; Windschitl, 2003) found out that inquiry-based activities can be threatening to some teachers who lack experience in conducting scientific research, because inquiry-based activities can produce unexpected outcomes or results, contrary to cookbook kinds of laboratory exercises in which teachers know the outcomes in advance. Roehrig and Luft (2004), Trautmann et al. (2004), Hogan Berkowitz (2000), as well as Wallace and Kang (2004), found that teacher perceptions of student ability and motivation constrained their dispositions to implement inquiry.

Some studies also indicated school culture as another impeding factor to science teacher practice of inquiry-based teaching (Munby, Cunningham, & Lock, 2000; Keys & Kennedy, 1999; Tobin & McRobbie, 1996; Trumbull, 1999; Wallace & Kang, 2004). The findings of the Wallace and Kang study of secondary science teachers on their classroom practice of teaching inquiry illuminates how school culture can even hinder practice of experienced teachers when considering implementing inquiry. The subjects of this study consisted of six experienced high school science teachers. Their experience ranged from 12 to 29 years. Subjects of this study perceived difficulties (e.g., curriculum and students) to implementing inquiry in their school culture. Likewise, in a study that spanned over several years, Trumbull reported that the environment experienced by beginning teachers ultimately hindered their instructional goals.

As to beginning science teachers’ perceived constraints of inquiry-based teaching, researchers have reported similar constraints as described above (e.g., Adams & Krockover, 1997; Crawford, 1999; Crawford et al., 2005; Eick & Dias, 39
beginning science teachers have less chance of success in implementing inquiry due to limited technical experience and practical knowledge of teaching. Other studies associated the success of beginning science teachers in implementing inquiry-oriented instruction discussed the difficulty of transferring, integrating and applying inquiry from their teacher education programs to classroom contexts (e.g., Geddis & Roberts, 1998).

Most beginning science teachers, similar to beginning teachers of other subjects, do not receive the support they need during their initial years of teaching. NCES (1999), for example, drew attention to the number of all beginning teachers who have an opportunity to participate in an induction program. A study conducted by Luft and Cox (2001) with beginning secondary mathematics and science teachers revealed that a great number of science (40%) and mathematics (55%) teachers were not being mentored by experienced teachers of their subject. The researchers also discovered that beginning science and mathematics teachers taught courses that they did not majored in.

Research studies examined for this study often cited a support system as the main need of beginning science teachers to overcome their struggle to implement inquiry-oriented activities (e.g., Eick & Reed, 2002; Loughran, 1994; Luft & Patterson, 2002; Roehrig & Luft, 2004, 2006; Salish I Research Project, 1997). Salish I Project researchers stressed that providing support to secondary science teachers during their first three years is critical if they are expected to develop and sustain inquiry-based orientation aligned with NRC’s (1996) goals of inquiry-based instruction.
In addition to the support beginning science teachers need, several researchers discussed required skills and knowledge that beginning teachers need to have to practice inquiry-oriented teaching effectively. The skills and knowledge include: a) classroom management, including students and material; b) practical knowledge; and c) pedagogical skills (knowing how to use supporting methods such as probing student questions, demonstration, etc.) (e.g., Abd-El-Khalick, 2004; Adams & Krockover, 1997; Crawford, 2000; Eick & Dias, 2005; Roehrig & Luft, 2004, 2006; Simmons et al., 1999).

Gaps in the Literature

The studies I reviewed found that the bulk of the research on ATCPs has been concerned with qualifications and characteristics of applicants. Some of these researchers have compared the quality of traditionally certified teachers versus alternatively certified teachers. Others have concerned themselves with the characteristics of the applicants to find out the motivation behind their interest in a teaching career and how these motivations affect the longevity of their retention in the profession. The main three gaps in the literature include limited number of empirical studies on alternative certification beginning science teachers’: (a) views and practices of inquiry; (b) needs, constraints, and classroom performance; and (c) practices of inquiry with respect to what they learned in their ATCP. This study will address these gaps.

If we look specifically at beginning science teachers enrolled in ATCPs, the literature decreases considerably. A large number of publications describe ongoing efforts to implement inquiry in pre-college science classrooms. However, little empirical work exists on alternatively certified beginning science teachers’ views or use of inquiry.
Exclusive concern with filling the teacher shortage has diverted attention away from understanding the problems, needs and classroom performance of beginning science teachers recruited and prepared through ATCPs. A number of researchers have asserted a potential research agenda for the teaching and learning of science as inquiry (e.g., Keys & Bryan, 2001; Koballa et al., 2005). Keys and Bryan, for example, presented a position that additional research is needed in a) teacher beliefs about inquiry; b) teacher knowledge base for implementing inquiry; and c) teacher inquiry practices. They believed that definitely the research on teacher knowledge used in inquiry-based instruction was the least developed among the domains they discussed. Koballa et al. suggested that the conceptions of teaching as related to reform practices (AAAS, 1989, 1993; NRC, 1996, 2000) held by participants in alternative science teacher preparation programs should be taken into account in the design of those programs to achieve the goal of preparing high-quality teachers.

Recognizing common concerns and gaps in understanding about inquiry-based instruction to produce highly qualified teachers in both traditional and ATCPs is critical. Indeed, such opportunities are important in refining inquiry-based pedagogy at all levels of education. Thus, I believe that the next logical step in the research is to understand alternatively certified beginning science teachers’ conceptions and practices of science classroom inquiry.
CHAPTER THREE
Methodology

Researchers have long argued the relative significance of qualitative and quantitative research (Denzin & Lincoln, 2000; Lincoln & Guba, 1985; Patton, 1990). Each of these approaches represents an essentially different inquiry paradigm, with researchers’ actions based on the primary assumptions of each paradigm. In this section, I give an overview of qualitative research methodologies. Then, I articulate on my reasons for the choice of qualitative inquiry to guide my research.

Qualitative researchers “stress the socially constructed nature of reality” (Denzin & Lincoln, 2000, p. 8). They interact with the context and participants in different forms and varying degrees while studying phenomena in their natural settings. They attempt to understand the participants’ world through their perspectives (Bogdan & Biklen, 1992; Denzin & Lincoln; Lincoln & Guba, 1985). The essence of qualitative inquiry, thus, is to understand how individuals make sense of their everyday lives (Hatch, 2002).

As a qualitative researcher, I believe that the world cannot be limited to objective meanings, but that research must take into account the interaction of researchers with the context and participants in different forms and varying degrees to develop understanding of the nested relationships. The use of quantitative methods in my research, therefore, would not be as powerful as qualitative research in helping me gain a better understanding of alternatively certified science teachers’ understanding and implementation of inquiry-based instruction in their beginning years of teaching. Next, I introduce phenomenography as research tradition and explain how I utilized this tradition in my research.
Research Tradition

Phenomenography is the qualitative research tradition that guided the study. Phenomenography focuses on developing, recognizing, describing, and apprehending the qualitatively different ways in which people experience certain phenomena or certain aspects of the world around them (Breen, 1999; Marton, 1981, 1992; Marton & Booth, 1997). The focus of phenomenographic research is to find the variation which differentiates the phenomenon for the participants, rather than finding the singular essence (Marton, 1996b). The categories of description constitute the primary results of study.

The word phenomenography, etymologically, is derived from the Greek words phainomenon (appearance) and graphein (description), rendering phenomenography, a description of appearances (Hasselgren & Beach, 1997; Marton & Fai, 1999). The word phenomenography was first used as a term in 1954 by German psychologist Ulrich Sonnemann (as cited in Hasselgren & Beach), although it has come to be primarily associated with the Department of Education and Educational Research in Gothenburg, Sweden, led by Ference Marton and his associates (Hasselgren & Beach). Phenomenographical research has been conducted here since the early 1970s (Entwistle, 1997a, 1997b; Hasselgren & Beach; Marton, 1988, 1994; Marton & Fai).

Ontological Assumptions

Phenomenography represents a non-dualist standpoint (Breen, 1999; Hasselgren & Beach, 1997; Booth & Hultén, 2003; Limberg, 1999; Marton & Fai, 1999; Rovio-Johansson, 1999; Trigwell, 2001; Uljens, 1996) in which knowledge is seen as a relation between the knower/person and the known/phenomenon, and learning is seen as a qualitative change in that relation (Booth & Hultén).
representation of a non-dualist standpoint in phenomenography is a reaction to representational epistemology and dualist ontology (Uljens).

Phenomenography is a second-order perspective (Hasselgren & Beach, 1997; Limberg, 1999; Marton, 1981, 1996b; Marton & Booth, 1997; Marton & Fai, 1999; Runesson, 1999; Trigwell, 2001) for empirical study (Marton, 1994, 1996a; Marton & Fai; Trigwell; Uljens, 1996) aiming to show the qualitatively different ways of experiencing various phenomena in which something, that appears to be the same thing, can be experienced or understood differently by different individuals.

There are two ways of posing the questions related to reality and people’s conceptions of reality (Marton, 1981). Any answer to the question “why do some children succeed better than others in school?” (Marton, p. 177) is a statement about reality. On the other hand, any answer to the question “what do people think about why some children succeed better than others in school?” (Marton, p. 178) is a statement about a person’s conception of reality. In the first and frequently accepted standpoint, “we orient ourselves towards the world and make statement about it” (Marton, p. 178); it is a first-order perspective. In the second standpoint, “we make statements about people’s ideas about the world (or about their experience of it)” (Marton, p. 178); it is a second-order perspective, “considering person and world to be internally related” (Marton, p. 175).

The understanding of reality may perhaps be expected to differ depending upon thinking and it cannot be expected to be completely true in any case. The truth of knowledge is uncertain (Svensson, 1997; Uljens, 1996). Reality is not seen as being “out there.” It is seen as being constituted of the connection between the person and the phenomenon (Limberg, 1999; Trigwell, 2001). Svensson stated, “Reality presents itself in human thinking as different related entities having the character of forming
units or wholes. What we refer to as knowledge is based on this differentiation of wholes” (p. 166).

The nature of conceptions is strongly related to assumptions about the nature of knowledge and thinking (Marton & Fai, 1999; Svensson, 1997). Knowledge is relational (it is varying in character and uncertain when it comes to the correspondence between thought and reality), not only empirical or rational, but created through thinking about external reality (Svensson). Therefore, knowledge and conceptions have a relational nature (Limberg, 1999; Svensson; Uljens, 1996).

Epistemological Assumptions

In phenomenology the ontological conjectures become epistemological in a common case; in other words, epistemology is represented by the ontological position (Breen, 1999; Marton & Fai, 1999; Svensson, 1997; Uljens; 1996). According to Svensson, description is important and it is related to both understanding of knowledge as a matter of meaning, similarities and dissimilarities in meaning, and generalization of meaning across objects. Svensson stated that, “The less generality of meaning is assumed the more important it becomes description of individual case . . . generality is empirically explored” (p. 167). He further stated that starting with description is important for fruitfulness. The following is his statement about epistemological assumptions related to results:

It follows from the view that relations have to be relations of something . . . although the meaning of the conceptions may be clarified in relation to a wider context, this clarification will be dependent upon focusing on the meaning of the conceptions themselves. This focus is also the basis for understanding what leads to a certain conception or what follows from it in different contexts. (p. 167)
As the purpose of this study was to: (a) gain an understanding of how beginning science teachers recruited through an ATCP from various science disciplines implement inquiry during their initial years of teaching; (b) describe challenges, constraints, and needs that they perceive in implementing inquiry-based science instruction; and (c) understand the relation between what they learn in their ATCP and their practice of teaching science through inquiry, there were certain benefits of using phenomenography as a research tradition to guide the research:

1. As a result of using phenomenography, I was be able to develop, recognize, describe, and apprehend qualitatively different ways in which alternatively certified beginning science teachers practice classroom inquiry.

2. Marton (1996b) asserted that “a careful account of the different ways people think about phenomena may help uncover conditions that facilitate the transition from one way of thinking to a qualitatively 'better' perception of reality” (p. 33). Therefore, phenomenographic study about the different conceptions of teaching through classroom inquiry that alternatively certified beginning science teachers possess may be useful for the design of ACTPs.

3. Because the descriptions of people’s experiences and understandings are characterized into categories of description, rationally related to each other, that structure hierarchies with respect to given criteria, I was be able to describe challenges, constraints, and needs that face alternatively certified beginning science teachers while implementing classroom inquiry.

4. Since phenomenography assumes that reality is not seen as being “out there,” but rather is seen as being constituted as the connection between the person and the phenomenon (Limberg, 1999; Trigwell, 2001), it was important for me
to know how reality of classroom inquiry presents itself in alternatively
certified beginning teachers’ thinking.

Thus, the methodological stance of phenomenology matched the focus of my research.

Research Questions

Overarching Question

How do alternative certification science teachers in A-STEP understand and implement inquiry-based instruction in their beginning years of teaching?

Sub-Questions

1. What do alternatively certified beginning science teachers mean by classroom inquiry?
2. How do alternatively certified beginning science teachers implement inquiry-based instruction in their teaching?
3. What do alternatively certified beginning science teachers perceive as constraints and needs for implementing inquiry-based instruction?
4. What do alternatively certified beginning science teachers perceive as factors that facilitate their implementation of inquiry-based instruction?
5. How are alternatively certified beginning teachers’ experiences of teaching science through inquiry related to what they learn in A-STEP?

Context of the Study

I conducted this research with beginning science teachers enrolled in an ATCP, A-STEP, at a Midwestern University (MU). This program, in partnership with school districts across the state of Missouri, is designed for individuals with an undergraduate degree in mathematics, science, or a related field to address teacher shortages in high-need areas. At completion of the program, students earn a Master’s
Degree and are certified to teach science or mathematics to grades 6-12 in Missouri. The ATCP has two tracks—one for full-time teachers (the Alternative Certification Program [ALT], a 24-month program, 35 credits) and the other for full-time students who serve a year-long internship in the classroom of a mentor teacher (the Accelerated Post-Baccalaureate Program [APB], a 15-month program, 35 credits). Students enrolled in either track at the middle school level complete three science methods courses versus four science methods courses at the secondary level for three credits each (see Appendix A for more information regarding the program course outline). Both tracks begin with an 11-week summer session at the MU’s campus. Students begin the program as part of a cohort that persists throughout the program. ALT students are hired by a school district under a Missouri Temporary Authorization Certificate and teach while they complete their certification program. Contrary to ALT students, APB students spend eight months working as teacher interns while they are in the program. During the program students are part of a learning community with other interns, mentor teachers, and university faculty members.

Participants

Gaining access to the participants is a political act that involves several stages (Denzin & Lincoln, 2000). First, I obtained potential participants’ contact and demographic information from the program coordinator. Using a purposive sampling approach (Hatch, 2002; Patton, 2002), I closely reviewed participants’ demographic information to be able select the research participants who could serve as rich cases of information (Patton). I wanted to select students from both tracks who had no prior experience in teaching any science subjects as full-time teachers prior to their enrollment in the program. I was not able to obtain the contact information for all
students in Cohort 1. As a result of my selection criteria, I ended up with nine students who could possibly have been involved in the study.

Having narrowed down the number of potential participants, I contacted these individuals to invite them to be involved in the study. I advised them each of the purpose of the study and the methods that I was going to use for data collection. I used a consent form to outline the procedures and issues related with the next steps (See Appendix B). Although my research was unlikely to harm research participants, I declared the risks and benefits that might be unpredictably involved in this research. Finally, I let the participants know that all identifying information was going to be removed from the data they provided to ensure their confidentiality. Though the study I made sure that I fulfilled the confidentiality.

Following this step, four potential participants agreed to participate in the study. However, after my initial interviews, two of the remaining potential participants declined to participate. Because I wanted to include four participants, I returned to my original list of the nine eligible students. I was able to recruit two more students to participate in the study. The participants consisted of four beginning science teachers, two from the ALT and two from the APB track. Three of the participants were in their first year of teaching and one was in her second year of teaching (see Figure 1 for more information regarding participants’ enrolment status in A-STEP at the time of data collection). All participants had undergraduate degrees in science or related fields and had met their graduate school entrance requirements (GRE ≥1000, i.e. combined total on the verbal and quantitative portions, 2.75 ≥ overall undergraduate GPA, and 2.5 ≥ undergraduate GPA in mathematics or science content courses). Prior to this study I had not had any interaction with three of the research participants, and I did not know anything about them. The fourth participant was a teacher who had been
involved in a pilot study I had conducted previously when she was a student in A-STEP in 2004 with prospective science teachers.

Figure 1. The research participants’ enrolment status in A-STEP at the time of data collection

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MC: Methods Course

Indicates the data collection time

In addition to the student research participants, I included two faculty members who had taught method courses to the participants in A-STEP. I present a detailed description of the teachers through separate cases in the next chapter (Chapter 4) and of the faculty members in the cross cases analysis section of this study (Chapter 5).

Data Collection

Interviews performed in a dialogical manner (Booth, 1997; Marton, 1994; Svensson, 1997; Trigwell, 2001) are the primary source of data collection in phenomenography. However, to gain full knowledge of the participants’ experience, I utilized data from different sources, in addition to interviews. These additional sources were essential to examine any discrepancies between participants’ statements and their actions if there were any. I used classroom observation, field notes, and unobtrusive data as additional data sources to supplement my primary source of data collection. I also conducted an individual interview with the two A-STEP faculty members. Next, I provide a discussion on and explain what these data sources involved and how I used these techniques in this study.
Interviews

Siedman (1998) wrote that storytelling is essentially a meaning-making process. When people tell stories, they select details of their experience from their stream of consciousness. Because I was interested in how the participants’ stories provided access to their experience, I used in-depth interviews (Hatch, 2002) as the primary source of data. Although I had predetermined questions to guide the interviews, each interview also depended on unstructured questions that developed spontaneously in the course of the interview.

Altogether I conducted four audio-taped interviews with each participant at different stages of their teaching. The goal was to gain an understanding of their experiences of inquiry-based instruction methods. I conducted the first interviews prior to classroom observations. I completed the first interviews with the research participants during summer, 2005 while they were on campus taking courses. Even though one of the participants had already graduated, I conducted the first interview with her at the same time. The first interviews lasted 60-90 minutes. During that time, I focused on establishing the context of the participants’ experience by asking them to share as much as they would like about themselves as teachers—including their experiences, their thinking about being science teachers, their existing beliefs about inquiry, and the preparation for teaching they had received prior to their enrollment into A-STEP (see Appendix C). The second interviews lasted 45-60 minutes and took place following the summer, 2005 session, at the beginning of the fall semester. At this time three participants had a full-time teaching position while one of them only had a part-time teaching position. The focal point of this interview was to find out about their views and current practices of teaching science through inquiry-based instruction in the context of their teaching settings. During this set of interviews, I
asked the research participants if they could tell me about a topic that they had recently taught (see Appendix C).

The third interviews were a series which consisted of a) an interview prior to entering the classroom, b) a pre-lesson interview before each observation, and c) a post-lesson interview after each observation. The first interview of this series lasted 30-60 minutes, and included discussion about the unit I was going to observe and the specific classroom setting. Each pre-lesson interview lasted approximately 10 minutes and each post-lesson interview lasted 15-30 minutes. Throughout these interviews, I focused on the participant’s practice within the context of her teaching. I encouraged the teacher to reflect on the meaning this teaching experience held for her (see Appendix C). The fourth and final interviews lasted 60-90 minutes and took place after I completed all classroom observations. I used this interview to find out about the participants’ experiences during A-STEP and what they thought that they had learned about inquiry-based teaching (see Appendix C) from the program itself.

It is important to mention that I avoided using the word “inquiry” during my interviews. I used the word only after a participant brought it up or indirectly through probing questions to allow each participant to talk about their practice of inquiry-based teaching. The only time I intentionally used the word “inquiry” was during my third interview to discover how they thought their lessons fit in inquiry-based teaching if they themselves did not mention inquiry-based teaching. This did not occur often, but in this case, I asked the participants the following questions, “If any, in what ways do you think your lesson used inquiry?” and, “Why?” or, “Why not?”

As mentioned previously, I also conducted a single interview which lasted 60-75 minutes during the winter semester of 2006 with two faculty members who had taught method courses to the participants in A-STEP (see Appendix C). The purpose
of these interviews was to gain an understanding of the views regarding inquiry held by the faculty members and the activities and models they used in helping their students understand what inquiry-based teaching is and how to incorporate it into their own teaching. It is also important to mention that I did not observe any of the classes they taught to A-STEP interns.

*Classroom Observations*

The main advantage of the interview is that it permits the participants to move back and forth in time – to reconstruct the past, interpret the present, and predict the future. The main advantage of classroom observation, in contrast, is that it provides here-and-now experience in depth (Lincoln & Guba, 1985). Guba and Lincoln (1981) offered the following arguments for the usefulness of observation:

Observation...maximizes the inquirer’s ability to grasp motives, beliefs, concerns, interests, unconscious behaviors, customs, and like; observation allows the inquirer to see the world as his subjects see it, to live in their time frames, to capture the phenomenon in and on its own terms, and to grasp the culture in its own natural, ongoing environment; observation ... provides the inquirer with access to the emotional reactions of the group introspectively – that is, in a real sense it permits the observer to use himself as a data source; and observation. . . allows the observer to build on tacit knowledge, both his own and that of members of the group. (p. 193)

Classroom observation demands first-hand involvement in the social world chosen for study. Immersion in the setting allows the researcher to hear, see, and begin to experience reality as the participants do (Marshall & Rossman, 1989). Thus, I had access to more than one form of reality in order to gain an understanding of inquiry-based teaching as experienced by beginning science teachers.

My classroom observations of beginning science teachers were vital in data collection. Prior to my entrance into the participants’ classrooms, I asked permission
from the appropriate school officials to enter the classrooms (see Appendix D). I observed each participant carefully in an effort to understand what, from their point of view, motivated their actions in the classroom and what these actions meant at that time (Schwartz & Jacobs, 1979). Furthermore, my presence in participants’ classrooms allowed me to see things that were overlooked or taken for granted by the participants and therefore were not revealed during the interviews or with other data collection techniques. Experiencing social phenomena firsthand also allowed me to include my own experience within the setting in the research analysis.

Classroom observations took place in the academic year 2005-2006. Throughout the classroom observations, I videotaped the research participants while they were teaching. The teachers were the focus of the videotapes. I watched each participant during the same period while she taught a unit from beginning to end. The length of the classroom observations with each participant varied. At two schools that used blocks (90 minutes each) as class period, I observed one teacher for four blocks, and another teacher for 10 blocks. At the other two schools, my observation spanned over 10 class periods (45 minutes each) with both teachers.

Hatch (2002) pointed out the importance of the representation of the observational data. According to Hatch, “If data are only the researcher’s impressions of what happened, then it turns out to be a study of researcher impressions of the social action observed, not a study of the action itself” (pp. 78-79). To prevent that, I ensured that the observational data were as careful a representation as possible of the action observed in the research settings. I tried to accomplish this through extensive field notes. During observations I also used field notes to provide a record of the chronological events and progress of research in addition to my own reactions to, feelings about, and opinions of the research process.
Unobtrusive Data

The last data collection source that I used in my study was unobtrusive data. Hatch (2002) depicted unobtrusive data as non-reactive in the sense that data are not filtered through the perceptions, interpretations, and biases of research participants. I collected artifacts such as copies of teachers’ lesson plans, handouts, and copies of the textbook unit to provide insight into the experience under investigation without interfering with the enactment of the experience.

Data Analysis

Denzin and Lincoln (2000) acknowledge that data analysis in qualitative research is ongoing as data collection proceeds. Therefore, I started data analysis immediately after data collection started and continued through the writing of this dissertation. In phenomenographical research, the researcher brackets his/her preconceived ideas (Hasselgren & Beach, 1997; Marton, 1994) and tries to express how his/her experience of the data may be characterized and how categories of description do justice to the content as experienced (Uljens, 1996). Accordingly, while analyzing the data, I made sure that I analyzed the transcripts with an open attitude (see “Triangulation,” “Peer debriefing,” etc., below), seeking what emerged as important and of interest from the text.

In phenomenography, the central focus of data analysis is on differentiating parts of the data “in terms of their internal consistency (do the elements show consistency in the referential and structural aspect), and the relations between them (do they together provide full coverage of variations in the total data) (Hasselgren & Beach, 1997, p. 194). With the purpose of determining the phenomenographic categories of description and their internal consistency, I applied an iterative data analysis process. All audio-taped interviews were transcribed in full and reviewed
twice for accuracy. I read and analyzed the transcripts to determine a set of analysis codes. I used NVivo qualitative analysis software to organize the data and searched for categories of descriptions across the data set. In addition to the transcribed audiotaped interviews, I watched all videotaped classroom observations at least once and sometimes twice to make sure that I was not missing anything I transcribed some parts of the videotapes that I thought might be useful in making my case.

There were several steps that I took into account to increase credibility of my findings during the analysis phase. These steps consist of triangulation, debriefing process, member check, and negative cases.

**Triangulation**

Patton (2002) stated that multiple methods of data collection allow researchers to observe if the results from different methods lead to similar findings about the phenomena being examined. If findings from different sources lead in the same direction, then researchers feel more comfortable and confident about the credibility of their findings (Bogdan & Biklen, 2003; Hatch, 2002; Lincoln & Guba, 1985; Patton). Therefore, before I made an assertion “to reduce the likelihood of misinterpretation” (Denzin & Lincoln, 2005, p. 453), I checked my claims against the data from different sources to confirm the claims and support them with illustrative examples.

**Peer Debriefing**

I chose one of my peer graduate students, someone who knew about the substantive area (inquiry) and the methodological issues of my research (Lincoln & Guba, 1985), with whom to communicate and share my findings. He reviewed my fully transcribed interviews and classroom observation notes of each participant. I accessed my peer’s reflection on the data via telephone, e-mail, and face-to-face
meetings as I proceeded. In the course of this interaction, I aimed to use debriefing as a process that would keep me “honest,” exposing myself to searching questions by an experienced peer doing his best to play “devil’s advocate” to investigate my biases, explore meanings, and clarify bases for interpretations (Lincoln & Guba). This also offered me an opportunity to evaluate feedback I received from my peer so I could revisit the data and reevaluate my initial interpretations. Finally, I used peer debriefing as a tool for catharsis, “clearing the mind of emotions and feelings that may be clouding good judgment or preventing emergence of sensible next steps” (Lincoln & Guba, p. 308).

**Member Check**

I applied member-checking to ensure the trustworthiness of my findings. In order to assure that I interpreted the participants’ views fairly, I provided opportunities to for participants to collaborate throughout the research process, inviting them to provide comments on summaries of my interpretations of their experiences. As I gathered feedback from member checking activities, I revised the summaries to take that feedback into account, refining and clarifying my interpretations, so that these summaries communicated the understandings I constructed (Hatch, 2002).

**Negative Cases**

My interaction with participants raised important questions and helped me identify emerging patterns as I gathered more and more information. Iterative analyses also lead to the emergence of negative cases. Lincoln and Guba (1985) consider negative case analysis as a “process of revising hypothesis with hindsight” (p. 309). According to them, the purpose of the activity is to refine conclusions constantly until they account for all known cases without exception. Thus, I used negative case analysis as an activity that would help me refine working hypotheses.
While performing negative case analysis, I checked and rechecked the data to see if all instances could fit within the emerging categories. In defining what makes a negative circumstance in implementing inquiry-based instruction, I examined the unique differences that created outliers.

*Role of the Researcher*

One of the major differences between qualitative and quantitative research is the underlying assumption about the role of the researcher. As a qualitative researcher, I believe that the world cannot be limited to objective meanings. During this study, I took into account my interaction with the context and participants in different forms and to varying degrees to develop understanding of the nested relationships. To be able to gain full knowledge of the participants’ experience, I immersed myself in the research settings as an onlooker observer (as opposed to a participant observer or active observer) throughout my classroom observations. Patton (2002) described an onlooker observer as one who completely separates himself or herself from the research setting as a spectator does. My engagement in these settings allowed me to hear, see, and begin to experience reality as the participants do (Marshall & Rossman, 1989).

I outlined the description of my roles and responsibilities as researcher in the consent form. Being aware that collection of credible data depended on the participants’ confidence in me as researcher, building and maintaining trust with the participants was a main objective in the course of the research. I used the period of prolonged engagement as an opportunity to built trust and rapport between myself and the participants. At first, the participants were reluctant to share information with me, mentioning their concerns about their professional relationship with the Science Education Faculty. For example, two of them were still engaged in A-STEP, one was
planning on returning as a doctoral student, while the fourth participant was a summer employee for the faculty. I demonstrated to them that their confidence would not be used against them and that the assurances of anonymity would be honored. I further ensured that the participants understood that they would have input and could actually influence the research process.

Finally, I tried to make sure that the observational data were as careful a representation as possible of the actions observed in the research setting. Additionally, I used field notes with the purpose of providing a record of my own reactions to, feelings about, and opinions of the research process.

Trustworthiness

In this section I provide information on anticipated limitations of the study and actions I took to increase trustworthiness. Critics of qualitative research have argued that there is no value in qualitative studies because they do not accomplish internal and external validity. To counter these critics, Lincoln and Guba (1985) explained that, in place of the traditional ideas of validity, qualitative researchers substitute the concept of trustworthiness. Trustworthiness of a study corresponds to the rigor of a study in conventional terms. Lincoln and Guba proposed four fundamental components that more accurately reflect the assumptions of the qualitative paradigms—credibility, transferability, dependability, and confirmability. Lincoln and Guba matched these terms to the conventional positivist paradigm—internal validity, external validity, reliability, and objectivity. I took advantage of the four fundamental components proposed by Lincoln and Guba to enhance the trustworthiness of the research.
Credibility

According to Lincoln and Guba (1985) the credibility criterion corresponds to the term internal validity utilized in conventional positivist paradigm. The main promise of the credibility criterion is to establish “the match between the constructed realities of respondents (or stakeholders) and those realities as represented by the evaluator and attributed to various stakeholders” (p. 237). By applying the credibility criterion, I demonstrated that I conducted my research in such a manner as to ensure that participants were accurately identified and described. The study must be “credible to the constructors of the original multiple realities” (Lincoln & Guba, 1985, p. 296). I utilized the following techniques to assure credibility of my study: a) Prolonged engagement, b) Persistent observation, c) Triangulation, d) Peer debriefing, e) Negative case analysis, and f) Member checking.

Transferability

In accordance with Guba and Lincoln (1989), the transferability criterion corresponds to the term external validity or generalizability utilized in conventional positivist paradigm. The main promise of the transferability criterion is to establish the applicability of the findings of a study to similar settings (Guba & Lincoln). Further, Guba and Lincoln stated that “transferability is always relative and depends entirely on the degree to which salient conditions overlap or match” (p. 241).

Transferability is achieved through a thick description of the research process to allow a reader to see if the results can be transferred to a different setting. In order to provide thick description, I present a rich and extensive set of details in relation to my methodology and the context. To provide thick description, I collected as much data about the experience of the beginning teachers as possible in an effort to understand not only “whats” and “hows,” but also “whys” and “whens.”
**Dependability**

To maintain dependability in my study, I took the following steps into account: (a) I was consistent with the research process to produce dependable results; and (b) I present clearly the processes I used for participant selection, classroom observation, interview, and unobtrusive data.

**Confirmability**

I provide references from the literature and cite other researchers’ findings that confirm my interpretations. I also address confirmability by including detailed excerpts from the raw data that support my interpretations and conclusions. Finally, the steps such as peer debriefing and negative case analysis that I took to address credibility of my study also enhance confirmability.

I am cognizant that my perceptions, beliefs, and values might have led my questions, observations, and interpretations to a certain extent as I carried out my research within the context of my study, even though I bracketed my preconceived ideas. Although my interpretation most certainly was subjective, I was alert that sustaining neutrality and credibility in the design, data collection, interpretation, and reporting of research findings was indispensable for the transferability of the results (Denzin & Lincoln, 1994; Guba & Lincoln, 1989; Patton, 2002).
CHAPTER FOUR

Introduction

This chapter centers on investigating the levels of understanding and application of inquiry and inquiry-based teaching by science teachers who are beginning their teaching careers. In structuring this chapter, first, I introduce two A-STEP faculty members’ views of inquiry. These two faculty members also involved in teaching method courses to the research participants. Then, I present four individual profiles of teachers who participated into this study. Each profile is divided into the following sections: background, teaching context, meaning of inquiry, constraints and needs, factors that promote inquiry-based activities – including the relation between a teacher’s education in A-STEP and how that influenced their teaching styles. A summary concludes each profile.

The Views of A-STEP Faculty Members

In this section of the chapter, I focus on the views of A-STEP faculty members, Professor Anderson and Professor Richardson (pseudonyms), who were science methods instructors for all four participants, and their understanding and use of inquiry-based teaching in science methods courses they taught. This section reports on their views of inquiry, i.e., their intended goals of teaching inquiry, practice, knowledge of beginning science teachers, and so forth. This section ends with an example of an inquiry-based activity used by Professor Anderson in his method course, the Moon Activity.

A-STEP Faculty Members’ Meaning of Inquiry

Professor Anderson stated that his understanding of inquiry was consistent with the NSES and described inquiry in terms of Inquiry and the National Science Education Standards (NRC, 2000). In this regard, he said:
To me, the five essential features of scientific inquiry: engage in questions, decide what information is needed to gather in order to answer the question - how you are going to go about gathering data and design a study - then gathering the data, deciding what the data means as evidence and then designing an explanation, communicating it, and justifying it to a community of peers, represent the main activities of a scientist, how science works, and how scientists think. (Interview, February 1, 2006)

Professor Richardson agreed that the five essential elements of inquiry are necessary for inquiry-based activities.

Both Professor Anderson and Professor Richardson explained that inquiry could take place at any place on the continuum of inquiry. They both emphasized that whether the students come up with the question or not is not the core of inquiry. According to them, a teacher can give a student a scientific question to investigate, and that still would be inquiry. Professor Anderson further elaborated on this statement and added that, “[The] teacher could give [students] both the procedure and the question to investigate in an inquiry….Students begin the investigation, gather information, and then there is a time for the students to take the information and develop some sort of an explanation. But, it is very guided,” he said (Interview, February 1, 2006).

*Necessary Skills for Inquiry-Based Teaching as Recognized by A-STEP Faculty Members*

“Teaching science through inquiry calls on lots of strategies that traditional teachers - the teachers that my students have had - do not, by and large, demonstrate,” (Interview, February 1, 2006) Professor Anderson explained. Professor Richardson concurred. They agreed that science teachers, whether they are expert or novice, need to have a good understanding of what inquiry is and is not to be able to successfully
incorporate inquiry into their teaching. Each stated that science teachers would need to have a strong foundation of content knowledge of their subject, as well as having good skills (i.e., questioning skills, classroom management). Professor Anderson added that teachers need to possess good facilitating skills while providing guidance to their students in inquiry activities (i.e., knowing how to help students design an investigation, gather evidence, and make explanations.) - “all those skills that you see scientists apply” (Interview, February 1, 2006). He concluded, “All those things are not easy to do. As a teacher you are calling on a lot of strategies, a lot of skills that many pros do not have” (Interview).

Both Professor Richardson and Professor Anderson acknowledged that science teachers need to demonstrate good skills in facilitating group work and creating an environment where it is okay to be wrong, yet that can challenge students at the same time. Finally, they were in agreement that it takes time and experience to be able to develop these skills.

_A-STEP Faculty Members’ Knowledge of the Program Students’ Incoming Views of Inquiry_

Professor Anderson and Professor Richardson believed that, in general, both preservice teachers and practicing teachers have misconceptions about what inquiry is. These misconceptions include seeing inquiry as discovery, inquiry as hands-on involvement of students working in a laboratory, and inquiry as questioning. In this regard, Professor Richardson commented that

Practicing teachers will identify themselves as being much more inquiry-oriented than if someone went in and actually looked at their practice and laid it against the five essential elements of inquiry. Most likely, it would not match up….Posing questions and trying to engage students is often equated with doing inquiry. However, they are not the same thing. (Interview, February 6, 2006)
Professor Anderson deemed that the misunderstandings about inquiry-based teaching stems from how science teachers learned science as students. “The general climate out there in the traditional teaching world is not consistent with what we are doing in the class,” he said (Interview, February 1, 2006). Based on his experience working with science teachers over a period of time, Professor Anderson noted, “I do not think beginning science teachers have a whole view of [inquiry] as a process. They see each thing we do in class as somehow separate and not integrated. So, they do not really understand [inquiry]” (Interview).

Although practicing and preservice science teachers have misconceptions about inquiry, both Professor Anderson and Professor Richardson acknowledged that they did not take any action to uncover what A-STEP students’ incoming views and understanding of inquiry were. Professor Anderson said,

What I need to do…is get them to define inquiry and ask them to hold onto their definitions. Then, maybe after we have done a moon study or [other activity] have them write what they think inquiry is and then compare that writing to the writing they had and then wrestle with the difference between the two ….That is what I should do, but I do not. (Interview, February 1, 2006)

Professor Richardson, on the other hand, stated that she assumed that A-STEP students could define inquiry because they took their first science methods course focused on inquiry-based teaching from Professor Anderson. Therefore, she did not see any need in trying to ascertain, formally, the students’ knowledge about inquiry-based instruction.

A-STEP Faculty Members’ Knowledge of Constraints of Beginning Science Teachers

The faculty members acknowledged that logistical, contextual, teacher resistance to teaching science through inquiry, and not having a clear understanding of strategies that support inquiry, if they ever faced them, as constraints that most likely
could hinder A-STEP beginning science teachers’ practice of inquiry-based teaching. Professor Anderson recognized classroom management as one of the main constraints that beginning science teachers face. He said that because inquiry-based activities require active student involvement beginning science teachers have difficulty in managing their classrooms. He commented, “You get students together in groups and they talk. Principals do not like noisy classrooms. Teachers next door do not like it either. People think you are a lousy teacher if your students are making a lot of noise” (Interview, February 1, 2006).

Time was the main constraint that Professor Richardson was apprehensive about. “I think time is a big constraint….It has become even greater because now [teachers] are responsible for more classes, more paperwork, and more after school stuff. [Therefore,] it is easier for them to put together a lecture” (Interview, February 6, 2006). Not having appropriate curriculum materials and support were what she also believed that A-STEP beginning science teachers were likely to be constrained by.

Anderson was concerned about A-STEP beginning science teachers’ understanding of strategies that support inquiry as the foremost constraint to their implementation of inquiry. He noted,

Each part of inquiry approach that teacher utilizes has strategies associated with it and that is where they are going to have difficulty with….I do not think they really take these strategies and make sense of them. You have got to take it and try to do something with it. Then you make sense of it. (Interview, February 1, 2006)

He added that he try to make his students’ experience of inquiry explicit. He said that “Once we did something I would step outside and say, ‘Okay, what did we just do here?’ And we would talk about how that was representative of inquiry” (Interview). However, he said, “The students do not understand why it is important to get students
engaged by asking questions. They see that we do it. They see that it is fun, but they
do not see how it relates to everything else” (Interview).

Contrary to Professor Anderson, Professor Richardson emphasized contextual
(school culture and mentoring) and teacher resistance as foremost constraints to
beginning science teachers’ practice of inquiry. She said that beginning science
teachers suffer from peer pressure and lack of support in their schools. “They are not
seeing other people practicing inquiry, in general. It is hard because it may not fit with
the culture of the school” (Interview, February 6, 2006). She described how while one
teacher is leading an inquiry-based activity, other teachers may be “racing through”
(Interview) lectures and therefore conceivably covering more material.

Professor Richardson felt that beginning science teachers do not have strong
peer support in that they are not invited to watch established teachers lead inquiry-
based lessons and not provided with useful materials. She stated that the more likely
scenario is that beginning teachers will witness only lectures by established teachers
and intuit that this is the easier and more acceptable path to take. “It is lack of
modeling, time, and access to good curriculum that is inquiry-oriented,” (Interview,
February 6, 2006) Professor Richardson stated as reference to some of the logistical
constraints that she believed hamper beginning science teachers’ use of inquiry in
teaching science.

Furthermore, as intern teachers under established supervising teachers,
beginning science teachers rarely have authority to change or determine the teaching
format of a class, Professor Richardson pointed out. In regard to A-STEP’s beginning
science teachers she said that it is likely that APB interns would face this constraint
more than ALT students who have had their own classrooms.
The people who are interning have constraints any time they are in someone else’s classroom…I have had students whose cooperating teachers—mentors—were not inquiry-oriented themselves. They were reluctant to let students try inquiry, [therefore] A-STEP students had to do a lot of negotiating to be able to do it. (Interview, February 6, 2006)

Finally, these two faculty members expressed that beginning science teachers’ own resistance to inquiry constrains their practice of inquiry-based teaching. To illustrate, Professor Richardson gave an example from her experience of working with A-STEP interns:

I found resistance to inquiry, and we had a big discussion about it. [A-STEP interns] expressed that they felt that they were being beaten over the head with inquiry. They were saying that is all this program focuses on and there are other ways to teach. (Interview, February 6, 2006)

Models, Approaches, and Activities Used by A-STEP Faculty Members in Inquiry as A Way of Science Teaching

Professor Anderson and Professor Richardson each discussed that, in their methods courses, their main goals were to help students: (a) learn about what scientists do during a scientific investigation; and (b) understand what student can do as scientists in the classroom to investigate a question, whether teacher-selected or student-developed. “We do our best to provide opportunities for students to experience those strategies and in some cases learn how to use them….That is when they develop an understanding of…inquiry,” Professor Anderson said.

Each professor outlined various activities and readings that they utilized in A-STEP method courses in order to model inquiry for the interns. Some of these activities were: Beak of the Finch, Stream Team, T-Rex, Rusty Nail, and the Moon Activity (for more information see professors’ syllabi, Appendix E). They stated that they make use of these inquiry-oriented activities to teach A-STEP interns about what inquiry is and is not, as well as teaching the difference between guided versus open
inquiry using a continuum of inquiry (NRC, 2000). I provide an example of the above-mentioned models, the Moon Activity, in a later section.

Both faculty members stressed that they were explicit about inquiry in their instructions and provided students numerous contexts through models where they could develop an understanding of inquiry. In these contexts, they said that students engage in the investigations by using questions provided by the instructors as well as questions the students want to investigate. “Model, deconstruct, scaffold planning, and then actual teaching followed by reflection is my sequence,” Professor Richardson said (Interview, February 6, 2006). She considered this instructional technique as the best way to confront A-STEP interns’ views of inquiry. She said, “I think this challenges their thinking [and causes them to pose these questions]: ‘Is this something I want to do more? Is this going to get too chaotic? What is going to happen?’” (Interview, February 1, 2006).

The central focus of his science methods courses was “the five essential features of inquiry,” Professor Anderson said. Using the essential features of inquiry, Professor Anderson made clear that A-STEP faculty members were explicit to their students that inquiry is not necessarily hands-on. “Three of the five essential features of inquiry - explain, communicate, justify - certainly are minds-on,” he said (Interview, February 1, 2006). To illustrate, he described one of the articles used in his science methods course written by Bybee (2002). This article portrayed three different classroom scenarios. Once students read the scenarios, he asked them, “Which one of these is representative of inquiry?” (Interview, February 1, 2006) Professor Anderson explained, “All three scenarios are representative of inquiry. In all of these scenarios the students are investigating data that is provided to them by the teacher. There is absolutely no hands-on. We explicitly talk about it” (Interview).
In another science methods course that Professor Richardson taught, A-STEP interns were exposed to a model illustrating that inquiry does not necessarily involve hands-on activity and students collecting data. Students, in this activity, did a computer-based investigation of the finch population of the Galapagos Islands (Beak of the Finch Activity) using real data on drought and rainfall, temperature, food supply, populations of a variety of kinds of finches, predators of finches, and so forth.

One of the goals that A-STEP faculty members had in teaching science methods courses was to make sure that their students would be able to differentiate inquiry from non-inquiry activities. To accomplish this, they made a point of frequently explaining to the students that not all hands-on activities are inquiry. Professor Anderson discussed two different versions of an activity, cookbook-style and inquiry-based, and provided a context for students to develop an understanding of how cookbook-style activities are different from inquiry-oriented activities. He stressed that inquiry-oriented activities are not supportive of verification but rather of investigation. He said,

The first [activity] was more supportive of verification. However, the second one was supportive of an investigation, supportive of inquiry. …When they finished doing the investigation they found out that there were two different versions. We compared what they came up with. We talked about how they felt when they did this, when they did that, etc. As a result, they [got] a sense of how the two were different.

(Interview, February 1, 2006)

Both Professor Anderson and Professor Richardson criticized their own science methods instructions in different ways. Professor Anderson acknowledged that he did not think that his secondary level science methods courses highlighted that discovery is different than inquiry. He added, “All I have ever done is talk about discovery. I have basically said that discovery is not a very truthful way of pursuing
the teaching of science because students cannot create conceptions” (Interview, February 1, 2006).

On the other hand, Professor Richardson felt that they put too much emphasis on creating an inquiry-based curriculum given that inquiry was not being emphasized in schools. “It is called overcorrection. We want them to get the idea that this is what they should be doing and this is what the standards are saying,” she stated (Interview, February 6, 2006). Professor Richardson conceded that the focus should shift back from attempting to create all new inquiry-based programs to making use of existing lessons that are inquiry-oriented.

*How A-STEP Faculty Members Addressed Anticipated Constraints of Beginning Science Teachers*

Professor Anderson and Professor Richardson had noticed common constraints faced by beginning science teachers in implementation of inquiry. In their science methods courses, they made efforts to prepare their students to be ready, once they begin teaching, to handle these constraints. Professor Anderson explained that in his science methods courses he tried to make sure that his students developed some strategies about: (a) how to engage students in an inquiry-based activity; (b) how to help their students form their own questions; and (c) how to manage a classroom where students carry out inquiry activities either on their own or as part of a group.

Professor Anderson deemed that knowing how to introduce an activity to engage students was not only an initial step but also a necessary one for successful inquiry-based activities. He further explained that using the right strategies while engaging their students not only helps teachers find out about their students’ prior knowledge, but also helps students to generate questions for their own inquiry investigation. Professor Anderson said that he incorporated a number of strategies in
his instructions that would help his students to understand how to engage their students in inquiry activities in the future. “They do things [such as] learn how to help students find a question, how to design an investigation, how to give a lecture, how to use a variety of different assessments to find out how students are learning,” (Interview, February 1, 2006) Professor Anderson said.

To illustrate how he utilized some of these strategies in his instruction, Professor Anderson described on the Rusty Nail activity. He explained,

We did an investigation on the process of rusting. I began this instructional sequence by having them take a nail and put it somewhere at home where it would rust….Two weeks later they brought it back to the class and I asked them to answer a few questions, [for example], where had they put [the nail] and what did they think was necessary for something to rust. (Interview, February 1, 2006)

Professor Anderson continued that, once the students put their answers on posters, “I realized what they were thinking, what they thought caused rust, and what they thought rust was. As a result of the discussion they developed questions to investigate” (Interview). He stressed that he was explicit about how he attempted to get the students to understand the instructional strategies. He said,

When we finished with the developing of questions to investigate I [asked]: What did I just do? What did I find out from all of the stuff that we did? Why would I do all this stuff? And they told me, ‘We did this because you got us to get interested in the nail and you figured out what our ideas were by looking at our posters. You saw what preconceptions we had about rusting, and you wanted us to develop some questions to investigate.’ (Interview)

He stated he posed further questions to his students, such as, “What would you do if a student does that?” and “How would you respond to students who break the rules this way or that way?” (Interview, February 1, 2006) Professor Anderson described one of the common strategies he uses in his inquiry activities. “In the
beginning of the second course, we put together a set of protocols of classroom behaviors that students thought we should have in the class. We wrote those up on poster boards. Those became our rules for classroom behavior,” he elucidated (Interview). He also noted that he used similar strategies to help A-STEP interns to develop teaching strategies that would facilitate group work.

While Professor Anderson provided information on how he addressed common constraints that beginning science teachers face, Professor Richardson felt that they focused on convincing students to create their own inquiry-based curriculum rather than teaching them how to take advantage of available inquiry-oriented curricula. She believed that they were not able to address the main constraint that beginning science teachers face —not having access to fully-tested successful inquiry-activities.

**A-STEP Faculty Members’ Expected Outcomes of Their Interns’ Practice and Understanding of Inquiry**

Professor Anderson and Professor Richardson stated that, as a result of taking science methods courses, they would expect A-STEP interns to have a good understanding of what inquiry is and is not. Their expectations were not only that students would be able to understand what the five essential features of inquiry are, but that they would also be able to distinguish and judge whether an activity is inquiry-based using the essential features of inquiry. “I would hope that they could distinguish inquiry from the 5E model,” (Interview, February 1, 2006) Professor Anderson said to illustrate his point.

They emphasized that they would anticipate that A-STEP interns would be able to make use of some, if not all, of the strategies they had taught for using of inquiry in their teaching. Both faculty members believed that A-STEP interns would
be able to employ inquiry ranging from teacher-directed guided inquiries, to student-directed open inquiries, along the continuum of inquiry (NRC, 2000).

Professor Anderson articulated that he would hope that A-STEP interns would try to incorporate inquiry into a lesson by either asking students a question that could result in some gathering of data or get the students to ask questions.

However, it would be fine if they asked a question, decided together how to gather data, and used the data to design an explanation….I think they would have an idea that guided inquiry is when the teacher provides a lot more structure and that full inquiry is where the teacher provides some structure, but not as much. (Interview, February 1, 2006)

Professor Richardson expounded on Professor Anderson’s statements, but with a slightly different perspective. “I would expect our students to be more student-centered, having kids collect evidence and make claims about it, if I were comparing them to traditional teachers who went through teacher education that was very lecture-based 15-20 years ago,” she said (Interview, February 6, 2006).

Professor Anderson acknowledged that the school culture where beginning teachers start their careers is “largely reluctant” (Interview, February 1, 2006) to support inquiry teaching.

It is an uphill battle I guess. When A-STEP interns enter teaching a number of them are going to fall back on the ways they observed in the classes that they had before they came to the university and the classes that they had in the university” (Interview).

He added, “But, I am hoping that what they learned in my classes will be a source to come back to and to think about and to act upon over time” (Interview).

“Inquiry is something that they are going to have to plan because the instructional materials that are available for most programs do not really include the kind of inquiry that we are supporting in our program,” Professor Anderson stated
(Interview, February 1, 2006). He clarified that he would expect A-STEP interns to implement inquiry, because he had given them tools to revise non-inquiry based instructional materials to inquiry-based and opportunities to practice the revision of inquiry-oriented instruction materials. He said,

What I say to them is [that] in the first semester [they] should take one activity, one topic, and revise it to an investigation that supports learning through inquiry, [and] another activity in the following semester. And then next year do those two again, but add two more. In the second year, now you have four. In the third year, you have six. By doing that, you can build up a number of opportunities for students to learn through inquiry. (Interview)

The Moon Activity

To illustrate the views of the intended goals of A-STEP faculty members in modeling inquiry, I include a short description of the Moon Activity used by Professor Anderson.

Professor Anderson described how he taught the Moon Activity. This included asking the students to tell him why they think they see different shapes of the moon. He explained that all of them believed it was because the Earth cast a shadow on the moon. Having explored students’ prior knowledge and introduced the activity to the students, he said, “Let’s investigate this” (Interview, February 1, 2006). For the following couple of weeks he asked the students to gather evidence by going out every night and drawing a picture of the moon relative to the horizon, describing its position in degrees and the time of day or night.

After data gathering, he had the students make a model using a Styrofoam ball on a meter stick. Holding it out in front of them at various positions around themselves, so they could see what side was lit and what side was not. This helped the
students understand the relative position of the moon to the Earth and to the sun on
the phases of the moon seen from Earth.

Commenting on how he modeled inquiry through this activity, Professor
Anderson said:

What I attempt to do at each step is, when the strategy is done, [to] say,
“Let’s think about what I just did as teacher.” I describe what it was
that I wanted to have happen, and I also talk about things that I don’t
think went so well. …Then eventually the students do the strategies
themselves. So, they have an opportunity to put them into effect.
(Interview, February 1, 2006)

After that, Professor Anderson asked the students to come up with questions
that they wanted to investigate. He called the approach “coupled inquiry” (Interview,
February 1, 2006). The first part was guided inquiry, which led to the second part
which was open inquiry. An example of an open inquiry was a question that two
students proposed to investigate, whether the lunar phases had an influence on the
number of human birth in a given period. They utilized hospital data regarding births
to answer their question. This illustrated to them that inquiry does not have to be a
hands-on laboratory activity. Professor Anderson emphasized that students can use
pre-collected data sets.

Summary of the Views of A-STEP Faculty Members

Faculty members agreed that science teachers, whether they are expert or
novice, need to have a good understanding of what inquiry is and is not to be able to
successfully incorporate inquiry into their teaching. In order to implement inquiry-
based activities, they deemed that science teachers would need to have a strong
foundation of content knowledge of their subject, as well as having good skills (i.e.,
questioning skills, classroom management). However, both faculty members believed
that, in general, both practicing and pre-service science teachers have an incomplete
view of inquiry. According to them, this view of inquiry also comprises misconceptions about what inquiry is. Faculty members believed that the misconceptions of inquiry stems from past experiences that science teachers had as students.

In addition, faculty members stated that they were aware of the constraints that beginning science face in implementing inquiry-based instruction. They stated that they made efforts to prepare their students to be able to handle these constraints and develop a better understanding of inquiry. They explained that the purpose of science methods courses were to help interns to develop strategies about how to carry-out inquiry-oriented activities such as (a) engaging students in an inquiry-based activity; (b) helping students form their own questions; and (c) managing a classroom where students carry out inquiry activities either on their own or as part of a group.

As result of taking science methods courses, faculty members stated they would expect A-STEP interns to have a good understanding of what inquiry is and is not. Their expectations were not only that students would be able to understand what the five essential features of inquiry are, but that they would also be able to distinguish and judge whether an activity is inquiry-based using the essential features of inquiry. They emphasized that they would anticipate that A-STEP interns would be able to make use of some, if not all, of the strategies they had taught for using of inquiry in their teaching—employ inquiry ranging from teacher-directed guided inquiries, to student-directed open inquiries, along the continuum of inquiry.
Profiles of Beginning Science Teachers

Profile 1: Andrea Newman, High School Chemistry Teacher

Background

Andrea Newman, 49, is a high school chemistry teacher and a first-year student enrolled in A-STEP’s ALT tract. Andrea did her undergraduate studies in chemical engineering at the University of Missouri-Columbia. She got her degree in 1978. In 1986, she completed a Master’s degree in Business from the University of Houston at Clear Lake. Between 1978 and 2005, she held a variety of positions in industry, including engineer, process engineer, senior engineer, staff financial analyst, staff engineer, corporate ISO program manager, independent chemical engineer, and business and quality consultant. She shifted to teaching during to personal reasons.

I got separated from my husband. My mother’s health was not very good and I wanted to move back here to where I had a family and friends as a support network. That is especially important because I am a single mom, and I’d like to have support with raising my daughter. I chose teaching because I wanted a job that was meaningful, but that also gave me a chance to be with my daughter more, to have the same schedule she does. As an engineer and consultant, I traveled a lot and that didn’t work very well for a single parent. (Interview # 1, October 4, 2005)

Prior to her decision to become a high school teacher, Andrea did substitute teaching at middle and high schools for a couple of years in her new hometown. During these two years she taught English, chemistry, mathematics, and history. She also taught a business class in which she instructed her students in word processing, accounting, and web design.

Her prior teaching experiences included teaching several industry-related classes related to the jobs she held in the industry. For example, she had taught ISO 9000 quality standards, statistical process, process improvement, and technical
engineering courses. The year before enrolling A-STEP, Andrea was a full-time teacher on a provisional certification. During that year, she taught chemistry, advanced biology, applied physics or principles of technology and facilitated advanced chemistry for students who were taking the class for dual credit through a university.

During this first year on provisional certification, Andrea said that her teaching methods were mostly lectures, homework, and worksheets with some hands-on activities. However, she acknowledged that her teaching improved over time after her enrollment in A-STEP. Andrea came to realize that she needed to add uniformity to her teaching process, to use teaching methods other than lecture. “I was kind of flying blind. I knew the material I was supposed to teach so well, but [now] after enrolling in A-STEP, I know a lot more about what students can learn at different ages,” she said (Interview #4, January 30, 2006).

First of all, I now understand that I need to make things as concrete as possible, especially for younger students. Second, I need to broaden the scope, not only lecture, because lecturing does not work for many students. Third, now I try to find ways to relate [the subject matter] to the students’ everyday lives, engaging their interests before I move on rather than just assume that I know what they want to learn. I used activities in the past but I didn’t know anything about inquiry. (Interview #4)

Teaching Context

At the time of the study, Andrea was teaching in a consolidated high school located between two Midwestern towns. One of these towns had approximately 1,000 people while the other had approximately 2,000. Andrea’s teaching load included two sections of physical science and two sections of chemistry. It also included one section of physics/principles of technology, and one section of advanced chemistry
which she co-taught with a college professor via Internet and interactive television to students who were taking the class for college credit. The number of students she had in each of her classes ranged from 12-30.

In-class observations for this study took place in one of the two sections of chemistry. The observations spanned ten class periods, each period lasting 45 minutes. The focus of the unit Andrea taught was the atomic structure. In this class, there were ten Caucasian students, six of whom were male and four female. The students were mostly juniors, with one sophomore and one senior. According to Andrea, the students in this class were the better students in the school. “Chemistry is a class that students are not required to take, so most of the students who choose it are above average in their science and math levels,” she said (Interview #3.1, November 4, 2005). She expected the students in this class to already know that there is such a thing as an atom and that different materials have different properties. “They learned that in a previous unit, and they had already been introduced to chemistry in junior high or middle school,” she said (Interview #3.1).

Classroom Practice

Andrea’s teaching practice appeared to be informed by what she learned at A-STEP. In her teaching practice, Andrea tried to use more than one teaching strategy to make her lessons more interactive. She believed that interactive lessons increased student motivation and they were more suitable to students with different learning styles.

A typical lesson, depending on what we are doing that day and where we are in learning a concept, will have a little bit of lecture…. I have a video or demonstration to illustrate the points or things we are trying to understand. I give students an example. As we progress with the idea, we do a lab. I break the large groups into smaller groups because that way they can learn from each other and after that they do the lab and
lab write-ups. Then we move on to the next part of concept. (Interview # 1, October 4, 2005)

Although Andrea explained that she did not like textbooks in general, she closely followed textbooks and used them to give reading assignments to her students. She said that she felt comfortable using her physical science textbook every day because it had good argumentation, hands-on activities, visuals, pictures of experiments, and the book generally flowed well. “I prefer this textbook to other textbooks because it examines common misconceptions and considers the different learning styles of students,” she said (Interview #2, October 25, 2005).

To teach the atomic structure, Andrea used several laboratory activities and few demonstrations. She focused on the early models of the atom, the discovery of the atomic structure, modern atom theory, and the changes of understanding of the nucleus. “I want my students to have a good understanding of the atomic structure because the atomic structure is the corner stone of understanding chemistry,” she said (Interview # 3.1, November 4, 2005). She added, “If [students] understand how a model came about, what kinds of tests were done, they would be likely to begin to understand the scientific thought process” (Interview # 3.1). Also, she said that once students understand the model of the atom, they would be able be to use that to predict how reactive an element would be and begin to understand how properties were dictated by how the atom is structured. “As I teach that, I also make sure that my students meet the science Grade Level Expectations (GLE) for the Missouri standards,” Andrea said (Interview # 3.1).

This unit was an extension of a preceding energy-and-matter unit, in which student studied elements and compounds. They also studied what made up elements,
compounds, and atoms. According to Andrea’s schedule, studying the periodic table is an unit that will follow.

The “Forced to Change” is an example of Andrea’s practice. Before she involved the students in the activity, she reviewed a test that they had taken earlier and reminded the students of related-material they had studied. She then lectured, for a few minutes, about how different scientists developed the theory of the atom based on the observations of static electricity. She utilized an overhead slide show and a timeline. After the lecture she moved to the following activity: She blew air into a balloon and asked Jeremy, one of the students, to rub the balloon against his hair for 30 seconds. While Jeremy was rubbing the balloon against his head, Andrea approached another student, Jason, and handed him a plastic cup. She asked that Jason rub the cup against his shirt. He did. After a short time, she got the cup back from Jason and asked Jeremy to hold the balloon in his hand. She then placed the cup near the balloon. Pointing to the balloon and the plastic cup she exclaimed -- “Look [the plastic cup] is pulling the balloon! The balloon and the cup are attracted to each other!” (Classroom Observation [CO]: Lesson #3).

Jeremy did not want to part with the balloon and kept on playing with it. When he moved it closer to his hair it became so clear that his hair was attracted to the balloon. “What is that called?” (CO: Lesson #3) Andrea asked. “Electricity,” (CO: Lesson #3) Jeremy replied. “Scientists noticed that when you rub certain things like metals, amber, or glass, objects were attracted to each other,” (CO: Lesson #3) Andrea said then paused to give students time to grasp the concept. “They called it static electricity,” (CO: Lesson #3) she continued.

Andrea then used the story of Benjamin Franklin flying a kite with a key on its string during a thunderstorm to explain to students how he concluded that an object
could have one of two kinds of electric charges -- positive and negative. “Particles repel each other when they have like charges and attract each other when they have opposite charges,” (CO: Lesson #3) Andrea emphasized.

Moving to discussing how the scientist J. J. Thompson was able to determine where positive and negative charges come from, Andrea also referred to illustrations in the textbook about what other scientists had done before Thompson. Using slide illustrations, Andrea focused on how scientists had studied a device called a cathode-ray tube. This tube could spin a small paddle, which suggested that it produced a stream of particles. Scientists before Thompson, Andrea told her students, found out that a magnet could deflect the cathode ray in the direction expected for negatively charged particles. Thompson built on such discovery to conduct his cathode ray experiments, she said.

Once finished with the lecture portion of the class, Andrea wanted her students to try a hands-on activity. “Now, we are going to simulate something that will deepen our understanding. Take out the worksheet (Appendix F—“Forced to Change”) and read it in your working groups,” (CO: Lesson #3) she instructed. She then distributed the materials that the students needed and told them how to set up ramps. The students conducted the activity in the following order: (a) Each group set up a ramp on the floor by placing a couple of books under one end of a sheet of cardboard; (b) the students placed a sheet of carbon paper on the top of the white paper and laid the papers at the base of the ramp; (c) they rolled both a small and a larger ball bearing down the ramp separately and marked where the ball bearings landed; (d) one student from each group held a magnet down at the base of the ramp before another student rolled down each ball bearing separately several times; (e) students moved the magnet to the other side of the cardboard and repeated the previous step.
According to Andrea, the purpose of the activity was for “The students to get a feel for the fact that magnetic fields can deflect [an object] and change its path” (Interview # 3.3, November 8, 2005). She said that the students were likely to fully grasp the concept “By experiencing how the magnets affected the path of the ball running down the slope of the cardboard ramp, and how this was similar to what Thompson did in his cathode-ray experiment,” (Interview # 3.3) even it did not have all the components of what he did.

To follow up, the next day, Andrea began her lesson with a demonstration that reemphasized the cathode-ray experiment. After the demonstration, but before the students reformed their groups, she told the students that they would need to think about what they had just seen for the benefit of using this information in their activities. At the end of the class, she stated that she believed the students had a chance “To see how the idea or the model of the atom was developed and how scientists figured these things out” (Interview # 3.4, November 9, 2005). She mentioned that the students were able to see how a magnet caused the movement of electrons in the demonstration. “[The students] saw it [electrons having charge] today, in the tube, that a magnet really does effect an electron. We saw that because we demonstrated it,” (Interview # 3.4) Andrea said.

The hands-on activity, from start to completion, spanned two class periods. During both class periods, while students were working in groups, Andrea moved among the groups and encouraged them to make good observations and to write these observations down. After the students completed the activity, she asked some questions to see if they could relate what they had just learned. Students were then asked to turn in their laboratory reports and Andrea moved on to lecture again for the remainder of the class period.
During an earlier interview in conjunction with this activity, Andrea said that in the preceding year, before she started her A-STEP education, she had taught atomic structure without including the simulation of Thompson’s cathode-ray tube experiment.

Now, I think any time that I can include an activity that students can do themselves, I do, because such activities give students an experience that they can relate to their abstract learning. It makes the learning more concrete, and helps them assimilate it. (Interview # 3.3, November 8, 2005)

**Meaning of Inquiry**

According to Andrea, “Inquiry is not only just learning science but it is also learning how to design an experiment, how to take a question and investigate it, and how to learn something and have it be valid” (Interview #2, October 25, 2005). The laboratory episode, Forced to Change, described in the previous section illustrates her view of inquiry to validate science. “What I was hoping to do was reinforce what I said in the lecture,” (Interview # 3.3, November 8, 2005) she said regarding her use of the activity. Further, she that inquiry is “Learning how to think and how to think in a way that leads to really discovering something. In the process of inquiry students have to think more and have to come up with how…to figure out things by themselves,” (Interview #2) she said.

Andrea differentiated inquiry-based teaching strategies from teacher-oriented teaching strategies. In inquiry-based teaching, she said that students learn science through making real observations. Then they use what they have learned from their observations to decide what they would like to do next. She also acknowledged that there is “inquiry” (referring to open inquiry) and there is “guided inquiry.” She had a different definition for each.
She said that;

First, a true inquiry first of all relies on the initiative of the students. Second, it is determined by how much I, as a teacher, tell them what to do versus letting them figure out what they want and need to do on their own to meet an objective. (Interview #4, January 30, 2006)

To clarify what she meant by inquiry versus guided inquiry she provided an activity focused on measurement of the density of an object, as an example. “I provided the students with the following materials: water, ethyl alcohol, and a plastic molly. Water and alcohol have known densities. The density of the plastic molly is unknown,” (Interview #1, October 04, 2005) she said. “Discovering the density by the students on their own with no direction from me would be inquiry. However, if I asked them the same question and then led them to the answer through questions, then it would be guided-inquiry,” (Interview #1) she explained.

Andrea perceived her role as a guide helping through activities and making certain that they come up with the right answers. She expressed that she can use an open inquiry activity in her classroom only after her students have already conducted a comparable activity through teacher-guided inquiry first. Returning to the object-density activity, she said that only after a teacher-guided activity of finding density could she feel comfortable assigning an open-inquiry activity on density because students needed the initial training and how conduct such activity on their own. She said that

In teacher-guided inquiry, if the students are going off on the wrong track, and are not quite having the concept right, you could help them adjust, so the final project, when they get there, is not all or nothing. I would say that with guided inquiry it is like you are setting them up to succeed and you are setting them up to learn. (Interview #2, October 25, 2005)
Andrea further explained that in a guided-inquiry lesson when the students asked her questions, she would tell them how to conduct their tests and what types of things they needed to look for to gain answers. She emphasized that she would not give them the answers, but rather would ask them leading questions to help them formulate their own path to the correct answers. “As long as one student responded with ‘I do not know,’ I would walk the students through other examples, without providing them with the answer, until they all understood the process and the answer,” (Interview #2, October 25, 2005) she said.

Andrea regarded the activity called “Forced to Change” as a form of guided-inquiry instruction “because I did not ask the students to replicate Thompson’s experiments due to equipment constraints. So this activity was not open inquiry in that it did not develop [the students’] thinking process. They did not have to figure out how to figure it out,” (Interview # 3.3, November 8, 2005) she said. She added

If I could have a cathode ray tube set up,…I would ask the students to figure out a way to do the experiment to see if we get the same results, to see if they can show that it has mass and charge, and have them put together their own procedure, and then see if they have any other questions and anything they’d want to try. (Interview # 3.3)

Constraints and Needs

Constraints. Andrea acknowledged that the courses she had taken in A-STEP contributed to her knowledge of how to become a better teacher, helping her change her teaching style from teacher-centered to increasingly student-centered through more and more inquiry-based approaches. However, logistical factors such as the extra teacher time needed for finding new methods and materials for inquiry-based activities, the extra classroom time needed for conducting such activities, class size,
and availability of would-be needed facilities were among the constraints she faced in her attempts to include more inquiry-based activities in her teaching.

It takes a lot more time to figure out inquiry than it does to try to do shorter activities…. I think it takes a lot of preparation which is hard to do when you’re teaching all new classes…. I have three different preps, chemistry, physics, and physical science. I have not taught physical science before…and [it is difficult] just trying to get lesson plans and grading done and then go to grad school at the same time. (Interview #1, October 04, 2005)

Another big constraint that she explained was the sheer volume of material that had to be taught. “Such volume cannot be taught through inquiry, given the limited time we have. When I have extra time I can try to modify an activity so [it is] more inquiry-based, but having extra time does not happen often,” (Interview #2, October 25, 2005) she said.

Managing a class of 26 students is an additional challenge to Andrea. Such class size, she said, makes it difficult to utilize open-inquiry based activities and also maintain a safe environment. “Safety is a priority. But given the fact that there are up to eight students who regularly engage in disrupting others in this particular class, I need to watch closely, and so I prefer to use hands-on activities that the students could perform at their desks,” (Interview #1, October 04, 2005) she said.

The last logistical constraint that Andrea elaborated on was the lack of equipment. “Last year my classroom budget was cut. That limited my use of inquiry because one must purchase the necessary materials to conduct successful inquiry-based labs,” (Interview #2, October 25, 2005) she said. “And regarding the “Forced to Change activity my students engage in, if I had a cathode-ray tube, I would encourage the students to replicate Thompson’s experiment,” (Interview #3.3, November 8, 2005) she added.
The second set of inquiry-impeding factors in Andrea’s teaching centered on her students. “They are not strong in mathematical ability, science background, motivation, and other critical-thinking skills,” (Interview #1, October 04, 2005) she detailed.

Andrea’s assessment of her students’ abilities was apparent during one of the observations conducted for this study. In one class period the students were working on an activity called “Isotopes of ‘Pennium.’” The students were observably having difficulty understanding what an isotope was. They expressed that they did not know what to do with the measurements they took. They struggled with the idea of fractional abundance and weighted average.

During that time, Andrea moved from one small group of students to another and tried to help them understand what each of the concepts meant. She told them how to use their measures, and provided them with examples. She also helped them with their calculations.

After class Andrea outlined her frustrations. First, she said that her students were used to non-inquiry based learning, i.e. conducting step-by-step cookbook style activities. Contrary to their earlier training, now, the students needed independent mastery of basic laboratory skills in order to perform inquiry-based activities. They did not have that. And their deficient mathematical skills showed in their struggle with the ideas of fractional abundance and weighted average during the “Isotopes of ‘Pennium’ activity.”

The main ideas of the lab were what is a weighted average, and how do you group isotopes. Well you group them by weight; and then calculate the relative abundance of each. But they really didn’t understand how to do this weighted average, basically did not know how to calculate an average, which is basic mathematics. I think math is wiping them out. (Interview #3.10, November 21, 2005)
Student level of motivation to initiate and participate in their own learning process is yet another of the factors complicating Andrea’s teaching. “They tend to wait for answers from me. We really need to work with the students on developing initiative and critical-thinking skills if we are to include many inquiry-based activities,” (Interview #2, October 25, 2005) she said.

She added that in addition to logistical and student-related factors, there were some personal factors that hindered Andrea’s commitment to inquiry-based teaching. She explained, “When I teach a subject other than physical science I feel constrained in finding and implementing inquiry-based activities. When I teach chemistry and physics I can bring in a lot better examples because these subjects are my strong suits” (Interview #1, October 04, 2005).

Andrea further acknowledged that the didactic style with which she had been taught in college had influenced her own teaching style and constrained her from doing more inquiry-based activities.

[The] background I came from was not inquiry based at all. When I went to school it was lecture, lab, notes, test, etc. I had a teacher in Chemistry who was really good and you worked independently a lot, but she had it pretty well laid out. You did not design your own experiments or anything. (Interview #4, January 30, 2006)

And as a second year teacher (but first year in A-STEP), during the time when this study was conducted, Andrea said that she did not have sufficient resources and knowledge of inquiry-based activities. That slowed her down, she commented.

Another thing is that during one’s first few years of teaching, one tries to make sure to hit all of the state’s GLEs, become familiar with the book and the materials, in addition to developing the lessons. I prefer to spend my time and energy in trying to meet these goals. When it comes to inquiry-based instruction, it is yet another level of added work…. Much of the materials I teach are not inquiry-based because it
takes a lot more time to figure out inquiry than it does to do shorter activities. (Interview #4, January 30, 2006)

**Needs.** Andrea acknowledged that there was a deficiency in her understanding and grasp of inquiry-based teaching, classroom management, and the ability to engage students in inquiry-based activities. “I need more help and practice with this whole inquiry idea. How do you integrate it into lessons, and how do you build inquiry skills in your students?” (Interview #4, January 30, 2006) she said. She thought that she was having a hard time using inquiry in her teaching because of the fact that she did not have a strong foundation of inquiry-based teaching. “I am trying it, but I am not sure I know what I am doing…. I want to know more about both [guided and open inquiry], because I don’t think you can just go to open inquiry,” (Interview #1, October 04, 2005) she said.

I want to know more things about how to engage [the students’] interest, like demonstrations and discrepant events.... I am trying to find ways to make it more student-directed, where they have to figure out what to do rather than I tell them what to do. (Interview #1)

But given where she stood at the time of the study, Andrea expressed that she preferred doing guided- inquiry based activities and aimed to gradually move towards open inquiry-based activities while continuing to build up her resources and level of mastery of teaching.

Reflecting on her preparation at A-STEP, Andrea had some suggestions that would make the strategies of instruction even more effective. “It would help me much more if an activity was explained more explicitly as I was experiencing it. For example, I needed to know the steps used in preparation and not only the materials that were delivered during instruction,” (Interview #4, January 30, 2006) she said.

I would love, at the end of a class, to get a copy of the lesson plan that the professor had used in order for me to use that as a model in my own teaching. That would help because sometimes it is hard to
concentrate on doing an activity as a participating student and also concentrate on how the classroom was set up and the activity accomplished by the professor. (Interview #4)

In addition to lesson plans detailing how inquiry-based activities were selected and utilized, she concluded, “Getting hand-outs, sources for added information, practice tools such as 5E, a variety of inquiry-based directions, tools for behavioral management in the classroom, tools for optimal use of collaborative groups, all of this would be very helpful” (Interview #4) to her and was needed for her success in teaching.

**Factors That Facilitated Inquiry-Based Activities**

The three main factors that facilitated Andrea’s use of inquiry-based teaching included (a) her perceived benefit of inquiry to students’ learning, (b) her reliance on the activities and models used in A-STEP, and (c) her prior work experience in the field that she became a teacher in.

In Andrea’s view, students benefit from inquiry-based instruction by becoming better at problem solving and critical thinking. “When you discover something yourself [referring to inquiry] it means you have to connect it to something you knew before and it is real to you….When you have to do [inquiry] then you are an active learner,” (Interview #4, January 30, 2006) she said.

It is not passive as in a lecture that goes in one ear, onto the paper, pass the test, then out the other ear and it is gone. [With passive learning, students] do not retain [information] as well and may get rote memorization rather than actual understanding. One gets a lot better shot at actual understanding with inquiry. (Interview #4)

Andrea also expressed that inquiry-based activities revealed the interdisciplinary nature of science. “Chemistry, Physics, Math and Biology are all
connected now, much more than before. I aim to help my students see that,”
(Interview #4, January 30, 2006) she said.

The models detailing the steps taken toward implementation of inquiry-based activities Andrea learned at A-STEP facilitated her inquiry-based teaching. Though she has been in the program for a few months only (she was in her second semester and had completed her first summer session), and though she wished that she had many more of those models, she expressed that she firmly believed that the courses she had taken in the program taught her a lot about how to incorporate inquiry into her teaching. She provided the moon project as an example to illustrate how the program made her think about the process of inquiry and learning.

This summer we did the moon project…. I never really thought about the moon much. It is just up there, you know. So, it was interesting to go out and observe it every night and figure out questions, and it kind of reconnected me with being a scientist and to get a feel for that process,…to learn about how to learn, how to teach people how to learn. (Interview #2, October 25, 2005)

Other projects Andrea named were the rusty-nail project, and the stream-team project. “I am basing [my activities] on what I learned at MU and the reading that we did for class on inquiry as the starting point, the base for how to design [activities] for my own class,” (Interview #4, January 30, 2006) she reported.

[For example], I am going to use the rusty nail experiment in Chemistry. I have already got [the students] putting their nails someplace to rust…. I am going to use the rust nail activity because the next chapter starts talking about each chemical formula and bonding, and we are going to start talking about different kinds of bonds which will lead to the next chapter which is reactions. (Interview #4)

The last main factor that Andrea mentioned had facilitated her inquiry-based teaching was her prior work experience. Said that whenever she saw a connection
between the subject she taught and her prior work experience, she that that to the attention of her students. “That helps make it real to them. For example, on the topic of density, I was able to tell them from first-hand experience about how density is being used in the chemical industry to separate materials,” (Interview #2, October 25, 2005) she said.

Profile Summary

Andrea Newman, previously a chemical engineer who held a variety of positions in industry, and was a high school science teacher enrolled in A-STEP’s ALT at the time this study was conducted, emphasized inquiry-based teaching. She utilized a variety of tools to illustrate the points in the lessons she taught. Such tools included laboratory activities, lecture, video, demonstration, and small group activities. Andrea’s teaching strategies were geared toward making the material she taught as concrete as possible for her students while engaging them in activities related to their daily lives.

Andrea said that inquiry does not involve learning science only, but it also requires learning how to design an experiment, how to take a question and investigate it, and then how to learn something and have it be valid. Andrea deemed that, in inquiry-based activities, students not only have to think to figure out things by themselves, but also these activities could help them learn how to think in a way that could lead them to really discover something. According to her, there were two forms of inquiry: (a) “inquiry” (referring to open inquiry) which meant relying on the initiative of the students with no direction from her; and (b) “guided inquiry” which occurred when the teacher told students what to do and how to conduct their activities. Additionally, to successfully perform inquiry, Andrea believed that students needed to have initial guided training.
Andrea stressed that she felt constrained by logistical and student factors. Logistical factors were shortage of equipment, class size, time needed both for conducting and finding new methods and materials for inquiry-oriented activities. Student factors included student’s level of mastery in science and mathematics in addition to their low level of motivation and students not having student critical-thinking skills. She also expressed that there were some personal factors that hindered her commitment to inquiry-based teaching, such as teaching a subject that was not her “strong suit.”

Alongside these constraints, she articulated that it was important to her that she teaches the inquiry-based approach to science. Factors that facilitated her practice of inquiry-based teaching included her perceived benefit of inquiry to students’ learning, her reliance on the activities and models used in A-STEP, and her prior work experience. Additionally, the belief that inquiry-based activities provided context for interdisciplinary nature of science facilitated her practice of inquiry-based teaching. Yet, Andrea acknowledged that there was a deficiency in her understanding and grasp of inquiry-based teaching, classroom management, and the ability to engage students in inquiry-based activities. As a beginning science teacher, she mentioned that she would have appreciated receiving help toward remedying her deficiencies.

Profile 2: Cindy Cruise, High School Biotechnology Teacher

Background

Cindy Cruise, 37, was a high school biotechnology teacher at the time of the study. She graduated from A-STEP’s APB tract. The year of the study was her first year teaching. Cindy had completed her undergraduate studies in biology in 1991. She obtained her degree from Colorado College. After college, she worked for four years at Synergene, a bio-technology company. There, she held numerous positions. Her
positions involved tasks such as performing analytical research and developing analytical tools related to High Performance Liquid Chromatography (HPLC) with proteins. She also trained the new technicians who joined the laboratory where she worked. Synergene went out of business, declaring bankruptcy. Cindy then found a new job in the same field –medical bio-technology. For the three years that followed, her work included a host of tasks such as performing quality analysis and running stability programs, not only for the company she worked for but also for other outfits with which her company signed contracts. Cindy quit that job after three years, when she became a mother. She returned to work after seven years, this time as a science teacher.

Teaching science was not Cindy’s first experience in teaching. During her college years, she tutored group-home students to help them through their General Educational Development (GED) testing. During three of the four years when she worked at Synergene, she was a part-time biology instructor in a tutoring program for students who were not performing to their full potential. The majority of these students belonged to under-represented groups. When she moved to another town for her second job, she got involved with a mentoring program. She worked with female high school drop-out students who were also teen mothers ranging in age from 14 to 16. As a mentor, she helped the teen moms with studying for the GED. And before joining A-STEP Cindy, worked with 7th grade students in what she described as an immersion program. For five weeks, she observed and assisted a science teacher twice a week for four hours daily.

Cindy said that prior to her A-STEP preparation, she based her teaching approaches on strategies she had seen her previous teachers use. As a student, Cindy said that she was “achievement-driven” (Interview #4, January 31, 2006) and liked
getting notes off the overhead. For that reason, she valued it when the students she taught took notes during the lectures she gave. However, she reflected, “I do not believe that I was able to meet my goals in full in the teaching I did before A-STEP” (Interview #1, July 16, 2005).

In the year following her A-STEP preparation, she reported that she used a broader approach. She strived to incorporate teaching about the nature of science with teaching the history of science.

For example, we did a unit on physics that focused on how Newton’s laws were a big deal not only from a scientific perspective, but also in that they affected the way the society looked at itself. This idea was new for my students. And I think it got them thinking about some of the science that’s going on right now and how it could affect their entire world views in only ten years from now. (Interview #1, July 16, 2005)

*Teaching Context*

*At the time this study was conducted, Cindy was teaching at a career and technical education facility. The facility was located in a midsize Midwestern town with an approximate population of 80,000. This facility served students from multiple high schools from inside and outside the county’s school districts. According to her school district, Cindy’s title was a Career Vocational Educator, teaching laboratory technology. Her job was to teach skills that students could take with them to the workplace or/and in higher education.

But Cindy did not limit the scope of her work to the title of her job. “I see myself as a science teacher,” she said. “I try to introduce to the students the nature of science and the nature of the scientific thinking process. As we
go forward, I focus on technology, techniques, and skill,” (Interview #2, October 21, 2005) she explained.

Cindy said that her philosophy was that a true science teacher introduced the scientific way of thinking as a value, no matter what the task was. “A physicist, a chemist and a biochemist have very differing specific fields and differing pieces of knowledge. But all three think in the same manner when you come down to brass tacks,” (Interview #4, January 31, 2006) she emphasized.

The observation period in Cindy’s class included ten class blocks, 90 minutes each. All were in Cindy’s biotechnology class. The unit I observed was about the topic of genetics in animals, plants, and bacteria. The class had six students in it -- four seniors, one junior, and one sophomore. In this class, there were five Caucasian students, four of whom female and one male, and one African American female.

Cindy commented that the students had relatively high GPAs and were successful in general in the school. She expressed that they had high interest in science. They wanted to pursue graduate level work in science. Because the course was considered as “practical arts” the students observed did not receive any science credit for this class.

Classroom Practice

Working at the Career Center, Cindy’s main focus was to prepare her students to be familiar with research methodologies, types of laboratory technologies, and work skills that they were likely to encounter in the future.

To do that, I frequently consult with scientists from a local research university and people from the industry. This way the students will leave with the skills that are in demand. I want my students to be able
carry-out research in a laboratory rather than follow procedures blindly. I also want them to have mastery of equipments used in a laboratory. That will help them to troubleshoot and develop some of their own methodologies. (Interview #1, July 16, 2005)

To illustrate her point, she gave the example of precision and accuracy in measurements-- “because there are things that need to be super accurate and precise, while there are other things to which high precision just does not matter,” (Interview #2, October 21, 2005) she said

To train her students in critical thinking, Cindy said that she constructed her curriculum around real-life problems. Students could use more than one approach to solve a problem. She explained that she preferred to use cooperative and problem-based learning approaches in arriving at solutions to real-life problems. She aimed to familiarize her students with the cooperative contexts similar to real-life work culture.

Guest lectures, arranged field trips, demonstrations, and experiments were activities and resources that Cindy brought into the classroom while teaching this unit. She planned the unit around an experiment -- the DNA Extraction Laboratory -- and utilized additional activities and resources in order to expand the learning related to the experiment.

Based on in-class observation, this section describes Cindy’s biotechnology class unit, Cindy’s reported goals for teaching this unit, class details, and how Cindy employed additional activities and resources into her practice.

In the biotechnology unit, Cindy focused on the foundation of genetics, explaining that students had learned previously some basic laboratory techniques and how to calculate the serial dilution factor. These skills would help them with this laboratory. She said that her aim was to help the students see how what they had learned previously was connected with what they were going to learn, and how
knowledge is cumulative. She acknowledged that students would have different backgrounds in the subject matter:

However, I expect that the students’ knowledge of this unit will vary. Not only do they have different backgrounds but they are also in different grade levels. But I expect that they all would know that DNA is the material that transfers genetic information from generation to generation. (Interview #3.1, November 7, 2005)

Cindy’s stated goals upon the completion of this unit were that the students would understand the basic mechanisms of DNA, RNA, how these two elements control inheritance, and how they differ among animals, plants, bacteria, and viruses.

Cindy did not adopt a textbook. Thus, prior to the first lesson in the unit, she required everyone to review online materials that she considered basic for the understanding of genetics. She chose a website that was interactive, using visuals to go from a person down to their tissue, down to cells, down to chromosomes, down to DNA. In addition, the website included a couple of interactive activities, such as including one’s own DNA molecule and then translating that DNA molecule to a protein. Cindy indicated that not only did she want to have the students refresh their knowledge of genetics, but also “to make sure all students are on the same page, or at least have the ability to be on the same page while reviewing the basics of genetics” (Interview #3.1, November 7, 2005). After completing the review, the students answered the questions they had on their worksheets that Cindy had given to them previously.

Acknowledging that guest speakers could share real-world knowledge and make more sense to the students than hearing information from their teacher’s mouth, Cindy invited guest speakers to the first block of this unit. The guests included three individuals from a local research university, Dr. Hamrick, a biologist, and, two
biology students -- one graduate and one undergraduate. The guest speakers mainly talked about their involvement in a maze root genomic research. They provided Cindy’s students with information on genomic research. Dr. Hamrick focused on visible mutations and function of genes in corn. She also discussed the importance of her research to human beings. She provided a historical background on the selection process of corn that Native American have been using for 9000 years. In her conclusion, she commented on interrelated sides of research that were taking place in the field of agronomy. Next, the students shared their research using poster presentations. Cindy’s students appeared to be listening excitedly. They asked questions and asked for more information.

For the following class period Cindy had initially planned to review the guest speakers’ talks with her students, allowing them to do presentations about what they learned. Afterward they would engage in designing their DNA extraction protocols. However, Cindy was neither able to review the guest speakers’ talks nor initiate the protocols activity. The reason was that she found out that her students had not taken their serial dilution laboratory reports seriously (had students performed this activity prior to my CO). They also had made many mistakes in the calculation of serial dilution factor. So, she decided to use the second block for going over the steps of serial dilution, including calculations. She wanted to make sure that the students knew how to calculate serial dilution because that was critical to the DNA extraction experiment.

During the third block Cindy implemented her initial lesson plan, yet slightly differently. Instead of letting the students do presentations on the guest speakers’ talks and then designing their protocols, she introduced the spectrophotometer. She showed her students how to utilize it. For the presentation, she divided the students into two
groups and assigned them to either the biologist or student speakers. As a group, the students were asked to present three most important ideas that they believed they got out of a guest speaker’s talk. As they worked, Cindy moved between the two groups and helped them.

I need you guys to go through the notes you took on our speakers and tell me what you thought the three most important points were…I am not looking for you to do a vocabulary exercise here. What I want you to do is give me three important concepts, top three…think about some big concepts. (COs: Lesson #3)

During both presentations Cindy asked a variety of questions to probe for more information and to create conversations about the important ideas that were presented.

Returning to the spectrophotometer and its function, Cindy showed her students how to use it with solutions that they had prepared for the previous unit -- dilution activity. She first demonstrated the steps then let the students perform their experiments following procedures outlined in the handout she passed around during the lesson (Appendix G – “Introduction to Spectrophotometer”).

Comparable to the strategy used for calculation of serial dilution factor, Cindy wanted her students to understand the procedure in order for them to be able to use it in the DNA extraction activity. “I had to do that because I realized that the students had made a lot of mistakes in their study guides that they turned in,” (Interview #3.3, November 11, 2005) she said. “I wanted to address the incorrect responses” (Interview #3.3). At the end of that day’s lesson, Cindy gave a short lecture on function of DNA.

Cindy included field trips in this unit to Dr. Hamrick’s research facilities--greenhouse and laboratory. Cindy and her students visited the facilities during the fourth and the fifth blocks. During the visits, Dr. Hamrick and her technician gave
Cindy’s class a tour of each of the facilities, provided information on each facility and shared information about the kinds of research that were taking place in each area.

Both in the laboratory and greenhouse, the students were introduced to some of the equipments used in the field of genetics research. For example, in the laboratory, the students were introduced to equipments used for DNA analysis and examined some of the agrose gels. At the end of the tour they were given an opportunity to do a simple hands-on activity wherein they pretended as if they were loading gels with the multi-channel micropipette.

Cindy planned to begin the DNA extraction laboratory activity right after the field trips. “I gave them three different readings on [protocols] that use different materials as the DNA source, and use different materials as the enzymes to break up the proteins within the cells,” (Interview #3.3, November 11, 2005) she said. Based on the information from these resources, the students were asked to design a protocol to efficiently obtain DNA as part of a demonstration for a fellow high school student.

They used different materials to precipitate out DNA. I also assigned a discussion group asking about what the best way to do this is and it’s got six different answers from six different biochemists on the best way to do it. (Interview #3.3)

In the lab, efficiency would be measured by percent yield. The DNA extracted would be analyzed later in the year while running gels (Appendix H- “Extracting DNA Worksheet”). The students were expected to define the source of DNA they were going use.

However, Cindy was not able to begin this activity until halfway through the seventh block. In between these times, she had the students present the important observations they made during the field trips. She required them to use the same
presentation format that they had used for guest speakers’ talks. For the rest of the
time, she addressed the frustration that students’ had in regard to her practice (see
constraints section for more information).

In the middle of the seventh block students started the DNA extraction
laboratory and it spanned two blocks. Cindy expressed that she wanted to make sure
that the students knew what they were doing. She provided everyone with a handout
laying out some guidelines and factors that they should consider in designing their
protocols (see Appendix H for more information). Students worked simultaneously
both on pre-lab activities and implementing their protocols. Cindy monitored their
work and provided them with the help and support they needed in designing and
implementing the protocols.

Later, she reflected on her role and said that she tried to have plenty of tools at
her students’ disposal. “If [students] ask for something, I try to get it for them or
suggest to them a reasonable substitute” (Interview #3.9, December 12, 2005). She
reported that she considered her role to be that of a facilitator, a safety supervisor,
someone to bounce ideas off of, rather than a source of information. “The students are
the ones who have control over the design and implementation,” (Interview #3.10,
December 14, 2005) she explained.

While Cindy was facilitating the activity she could see that the students were
adjusting their protocols to take into account limitations and unconsidered factors that
they had not initially considered. She explained that this was a sign of understanding
that “no matter how well they had planned their protocols, the first time they run an
experiment they have to make adjustments” (Interview #3.9, December 12, 2005).
Cindy seemed happy to see this happening and reminded the students to record their
adjustments with explanations.
At the end, however, not all three groups were able to obtain DNA from their sources. The group of Jason and Carry was one of the groups unable to extract DNA from their source. Jason and Carry got frustrated and commented that they failed to meet the instructor’s expectation—i.e., to efficiently obtain DNA measured by percent yield. Jason raised his voice and yelled at his classmates a few times to express his frustration. Cindy told Jason and Carry that it was okay if they did not end up with the outcome they had wanted. She asked that they record and report every single step taken during the procedure. “You always have results. They may not be the ones you wanted or they may not make sense to you at that moment, but even quote unquote no result is still a result,” (CO: Lesson #9) she instructed.

Carry was also worried, but she was calm. She asked the instructor if they could redo their experiment. In response, Cindy advised them to focus on the evidence they had in their hands – the observable differences, such as color and consistency.

On the last day of observation period, which was the 10th block, the students gave a quick synopsis of their protocols. They presented their results and talked about percentage recovery of DNA from their sources. They also discussed what they thought could improve their protocols based on their experiences. After the presentations, Cindy revisited the disappointment that Jason and Carry had with their experiment. She explained that she was pleased to see students being able to use evidence to make conclusions about their procedures.

*Meaning of Inquiry*

“For me, [inquiry] means to try to set up an environment where students can learn the scientific process of problem solving at the same time that I try to teach them the academic material,” (Interview #2, October 21, 2005) Cindy said. “The scientific
thinking process is not something that students would learn by reading a science textbook” (Interview #2)

Cindy regarded problem solving as an essential part of inquiry-based teaching, distinguishing inquiry from lecture. She also delineated two types of inquiry -- inquiry with “little i” and Inquiry with “Capital I.”

In Inquiry, with “capital I,” students carried out research on their own. In Inquiry-based activities, to be able to perform, students needed to start by examining their misconceptions and becoming familiar with current literature on a topic that was their subject of study, design experiments, collect data, work collaboratively to analyze the data, and come to some sort of conclusion, in addition to doing some type of authentic presentation of the findings. For Cindy, if it did not have all of these components, instruction did not qualify as Inquiry.

Cindy regarded “DNA Extraction Laboratory” as an example of [I]nquiry. “Students got practice on converting other people’s methodology to their own and to be able to take information from multiple sources. [They] examined [multiple protocols] and then synthesize them into one piece…in order to design and execute their experiments,” (Inquiry #3.8, December 6, 2005) Cindy said. She added, The students analyzed data they collected within their team…they were modifying their experiments based on the evidence that they saw and draw some conclusions from that in order to apply it to the next step…They did talk amongst themselves about what worked and didn’t work for the teams that were ahead or behind them, so there was interaction not only between the team members but across the various teams They collaborated with other teams to share data, to ask questions…So, all of those are part of the nature of inquiry. (Interview #3.10, December 14, 2005)

Inquiry with “little I,” however, according to Cindy, included activities that did not comprise all features of [I]nquiry. Cindy recognized inquiry-related activities
as small activities that had some elements of Inquiry to them. She described inquiry as activities that took place in two different forms. “In the first case, it means to get to the root, to ask… [in inquiry] students are asking questions, and trying to capture data which will answer such questions,” (Interview #4, January 31, 2006) she said. She added,

The first lesson with guest lectures was an example of inquiry because the students were introduced to new topics and they asked questions, took information off the posters, and worked together to figure out what the researches were communicating. I was listening to one group while I was talking to another and I heard them working together going through the steps of the poster saying, okay, what does this mean? Why did they do it this way? Explain it to me again. So, the students were introduced to something very new, in that they were asking questions and that they were taking information off the posters and working between themselves to try and figure it out…. That collaborative approach to understanding new material to me is part of inquiry. (Interview #4)

In the second case, Cindy regarded inquiry-based approaches as activities that required students to derive conclusions from given data using new tools and procedures that were taught to them. An example she gave was the spectrophotometer activity done in the third block. According to her, what made that lesson inquiry was that the students worked collaboratively and were required to draw conclusions based on what they knew and evidence that they obtained from data.

To further explain what she meant by inquiry, Cindy gave an example of when she lectured on how to do the math to examine pipetting skills and used a demonstration to show the students how to use pipettes. She said that she let the students loose to do pipetting multiple times at different volumes and had them look at their data through the statistical tools they had discussed—standard deviation, relative standard deviation, and percent error. Afterward, “we bring all data together
as a class to look at trends to see if there were some general statements we could make regarding accuracy, regarding precision when looking at different sample volumes with using the same instrument,” (Interview #2, October 21, 2005) she said.

“To me, this is [i]nquiry because they try to analyze the data to make conclusions. However, because in this case I give students the experimental procedure and the statistical tools to make their evaluation, they were not doing [I]nquiry,” (Interview #4, January 31, 2005) she added.

Constraints and Needs

**Constraint.** Although Cindy’s stated goal was to teach practical skills (because teaching such skills was the mission of the Career Center in which she worked), she regularly attempted to make efforts to incorporate inquiry-based activities in her teaching. But the lack of freedom to fully focus on the activities she felt passionate about teaching left her feeling somewhat constrained.

Additional constraining challenges included students’ lack of motivation and their limited skill level and limited knowledge in mathematics and science. “I would like it if my students enjoyed the open-ended side of my lectures and did not worry about taking notes and recording things for the sake of test,” (Interview #3.6, November 21, 2005) she said.

Contrary to Cindy’s wishes, however, her students appeared to be mostly focused on getting high grades. They also appeared to expect her to show and tell them fully how to do a task rather than think about it for themselves.

“They often function like stenographers copying notes down word by word,” (Interview #3.6, November 21, 2005) she complained. She gave the example of the class period when Dr. Hamrick gave a lecture to her students. “Rather than listening
for big ideas, one student who was busy taking down notes interrupted the talk in the first sentence to ask Dr. Hamrick about the spelling of a word” (Interview #3.6).

“I like to create positive learning environments where students could engage in inquiry-based projects rather than engage in little worksheets,” (Interview #3.7, November 30, 2005) she said. However, “the students do not seem to like experimental settings and they have been saying that they are having difficulty with inquiry-based learning,” (Interview #3.7) she added. “They call such settings disorganized and lead them to feel that everything goes above their heads. They say that their learning is not totally accessible and useful to them,” she commented. “That surely affects their level of motivation,” (Interview #3.7) she concluded.

During the observation of block #7, I was able to observe some of the frustrations experienced by Cindy’s students. On that day two students expressed their frustrations to Cindy just before the lesson began. So, instead of starting the lesson, Cindy gathered everyone in a circle in order to talk about their concerns. “It has come to my attention through more than one student that you are frustrated,” (CO: Lesson #7) she started. “I want you to be challenged, but I don’t want you to be frustrated, and there is a difference,” (CO: Lesson #7) she continued.

She encouraged the students to give her constructive feedback. Many responded by sharing their thoughts and feelings concerning inquiry-based instruction. They said that they learned only little and that they felt they had been wasting their time. “I think it is a kind of ridiculous that we are in our 3rd or 4th month of the school and I have not felt like I have learned anything,” (CO: Lesson #7) Jason said. Many claimed that smaller activities with instructions and an answer key would have benefited them more. “In chemistry, we have a worksheet for homework. The
answer is a number and I can check my answers. If I get it wrong I ask,” (CO: Lesson #7) said Ashley.

In response to her students’ frustrations, Cindy acknowledged that they needed to have a solid understanding of the basics of mathematics and science in order to benefit from and inquiry-based learning. Her students did not appear to have such basics. Referring to the serial dilution activity, she said that she discovered that her students did not have the foundational mathematics abilities required for inquiry. “They seem to have a mathematics phobia. They very much dislike using math to analyze a result” (Interview #2, October 21, 2005).

Another constraint Cindy perceived was that her students seemed to leave behind any learning that they were no longer required to be tested on. I observed this phenomenon during Cindy’s class on serial dilution. Cindy had to re-explain a previously taught unit in order to be able to add a new level of learning. “They all had forgotten all about the dilution factor even though they had been tested it on about two weeks ago,” (Interview #3.6, November 21, 2005) she said. In re-explaining the previously taught information, she lost an entire class period.

Shortage of equipment needed for implementation of inquiry activities was another major constraint for Cindy’s teaching. During the observation of the spectrophotometer experiment and DNA extraction activity, for example, the quantity of DNA available for student use was not sufficient, and there was only one spectrophotometer for the entire class. “If we had two or three of them we would not have to stretch the lesson to two or three class periods,” (Interviews #3.3, November 11, 2005) she said. “I borrow equipment from other departments, and I even had my own food processor in,” (Interview #3.9, December 12, 2005) she added.
Needs. Cindy fully acknowledged that as a beginning science teacher she had many unmet needs. First, there was the need for access to successful field-tested, inquiry-based activities that would “cement” students’ understanding of science without confusing them with misconceptions.”

It was in A-STEP that Cindy got introduced to the idea of teaching through inquiry. “My expectation about going into A-STEP was that they would spend a lot of time training us in very specific methods of teaching,” (Interview #4, January 31, 2006) she said.

To her surprise, “there was so much focus on inquiry-based instruction as the only method to teach science,” (Interview #4, January 31, 2006) she added. “In general, I did not feel there was a lot of teaching about teaching going on with the exception of the first six hour class, which was kind of a basic psychology methods,” (Interview #4) she said.

“I think that a healthy classroom involves more than one teaching technique. I don’t think I got a good foundation of other teaching methods,” (Interview #4, January 31, 2006) she said. “To use a metaphor, I feel like I had left my carpenter training knowing how to use a hammer, but not knowing how to use other tools in my toolbox, and that was a major disappointment,” (Interview #4) she commented.

One key tool Cindy said she needed regarded how to assess students’ prior knowledge of a topic in order to teach them what they needed to learn and what they were ready to learn rather than teach them what they already knew.

She stressed that having the experience of being able to actually apply what she had studied in her work environment, a high school classroom setting, would have been a tremendous benefit to her. Cindy regretted that she did not really have such
opportunity. What she needed, she concluded, was a safe and supportive environment in which she could teach what she learned, the inquiry-based methods.

Cindy believed that some of her needs stemmed: a) from A-STEP’s excessive focus on inquiry teaching, b) disproportionate use of subject specific activities, d) the contradiction she had with her mentor teacher.

“The “A-STEP faculty members were training us how to be the heads of the department and be the rebel rousers when it came to deciding curriculum,” (Interview #4, January 31, 2006) she said. She added, “They were arming us to be rebels to go out and change the world rather than how to go in and be a first, or second, or third year teacher” (Interview #4). She did not seem that she understood the purpose of some of the activities utilized in the program. She described some of the exercises as pointless busy work. “One professor had us do a moon journal. We were supposed to go out at a certain time each night and watch the moon and record it in our journal,” (Interview #4) she explained. She concluded, “I just really did not see what we gained in terms of being able to teach young people by us going through this exercise” (Interview #4).

Cindy also made a comment that other types of activities used in A-STEP were also problematic because they were specific to only one subject area.

There was a faculty member who heavily focused on examples from biology. The chemists and particularly the physicists in our group went nuts because everything was about Biology. They did not feel that they were learning much about how to teach in their subject areas. (Interview #4, January 31, 2005)

Cindy also emphasized that her experience with her mentor teacher was so contradictory to what she had been taught about inquiry in A-STEP.

I just felt like I was being taught you should teach this way, you should teach this way, you should teach this way and when I went to teach I
was told that what I did was useless and I needed to do it differently. (Interview #4, January 31, 2005)

Factors That Facilitated Inquiry-Based Activities

Cindy believed that A-STEP and her past experience facilitated her practice of inquiry. In spite of the constraints she faced in teaching using inquiry-based methods, Cindy explained that there were factors that she learned during her time in A-STEP that facilitated inquiry-based teaching. Such factors included framing lessons in a context relevant to her students, relevant to the work of scientists, and teamwork. Doing so not only allowed the students to participate but also to work cooperatively, develop critical thinking skills and maintain high levels of motivation while learning about the process and nature of science.

“Team work allows them an opportunity to feed off of each other’s ideas and build upon them,” (Interview #1, July 16, 2005) she said. “And as they construct their own understanding through experimentation that is related to their lives, inquiry becomes much more a part of who they are, rather than just learning it for a test,” she added. She cited as an example the DNA extraction laboratory her students did. My kids were so excited about writing those protocols. One of them took those protocols to the Biology teacher and said, “Look what we did--we wrote our own protocols.” The DNA activity and other similar activities improved the students’ writing and public speaking skills, taught them that science is a world-wide project with people from various countries reviewing one article. It also taught them about peer-reviewed journals and that not all science is high-tech. Questioning sources of information, the students developed a critical eye toward sources on the Internet and methods to evaluate these sources. I think my students also got a glimpse into how collaboration functions, and that the day-to-day simple make huge progress in research. (Interview #4, January 31, 2006)
Additional benefits to the students, Cindy pointed out, included the repeated observation that scientific research occurs in a continuum, and that scientists build on one another’s research and findings. “Inquiry-based activities show students that science is a process of gathering evidence in order to understand results. Whether there is a desired result to an experiment or there is not, both outcomes are useful information for the researcher,” (Interview #3.9, December 12, 2005) she emphasized.

Though Cindy was dissatisfied with what she perceived as shortcomings of A-STEP, she emphasized the aspects of the program that had helped her.

A-STEP not only shook up my world views in terms of what I could do in the classroom, but it also reinforced the reasons why I became a science teacher. I would love for my students to go on in their professional lives to become scientists. Most of them will not, but I teach the way I do so that they all can have a spark of curiosity and critical thinking skills even if they never do science officially academically again. For example, I want them to think like scientists when they go into the voting booth. (Interview #4, January 31, 2006)

Cindy acknowledged that A-STEP’s approach had dramatically changed her teaching strategies.

I do not have to explain everything because the students own their processes and search for understanding. I also assign readings and initiate discussions rather than just give ready answers. And rather than have each student do an experiment and compare findings to an ideal goal – something traditional teaching encourages – using A-STEP strategies, my students combine data from multiple groups. They are little scientists; they pool our data. They decide based on evidence they see. (Interview #4, January 31, 2006)

Learning to integrate mathematics and science was another factor facilitated by A-STEP that Cindy cited. “Previously, I had thought of science and mathematics as two different subjects and I never thought of them as integral, even though I had used
mathematics all the time in my professional career,” (Interview #2, October 21, 2005) she said.

Virtual labs, which Cindy used to educate her students, provided the opportunity to combine science and mathematics and examine how they interacted and were tightly woven. Cindy mentioned that she learned about how integrate science and mathematics in A-STEP.

The fact that Cindy took up teaching after having spent time working in the scientific industry was a second key factor that facilitated her teaching of inquiry. “They do not question me,” (Interview #4, January 31, 2006) she said. “You have been there; I get it. You know it first-hand,” (Interview #4) she related that one of her students had said. She explained, “There are two ways in which my previous experiences in the industry come into play. First, I am always aware that there are many approaches that one can choose from to carry out any given activity” (Interview #4). Therefore, “I don’t limit the format of my student’s work,” (Interview #4) she said.

In that DNA extraction lab, for example, I found multiple protocols for the students. I think a lot of times high school teachers and high school students think that there is only one great way to do a particular task, but there is not. (Interview #4)

Secondly, she said that she draws on her previous work experiences to teach students good laboratory and technical skills.

From my previous work, I am very aware of how evaluating evidence accurately, in order to make a conclusion, requires excellent knowledge of technical lab skills. Without such technical skills it is hard to achieve a high level of accuracy while conducting an experiment. (Interview #4, January 31, 2006)
Profile Summary

Cindy Cruise was previously a science industry professional. A-STEP graduate, she taught high school science in a Career Center and emphasized inquiry-based activities in her teaching. She utilized a variety of teaching tools to educate her students. Such tools included lab experiments, field trips, readings, group discussions, guest speaker presentations, and reports. Cindy’s teaching strategies were geared toward assisting students in cultivating critical thinking skills, whether they eventually chose science as a professional path or chose other professional fields.

Cindy deemed that, in order to learn the scientific thinking process and nature of science, students needed to engage in inquiry-based activities. According to her, there were two forms of inquiry: (a) [I]nquiry with “capital I” which meant that students carried-out independent research from questions through results; and (b) [i]nquiry with a “little i” in which students derived conclusions from given data using provided tools and procedures. Even though the two types of inquiry had distinctly different meanings for Cindy, she believed that both required collaborative work. Cindy aimed to engage the students in both types of inquiry. Additionally, she believed that for students to successfully perform [I]nquiry, they needed to master a large variety of [i]nquiry activities. Cindy felt constrained by logistical factors, such as shortage of equipment. She also felt constrained by students’ level of mastery in science and mathematics in addition to their lack of motivation. There were also constraints that she believed that she was not fully prepared in A-STEP such as assessing students’ prior knowledge and employing a variety of teaching strategies. Yet, Cindy acknowledged that, as a beginning science teacher, she would have appreciated having access to successful field tested models of inquiry-based activities at her disposal.
Against these constraints, Cindy articulated that it was important to teach using an inquiry-based approach to science. Factors that facilitated her practice of inquiry-based teaching included the knowledge she gained during her preparation in A-STEP, and her prior work experiences.

Profile 3: Lisa McDowell, Middle School Science Teacher

Background

At the time of the study, Lisa McDowell, 42, was a first-year middle school science teacher and a first-year student in A-STEP’s ALT tract. Lisa obtained her undergraduate degree in animal science in 1992 from Murray State University, KY. After graduating, she worked in a chicken farm that she owned. In 1999, she re-enrolled at Murray State University and obtained a Master’s degree in agriculture.

Lisa had been involved in teaching in several different contexts prior to her enrollment in A-STEP:

First, when she was a graduate student at Murray State, she taught a poultry science class for a semester and assisted a college faculty member. “As a teaching assistant, I used lecture as the main teaching method, but the students and I also visited a poultry farm, a hatchery, and a poultry processing plan,” (Interview #2, October 15, 2005) she recalled.

Second, Lisa had the experience of being a language instructor at a private tutoring school in South Korea. There, she taught students whose ages ranged from 4 to 64, she said. That led her to become the head program coordinator in a language program at one of the South Korean universities. She said,

At the university I worked on developing the ESL (English as Second Language) curriculum and taught English at an after school program. But, after spending seven years away from the USA, I decided to come back and continue my teaching career in my home state, Missouri.
Now, as a science teacher rather than an ESL teacher, because I had a solid background in science. (Interview #1, July 31, 2005)

Third, once back in the US, Lisa worked as a substitute teacher for three months in a private school in Columbia, Missouri. She taught all subjects to grades 4th through 7th.

Teaching Context

At the time this research was conducted, Lisa was teaching at a school located in a very small rural Midwestern town that had the population of approximately 325 people. Lisa’s work assignments included teaching general science to grade 7th and 8th in addition to biology to sophomore students. The school she taught in had all grade levels from elementary to high school. Many parochial school students entered in the public school system after 6th grade. In total, the enrollment in the junior high and high school was about 370. The number of students Lisa had in each class ranged from 20 to 30 students.

The in-COs for this study took place in the 7th grade science class which had 26 students in it – all Caucasian, 14 of whom were male and 12 female. The observation lasted for 10 class periods, 45 minutes each.

In describing the general academic abilities of her students in this class, Lisa said that “compared to other students in the school, they were slightly above average” (Interview #3.1, January 4, 2006). However, five of Lisa’s students in this class had physical challenges. Two of them had hearing impairments, two had IEPs for ADD and reading problems, and one had spinal bifida. “The special needs students are very good students,” (Interview #3.1) Lisa emphasized.
During the timeframe of this study, Lisa appeared to be eclectic in her teaching approach. She expressed that she had what she described as a “well-rounded knowledge and a good background in science” (Interview #1, July 31, 2005). “I try to use lecture, and also find time for students to try whatever they want to try,” (Interview #1) she said. As a new science teacher, it was important for her that students actually became interested in something instead of feeling that they had to learn only for the sake of tests. “I want to stimulate their curiosity and engage them in hands-on activities where they can see how science is applicable to their daily lives,” (Interview #1) she mentioned.

But the textbook Lisa used, she called it “from the old school,” (Interview #2, October 15, 2005) did not fully support her teaching vision. She said she had not chosen this textbook. It had been around for about 10 years, making it outdated, not having any online supplement, and not having enough materials for student self-evaluation. The positive aspects about this book that Lisa pointed, however, were that “it has a thick workbook, a teacher bank/test bank, including three versions of each test in various forms of assessment, in addition to a laboratory manual” (Interview #2).

She said the way she addressed the weaknesses of the book was by modifying the content. “I add or skip as I see fit, and also I adjust the material in light of my own personal knowledge, sample textbooks, online resources, past experiences, and feedback from other teacher in the school,” (Interview #2, October 15, 2005) she added.

Lisa’s teaching approach, (appeared to be centered on the social-constructivist view) incorporated numerous collaborative activities. “I believe that learning requires
social interaction,” (Interview #1, July 31, 2005) she confirmed. When asked about her sense of mastery of inquiry-based instruction, she expressed that she had known very little about this approach of teaching until she joined A-STEP.

“I had never personally experienced it myself except for when I did my own master’s degree. I would not say I had. I mean, not even college did I ever experience any inquiry based teaching. So, that was kind of new. I did not really know of that concept before I started the program. (Interview #4, February 8, 2006)

Prior to that, the first time she had experienced hands-on research, which she called inquiry, was during her master’s program. She said that

For my master’s thesis, I compared a known quantity of chicken litter to another type of chicken litter of which the nutrient content had not been well established. I did samplings from ten chicken houses and ran the nutrient contents as a fertilizer value that’s nitrogen, phosphorus and trace minerals. (Interview #1, July 31, 2005)

The unit observed for this study focused on rocks and minerals. Lisa, who described herself as a rock hunter, was going to teach this unit for the first time. Prior to teaching this unit, Lisa had taught about density. For the rocks and minerals unit, Lisa’s expressed goals were that students would be able to describe qualities and properties of rocks and to develop better descriptive skills. Both in this section and the rest of the text, I used the concepts: rocks and minerals as they cited by Lisa throughout interview and my classroom observations.

The tools Lisa utilized in teaching included a form she handed to students and called a “note guide;” rocks and minerals that came from the Missouri mining council; several rock collections; and the textbook.

On the first day of teaching this unit Lisa clarified her expectations to the students. “I would like to have us do more cooperative learning, group work, and
hands-on activities. But I ask that you be quiet as you work and stay on task,” (CO: Lesson #1) she announced.

To find out more about students’ prior knowledge of rocks and minerals, she asked them to form groups of four to five students. Each group was to make a list of rocks and minerals the students in the group already knew and to answer the question Lisa had on board the: “How can you tell what kind of substance a rock is made of?” (CO: Lesson #1).

Several minutes later, Lisa alerted everyone that they might find more information about minerals and rocks in the class if they look around. She pointed to the two posters on the wall. “Looking around is so important because one can find a lot of information, no matter what the question is. The environment is filled with answers,” (CO: Lesson #1) she said.

At the end of the activity, Lisa asked the groups to count the rocks and minerals they had on their lists in order to determine which group got the most. However, the students were not to share the names of the rocks they had on their lists. Now Lisa passed around small bags containing different Missouri rocks, and asked the students: “How can you differentiate rocks and tell one from the other?” (CO: Lesson #1). The students were talking very loudly in their groups and did not seem to be focused on examining the properties of the various rocks or on thinking of a procedure for rock differentiation. “I do not think I achieved my goals today,” (Interview #3.1, January 4, 2006) Lisa said after this class.

The next day, she started her lesson with having the students examine the structures of their pencils. “If you may think that rocks and minerals are not too important in your life, I have something that I would like for you think about. Take a look at your pencils,” (CO: Lesson #2) she said. The students began to examine their
pencils. “Give me some ideas about something you think might be in your pencil…do you know what makes that pencil blue?” (CO: Lesson #2) she asked a student named James. But he had no idea. “It is a mineral that makes it this color,” (CO: Lesson #1) she explained.

Next, utilizing an overhead, Lisa asked students to read information about pencils. Repeatedly, she was asking the students to be quiet and pay full attention when the information was read. Otherwise, she would not let them do the activity “Fingerprints from Graphite,” she warned. Before beginning the activity, Lisa had the students write in their journal at least 40 words about facts they had just learned about pencils.

Then, from the overhead, a student named Kyle read the first two points in the directions for conducting the “Fingerprints from Graphite” activity (Appendix I). Another student named Diana, who seemed to not be paying attention, was unable to repeat what Kyle had just read when prompted by Lisa. Students Teresa and Dustin also seemed to have not been paying attention. Their answer to Lisa’s question about what Kyle had just read was the same, silence. Other students did not give the correct answer either, although it was right in front of them on the overhead.

In apparent frustration, Lisa told the students what to do. “You are going to rub your fingers against the graphite, get them dark enough so you can see the graphite very well. It does not matter which finger you use but then put the tape on your finger, pull the graphite off your finger, then put the tape on to the back of the scratch paper,” (CO: Lesson #2) she instructed.

The students appeared to know what to do now, and began to do it. Meanwhile, Lisa asked them questions about what they thought might be the purpose of the activity. The students appeared to have as difficult a time answering this
question as they did the first. So Lisa told them what the purpose was, and asked that they take notes on what she said. “Basically, you were able to transfer your fingerprints because of the lead. The lead acts like lubricant in some ways, almost like ink even its dry…so minerals have a lot of uses,” (CO: Lesson #2) she concluded.

On the third day of the observation, Lisa told the students that they could review their notes from the day before for a few minutes, and after that she gave them a quiz. Then she performed two demonstrations that were about identifying properties of rocks -- hardness and density.

Following the demonstrations she asked some questions: “How can we design an experiment? How can we find out what kind of rocks we are working with?” (CO: Lesson #3). One student answered, proposing several ideas that could be used to identify rocks. His ideas, however, were mostly incorrect, and did not draw on the information Lisa had shared previously or the notes she had expected him and others to have taken down.

“Do you know how to do a density experiment already? Have we done one?” (CO: Lesson #3) Lisa asked. All the students replied that they had. “What else could we do to identify rocks?” (CO: Lesson #3) she continued. “Scrap,” (CO: Lesson #3) a couple students responded at the same time. So, Lisa moved to introducing the Mohs hardness scale. She talked about the hardness of materials based on this scale. She mentioned diamond, quartz, glass, and a human being’s fingernails. “The Mohs scale is a relative scale a man named Mohs had invented. It’s used out in the field. It is not perfect,” (CO: Lesson #3) she commented. “What do you guys know about quartz? What about glass?” (CO: Lesson #3) she continued.
To illustrate, she asked the students to rub a piece of quartz and a piece of glass against each other. But leaving this activity without allowing students to communicate what they had thought, she moved on to a demonstration.

“What do you know about rocks and water?” (CO: Lesson #3) she asked the students as she held a volcanic rock in her hand. “Rocks sink in the water” (CO: Lesson #3) replied a student named Emily. So Lisa asked Emily to come to the front. She gave Emily the rock and asked her, in a minute, to drop it into a bucket filled with water. “Everybody: will this rock sink or will it float?” (CO: Lesson #3) Lisa asked before letting Emily drop the rock. Different voices answered: “Float” “Sink, “Float” (CO: Lesson #3). But the rock did not sink. “Why do you think that it is floating?” (CO: Lesson #3) Lisa asked the students. “There are little holes in this rock,” (CO: Lesson #3) said Emily. Now Lisa began to lecture. “This is a volcanic rock. It got air trapped in it. It weighs much less than water does,” (CO: Lesson #3) she explained. “What does that tell you about this rock? Is it denser or less dense than water?” (CO: Lesson #3) she asked.

During Lessons 4 and 5 Lisa engaged the students in similar type of activities focused on ways to identify physical properties of rocks. “I am hoping that they would eventually say, ‘Hey, I was able to see the texture of graphite and other rocks on my finger; I could see my fingerprints by rubbing on a rock and by making a print. I can do that to describe or show the texture of the rock,’” (Interview #3.5, January 11, 2006) she said.

Even though Lisa had planned to engage the students early in the “Mineral Identification Laboratory” (Appendix J) she was not able to start that until the sixth lesson. During the activity, the students tested rocks for different physical properties. When asked “How would the laboratory fit into the unit?” she said that
It was at the core of the unit -- describing physical properties of rocks, investigating how to find out about…their color, density, streak, crystal, and texture. She mentioned that she found the activity in an online resource. She added,

But I did modify this activity for density and texture. I added those. It had cleavage and fracture on it also which I did not feel was safe to do with 7th graders…but it met my objective goals…It had the questions and the information that I needed on the sheet. (Interview #3.6, January 12, 2006)

To be able to conduct this activity, Lisa used another teacher’s laboratory because she said she thought that it was not right time to start the activity. Once the students were settled in, she began the lab: “We are going to do tests for color, streak, luster, crystal shape, density, and hardness, and there is an acid test too. We are not going to do magnetic and florescence tests. You will work on three rock samples,” (CO: Lesson #6) she said then she clarified the rules and procedures for the activity.

Next, she divided the students into eight groups, each having three to four students. They were to work at four stations each of which could accommodate two groups at a time for two different tests. While performing their tests to identify physical properties of the samples, the students were to stick to the same rock samples that they started with, all the way through the activity.

At each of these stations, there were instructions on how to complete a specific test. Lisa gave four minutes for conducting each test. Once the students were finished with a test they moved on the next station. Meantime, Lisa was moving among the groups to see whether they were doing what they were supposed to do or not. If she found them off task she directed their attention back to their experiments. If they did not know what to do, she told them what to record and how to perform their tasks.
Most of the time during the observation for this study, the students were loud, appeared off task, and did not seem to focus on the instructions they needed to follow for their tests. Thus, several times, Lisa stopped the activity and asked them to be quiet, “Otherwise I am going to cancel the activity” (CO: Lesson #6) she warned. Finally, at one point, Lisa sent one of the students to the principal’s office and excluded another from completing the activity.

Resuming the work, she required that students to turn in individual laboratory reports, even though they had worked in groups. She said she wanted to see that each one of them had done the work.

The following day, Lisa started class by asking questions about the tests that the students had performed during the “Mineral Identification Laboratory.” She said that she wanted to jog their memories about how they did and what they did during the activity in order to reinforce their learning. As she spoke, the students took notes and drew some crystal shapes of rocks in their study guides. After they were done drawing, Lisa passed out a box of rocks that had samples of crystal shapes to the students, so they could examine them.

**Meaning of Inquiry**

Lisa expressed that she viewed inquiry-based teaching as teaching that mainly consisted of unstructured and student-driven activities. She seemed to regard problem identification and problem solving as essential parts of inquiry-based teaching.

It is necessary to set up situations where students can generate their own ideas and come up with their own questions to test for inquiry based activities. And I prefer demonstration or what I call ‘discrepant events’ prior to implementation of what I see as inquiry-oriented activities. (Interview #4, February 8, 2006)
Lisa identified the “Mineral Identification Laboratory” she taught on the sixth day of observations as inquiry-based teaching. According to Lisa, there were two factors which made the activity inquiry.

“First, the students had tested rocks for each physical property that they were required to perform for the activity. They came up with the ideas tested on their own,” (Interview #3.6, January 12, 2006) she said. She was referring to the procedures during the earlier activities that included identifying luster, density, hardness, and so on. The procedures took place prior to the “Mineral Identification Laboratory”. She added,

I was actually getting them ready to generate ideas about how to do this inquiry lab, i.e. the Mineral Identification Laboratory. Initially, with the Fingerprints from Graphite activity, I wanted them to think about how maybe they could report the texture of the rock. (Interview #3.6)

Second, Lisa believed that she did not provide detailed instructions to the students on how to carryout the activity. To illustrate, she used one of the tests, Mohs hardness scale, which the students were to complete for the activity. “They were given a nail, a piece of glass, and rocks with different degrees of hardness and they tested those rocks. There were some instructions there, but they had to basically figure out the procedure on their own,” (Interview #3.9, January 18, 2006) she said. “Basically, it said if a rock scratches a piece of glass then it is harder than the glass…and to use that to compare how these things would or would not scratch each other. So, I think that was inquiry,” (Interview #3.9) she confirmed.

I did not sit there and hold their hand. There was general step one, step two, but there was not detailed step one, step two. I mean, it was just put one drop of acid on, or put one drop of acid on the rock and observe what happens. I did not say unscrew the cap and take your
mineral and be careful and wipe it up with a paper towel. I did not give them that much. (Interview #3.9)

But Lisa had strong reservations about inquiry-based teaching as the primary way to teach science. She said she considered it a “fashion trend” (Interview #2, October 15, 2005). She affirmed that she did not think inquiry was a panacea to teaching all science. She felt it was another trend in education. “Yes, it has its value and place, but to throw out the whole curriculum in the interest of inquiry? I think that is not appropriate. You would be throwing out the baby with the bath water,” (Interview #2) she protested. She added,

There is a good reason why we have had 2,000 years of similar-type ways of science education. I think this inquiry-based is the newest, hottest thing now just like 25 or 30 years ago it was all TV learning. Then, we were told that everybody was going to be learning with TV and we would not have any classrooms at the university anymore…Now, we are told that everybody’s is going to be learning through the Internet and we will not have any classrooms anymore. (Interview #2)

Lisa also expressed that she was not sure whether the 5E instructional model promoted in A-STEP was, like the inquiry-based teaching, just another fad in science teaching. “I have been in teaching long enough to see that there are fads that come and go and I am not certain if this one is not the same old thing with a different name,” (Interview #4, February 8, 2006) Lisa said. She regarded the 5E instructional model as steps taken by students to do inquiry. “I see 5E as a way of trying to get students engaged and more participatory in their own learning of science,” (Interview #4) she said.

I see [inquiry and 5E] pretty well integrated….I see where they match pretty well…you got to get [students] engaged to get them to start thinking about what a problem might be and then you got to get them to start exploring possibilities of how to solve the problem…So, I see
where it is a way of explaining the steps in inquiry teaching. (Interview #4)

*Constraints and Needs*

*Constraints.* Lisa outlined logistical and student-related factors as the main constraints to using inquiry-based activities in her teaching. The specific factors included school culture, classroom management and student behavioral issues, students’ skill level in mathematics, and the availability of needed time for such time-demanding activities.

“In the beginning, I tried to do inquiry with the students,” (Interview #2, October 15, 2005) she said. “But at that time, I had little idea about the students and the school culture also” (Interview #2). She continued,

Quickly I found out that the students did not know how to work in groups, and working together was not an expectation here. Also, doing critical thinking was not an expectation. So, introducing inquiry-based instruction in a school culture where students were expected to be passive recipients was a bit of a challenge. (Interview #2)

When asking for help in order to manage students during the inquiry-based activities she attempted to do, she said she did not get much support for persisting with the inquiry approach. “I was even discouraged from continuing with inquiry-based teaching. My mentor teacher and the principal agreed. My principal said, ‘The students need to be told to sit down, shut up, and do their work’” (Interview #1, July 16, 2005).

But the behavior of the students in Lisa’s class was the most obvious challenge to conducting inquiry-based activities. “A number of students make classroom management truly difficult. Perhaps the large numbers are a reason,” (Interview #4) she speculated. “A science-major friend of mine from Sweden who came to visit told
me that they did inquiry there, but in [science] classes they had only six to eight students, not twenty four like we do,” (Interview #4, February 8, 2006) she said.

In an after-class interview for this study, Lisa recalled in frustration the “Mineral Identification” activity, and the disruptive level of lack of student attention to the activity while she tried to teach them. “Yes, they generated some ideas,” (Interview #3.6, January 12, 2006) she acknowledged, “but too much off-task behavior was going on,” (Interview #3.6) she qualified. Consequently, “what I have ended up doing in inquiry-based settings is to try to threaten the students. I have ended up just literally shutting off or modifying the inquiry,” (Interview #3.6) she said. “So, I am not going to do that kind of inquiry stuff as much…I am going to lecture more,” (Interview #3.6) she concluded.

Several times in the rocks and minerals unit Lisa threatened the students that if they were not quiet during an activity, either she would not let them finish the activity or would not release them after the bell rang. Instead, she told them, she would keep them in the classroom for a few minutes to punish them because of their behaviors.

Reflecting on her desire to teach through the inquiry-based approach, Lisa regretted that she had to resort to using cookbook types of activities because of the student behavioral issues she was facing.

Student behavioral issues were complicated further by students’ skill levels in the mastery of mathematics in addition to their levels of motivation. “In my understanding of inquiry, students needed to be able to identify a problem, generate questions, and then generate procedures to solve the problem, and then arrive at conclusions,” (Interview #4, February 8, 2006) Lisa said. She added that the 7th and 8th grade students in her class could not figure out what the problem was even when she led them step by step with questions. “I think they do not have the reading skills
and math skills that are necessary for building knowledge and learning science,” (Interview #4) she said.

In an attempt to address this problem and gain the attention of the students during class and spark their enthusiasm for further learning, Lisa used a “discrepant event.” “I floated an ice cube on oil to show that the density changes with water. I thought that they would become engaged in what they saw and ask questions,” (Interview #2, October 15, 2005) she explained. She observed that they did ask some questions, “but when I said let’s design some experiments that involve density, none of them could not make that cognitive leap,” (Interview #2) she said.

Student level of motivation was also a decisive obstacle to inquiry-based teaching, according to Lisa. “My students like to know the right answer. Otherwise, they think they would not please the teachers, and since inquiry is not about knowing the right answers right away, they seem to lose motivation,” (Interview #2, October 15, 2005) she commented. “Also they seem to view the time allotted for inquiry as time to socialize, and that does not allow for the focused thinking that science requires,” (Interview #2) she added.

In addition to the school culture, classroom management constraints, and student skill and motivation levels that Lisa said she faced, she also recognized time as a key logistical constraint. “I should not have wasted two days of class trying to get the students to generate what tests we should do and how we should do the tests,” (Interview #3.6, January 12, 2006) she said, referring to the procedures she had tried to guide her students to do prior to the “Mineral Identification” activity. She speculated that
I would like to find alternative ways to fulfill the objectives of this class. In the future, I might do a museum walk with them, and encourage them look at different rocks with luster, cleavage, fracture etc. They might start thinking about those properties. (Interview #3.6)

Needs. Though Lisa indicated that she had learned in A-STEP the theory behind inquiry-based learning and how to incorporate inquiry-oriented activities in her teaching, she said she did not feel that what she had learned was yet fully transferable to her classroom. To remedy that, she outlined the resources she needed. “I would like to learn more about classroom management, teaching tools for engaging the full attention of the students, approaches for helping students to generate questions and carry out independent research on their own, and effective supervision strategies,” (Interview #4, February 8, 2006) she said. “Yes, I have learned a bit about that in A-STEP,” she acknowledged, “but it was not enough, especially in relation to large class size and students inclination to socialize during the class period,” she added.

With the level of resources she had access to, Lisa appeared to feel discouraged about teaching inquiry effectively. “I do not have the skills right now to manage all aspects involved in teaching inquiry to a large class and carry out that successfully,” (Interview #4, February 8, 2006) she acknowledged. She continued, “Neither my prior experience of teaching ESL, nor the summer class in which I had learned about classroom management in A-STEP during my first year are enough resources,” (Interview #4) she said. Because she knew that by doing inquiry, students learn in depth, and also such learning approaches boost their confidence, she asserted her goal was to learn well how to teach them to come up with their own questions, and help them design and carry-out independent research.

The frustration Lisa said she felt in response to the constraints and shortage of needed resources seemed to exacerbate the situation, creating an additional need.
“When I brought up the struggles I have been facing to A-STEP student supervisor’s attention, the response I got from the supervisor was ‘Good luck! You are going to have a long year’,” (Interview #2, October 15, 2005) Lisa said “That was not helpful at all,” (Interview #2) she reflected. “I wished that A-STEP had an online forum where I and other teachers in the program would have an opportunity to talk about our needs and the issues we face,” (Interview #4, February 8, 2006) she said. “The teachers need a place where we can address our frustrations, and more importantly, we need to see many examples of successful inquiry teaching that are appropriate to the levels of our students. In my case it would be middle school level,” (Interview #4) she said. “I have yet to see something that is truly inquiry-based that works with this age of students. I have seen some stuff on the NASA channel where they had high school students doing inquiry-based activities that worked…but I have seen nothing relating to middle school students,” (Interview #2) she said.

More supervision or…somebody that will help the teachers with the frustrations that they are dealing with…when I go talk to other science teachers that are out there, they are not able to do it either. They are facing the same kinds of frustrations with doing this inquiry stuff. (Interview #4)

Factors That Facilitated Inquiry-Based Activities

The factors that facilitated Lisa’s use of inquiry-based teaching included her perceived benefit of inquiry to students’ learning, the activities and models used in A-STEP, other activities used by other science teachers whom she knew.

In spite of the numerous constraints to teaching inquiry in Lisa’s “old-fashioned” school in general and in her hard-to-control classroom in particular, she expressed that she believed that inquiry had many benefits for students. “I think it increases critical thinking skills, boosts confidence, helps the students organize their
thoughts, and it provides a context for a better and in-depth learning. It can increase their enthusiasm also,” (Interview #2, October 15, 2005) she assessed. “And it gives the teacher a lot of joy when students show enthusiasm,” (Interview #2) she said.

When teaching inquiry-based activities, Lisa relied on models she had learned during the summer courses of A-STEP. She also used additional models she found through her own research efforts. The sources for these models included friends who had taught science previously, books, journals, online resources, science oriented TV channels and programs such as the NASA channel, and conversations with colleagues. “For example, I found out about the ‘Mineral Identification Laboratory’ activity, located it on an online resource, and adapted it to meet my objectives,” (Interview #3.6, January 12, 2006) she said. But it was the interaction with colleagues from other schools that supported Lisa most and encouraged her efforts to continue to include inquiry-based activities in her teaching. “They give me good ideas and advice. And when we talk, I also find out what kinds of activities they do in their classes, and their approaches for implementing inquiry. They are my strongest element of support,” (Interview #2, October 15, 2005) she concluded.

Profile Summary

Lisa McDowell was a first-year middle school science teacher and a first-year student in A-STEP’s ALT tract with a Master’s degree in agriculture. She had been involved in teaching in several different contexts prior to her enrollment in A-STEP and had held positions such as language teacher, graduate teaching assistant, and substitute teacher. Lisa’s teaching approach involved social interactions. She included group activities, and attempted to emphasize inquiry-based approaches. She utilized a variety of teaching tools such as lecture, textbook, samples of materials, note guides, video clips, demonstrations, and a tool she called a “discrepant event.” Lisa’s teaching
strategies appeared to be geared toward stimulating students’ curiosity and engaging them in hands-on activities where they could see how science was applicable to their daily lives. However, in practice Lisa’s teaching did not capture student interest or engage them intellectually.

Lisa viewed inquiry-based teaching as teaching that mainly consisted of unstructured and student-driven activities. She regarded problem identification and problem solving as essential parts of inquiry-based teaching. Also, she called inquiry and 5E “fashion trends.” She regarded 5E instructional model as a model that provided steps to be taken by students in order to ultimately engage in inquiry.

She expressed that she felt constrained by logistical and student-related factors that hindered her attempts to continue to emphasize inquiry-based teaching. The specific factors included school culture, classroom management and student behavioral issues, students’ skill level in mathematics, and the availability of needed time for such time-demanding activities.

She did not feel that what she had learned in A-STEP was fully transferable to her classroom. She expressed that she needed to learn more about classroom management, more of teaching tools for engaging the full attention of the students, approaches for helping students to generate questions and carry out independent research on their own, in addition to effective supervision strategies.

In spite of the constraints Lisa faced to using inquiry-oriented activities in her teaching, she outlined the factors that she thought facilitated her efforts. These factors included her perception that there were benefits to the students from her using inquiry-based learning; the activities and models she had learned from A-STEP, and other activities she adopted from curricula of other science teachers whom she knew.
Profile 4: Sara Bullock, High School Biology Teacher

Background

Sara Bullock, 24, is a high school biology teacher. At the time of this study she had been teaching for two years, after graduating from A-STEP’s APB tract in 2004. Prior to her A-STEP experience, she had completed a bachelor’s degree in environmental science at the University of Notre Dame in 2003.

Sara decided to become a teacher during her undergraduate education years. “At that time, I started to recognize the important role high school teachers play in shaping the future of their students,” (Interview #1, July 14, 2005) she said. “I would not have attended college without the support and facilitation I got from my high school science teachers,” (Interview #1) she added. “But I also liked teaching in general and for a long time I have been taking every opportunity to teach that came my way,” (Interview #1) she said.

When Sara was in high school, she taught children, grades 2 through 4. Her position was a Sunday school assistant. Her responsibilities included planning skits, organizing crafts, and storytelling for 15 students.

Right after graduation from college, she got a summer position as a supplemental instructor in mathematics for nine newly accepted students at St. Louis University. Her responsibilities included attending mathematics lectures with the students she taught, directing the general work of the group, tutoring one-in-one, assisting students with homework, reviewing test sections, and grading papers.

During that time, Sara’s teaching style was heavily didactic. “From that teacher-centered style, I considered myself to be the only source of information for my students,” (Interview #1, July 14, 2005) she reflected. “I tried to dominate the lecture, and the students did not have an opportunity to speak about their own
learning. I was following the style that my own high school teachers had used,” (Interview #1) she explained.

When joining A-STEP, Sara said that her main expectation was to learn how to properly teach biology. Because she had done little inquiry-based learning up until that point, she was surprised when the concept of “inquiry” was introduced, in the summer of 2003.

In A-STEP I learned that teaching science requires student involvement, and the utilization of various strategies. As soon as I learned that, I felt I no longer wanted to dominate the class and be the only source of information for my students. That was a major shift for me. (Interview #2, October 11, 2005)

**Teaching Context**

During the time this study was conducted, Sara was teaching at a high school located in a midsized, Midwestern town. The town’s population was approximately 90,000, excluding students who attended the three local higher education institutions. Sara taught standard biology to grades 10th through 12th. She taught an average of 21 students in each of her classes.

Observations for this study took place in one of the 10th grade classes where Sara had 24 students -- mainly 10th graders and a few 11th and 12th graders who were repeating the class. The observation spanned four class blocks, 90 minutes each. The topic she taught during the observation was photosynthesis.

Eighteen of Sara’s students in this class were Caucasian, eight of whom were males and 10 were females. Five students were African-Americans, including one African-American female. There were two students to whom English was a second language. Sara, however, said that she did not think that language was a barrier to
learning in her classroom. The two students who were not native English speakers appeared to have a good level of mastery of the English language.

In Sara’s assessment, five or six students in her class were well above the average sophomore level and two were below that average in their academic achievements. In comparison to the entire student body of the school, Sara assessed that most of the students in her class were academically about average or slightly above average.

Classroom Activities

Sara mentioned that the photosynthesis unit was an extension of previous unit that focused on energy. In the energy unit, the students learned about enzymes. Based on that, Sara said that she expected that the students already knew about chloroplasts and chlorophyll, and had a basic understanding of what photosynthesis is. Therefore, the goal of the new unit focused on -- “What photosynthesis is, how plants grow, how photosynthesis affects everything that we do because we take so much from plants and animals and we need photosynthesis as well to get food,” she said (Lesson #3.1, December 15, 2005).

Sara based her classes on curriculum and materials that had been developed and utilized by other biology teachers in the school where she taught. “I am a new teacher [in the school]. I do not feel the need to develop my own curriculum nor look for an alternative one,” (Interview #2, October 11, 2005) she said. I like being on the same page with other biology teachers in the school. And the teacher edition of the textbook I use outlines lesson plans according to 5E model. I do not follow the curriculum too closely. But I rely on it. I teach the parts that I am familiar with and give students homework based on those sections. (Interview #2)
During the observation conducted for purposes of this study, Sara incorporated several teaching strategies in order to keep her students motivated and to keep them from getting bored. In the unit observed, on the first day of teaching, Sara started with a warm up question: “What do plants need in order to make food?” (CO: Lesson #1, December 15, 2005) “Photosynthesis” (CO: Lesson #1) one of the students replied. To that response Sara posed another question: “What do plants need in order to do photosynthesis?” (CO: Lesson #1) “Oxygen, chloroplast, sunlight, water, carbon monoxide, water, sugar,” (CO: Lesson #1) answers came from various sides of the room.

“In order to do photosynthesis [plants] do not need all of those things,” (CO: Lesson #1, December 15, 2005) Sara told her students. “Other teachers told me yesterday that you had learned this stuff in the 4th grade and 6th grade,” (CO: Lesson #1) she said. “But, let’s find out together what they need exactly,” she proceeded.

“Several elements go into photosynthesis. Some of what you named is correct. Others are not,” (CO: Lesson #1, December 15, 2005) she explained. Sara then introduced the reactants and products of photosynthesis using the chemical equation of photosynthesis. “This equation is very important. You will be asked to repeat this equation many times throughout this unit. So you do need to memorize it,” (CO: Lesson #1) she emphasized.

Then she moved to another question. “What do you know about chloroplast and its function?” (CO: Lesson #1, December 15, 2005) she asked. The students’ response was silence. Then Sara reviewed the unit she had taught about two months before about chloroplast, and reminded the students of the contents of that unit. She then showed a video clip about photosynthesis and examined what the students retained from it using a simple True/False questionnaire.
Following the video clip the students were instructed to take out their “Photosynthesis Demonstration Experiment” worksheets (Appendix K). She read the instructions aloud (Appendix K, “Experiment # 1: Blue Water”). Sara then divided up the students into small groups of three to four and asked that they perform the steps she just read to them.

While the students worked on a task, she appeared to be trying to link the students’ tasks with the main focus of the lesson.

“Take a look at your experiments. The one that was blue has stayed blue. The one that was yellow has stayed sort of yellow. But in this third example,” [referring to a tube that had elodea in it] (CO: Lesson #1, December 15, 2005) she said, “It is kind of going back to blue. Why do you think this is happening?” (CO: Lesson #1).

“Because it is taking carbon dioxide and putting air back into it,” (CO: Lesson #1, December 15, 2005) one student replied. “What part of air?” (CO: Lesson #) she asked. “Oxygen,” (CO: Lesson #1) he said. “Yes,” (CO: Lesson #1) Sara confirmed. “Oxygen is what makes that tube blue and carbon dioxide is what causes it to become yellow,” (CO: Lesson #1) she explained. “If photosynthesis is happening, we would have oxygen and that would make the tube gain a blue color” (CO: Lesson #1).

For the next activity, taken from the same worksheet used for the first one (Appendix K, “Photosynthesis Experiment # 2: Test Tube Trap”), Sara held out a beaker filled with water. The beaker had a funnel in it. The funnel was upside down and had an elodea plant underneath it and a test tube on the top. The test tube was full of water, leaving only one centimeter of empty space.

“Observe the apparatus…as is described to you, make a quick sketch of the apparatus in the space below,” (CO: Lesson #1, December 15, 2005) Sara read from
the worksheet. After reading the first question, she assigned the students to work individually on the rest of the questions from their worksheets.

To help the students memorize the equation of photosynthesis, Sara asked them to use colored pencils to illustrate the various components. She said, “The students, later on, will recall the equation by recalling the visual illustration they had created” (CO: Lesson #1, December 15, 2005).

The last activity of that day’s lesson was to discuss the article, “Why Study Photosynthesis?” by Devens Gust, Professor of Chemistry and Biochemistry at Arizona State University’s Center for the Study of Early Events in Photosynthesis. (Appendix L). Dr. Gust’s article had been used by other biology teachers at the same school. In his article, Dr. Gust briefly writes about the process of the photosynthesis. He highlights the areas where photosynthesis has direct or indirect effects on human life. Dr. Gust explores nine areas in a paragraph or two and illustrates how photosynthesis research is critical for maintaining and improving quality of life for humans. Some of the areas discussed include photosynthesis and medicine, photosynthesis and energy, and photosynthesis and electronics, photosynthesis and energy production. Sara divided her students into groups of two to three and assigned each group one of the nine areas. They were to read the article, discuss it, then make presentations about the most important aspects of photosynthesis as related to that topic area.

This activity required two block periods to complete, and student teams presented their findings reading from overheads. After the presentations, Sara talked with the students individually about their overall progress throughout the semester.
During all the classes observed, Sara followed the same teaching pattern -- starting with a warm-up question with the purpose of connecting the previous lesson with that day’s lesson, emphasizing students working in small groups, showing video clips, having students illustrate concepts through drawing, and having students do presentations. For assessment she utilized several strategies including quizzes and semester exam reviews.

Because Sara put extensive emphasis on the need to memorize the chemical equation of photosynthesis, I asked: “What do you wish to accomplish by having the students memorize the equation?” (Interview #3.3) Sara’s answer was geared toward the curriculum goals.

I think learning that equation and understanding it is the objective of teaching this unit. They need to learn where the reactants come from, and what the equation is. Repetition is the only way to memorize something. Also, I notice many students have a misconception about what plants eat. They seem to think that a plant gets bigger because of the nutrients it takes from the soil, and I do not want them to think that. (Interview #3.3)

Meaning of Inquiry

Sara defined inquiry-based instruction as a teaching method where students either solve problems or discover scientific topics on their own. She understood that in inquiry-based learning, students choose questions and figure out answers without anyone giving them steps to follow in order to arrive at an answer. She stated,

If students decide what they want to study, for reasons of their own, that is certainly inquiry-based learning…It means that students get to discover on their own certain scientific topics and that will ultimately help them better remember topics studied. (Interview #2, October 11, 2005)

Students having a choice in what they want to study was to Sara a determining factor as to whether an activity was inquiry-based or not. Thus, according to her, the
purpose of inquiry was for student to see their instigations answer the question they chose to study.

Sara cited the “Mealworm Laboratory” as an example of an activity she had taught that included two different parts: non-inquiry and inquiry-based learning (Appendix M). In the first part, “I determined the independent variable (surface texture) and the dependent variable (distance covered by mealworms in one minute), and had the students follow exactly the same procedures outlined on the handout,” (Interview #2, October 11, 2005) she said. According to Sara, the students were required to make observations about how mealworms responded to their environments, and were also required to complete the experiment and the data analysis. In the second part, she described how that each student chose an independent variable to test a hypothesis while keeping the same dependent variable from part one.

Sara said that the two parts of the activity differed in the level of student input. The second part of the activity incorporated inquiry because the students were free to determine the independent variable, specifically, the type of surface they wanted the mealworms to crawl on (e.g., countertop, glass, or in water).

If the students get to choose what they do to their mealworms, then I would say that is more along the lines of inquiry than when I choose what you do…The first one we did as a class together where I set down the variables, I do not think that was [inquiry]. The second one where they got to choose the independent variable, I think that was [inquiry]. (Interview #2, October 11, 2005)

Sara acknowledged that there was also a continuum of inquiry, comprising different forms of inquiry defined by the level of teacher involvement in the activities. Sara explained that she learned the continuum of inquiry in A-STEP. Based on the degree of guidance, she named two ends of the continuum – the “teacher guided” and “student directed.” “Inquiry could take a place at any point between the two ends of
the continuum... You could either be really, really teacher-centered or really, really student-centered on the continuum. We went over that quite extensively in A-STEP,” (Interview #2, October 11, 2005) she said.

On one end, the teacher presents the problem, give the students all the resources, and tell them how to solve it. On the other end of the spectrum, the teacher says hey, figure out a problem, and figure out how to solve it. (Interview #2)

According to Sara, the activity that involved learning from the article “Why Study Photosynthesis?” was at the teacher-directed end of the continuum according to Sara. In this activity, the teacher posed the questions, provided resources, and told the students how to answer questions and communicate results. “What had made the activity inquiry was that the students had to seek the information... do something on their own to be inquiry and they did it because they found what they needed,” (Interview #3.2, December 19, 2005) she said.

[It] was very guided-inquiry where you tell them what to find, where to find [the benefits of photosynthesis]..., and how to communicate the results... It was guided because I gave them so much. They did not have to search through books or the Internet to find benefits of photosynthesis... I told them this is where you are going to find what you need. (Interview #3.2)

Differing from teacher-directed inquiry, Sara recognized student-guided inquiry as students carrying out independent research to answer their own questions while the teacher provided minimal input to the activity. In this type of inquiry, the students are the ones asking questions, designing investigations, utilizing their own resources, deciding how to answer questions, collecting data, and communicating their results on in a format they choose.
Sara suggested that an inquiry-based activity can be an excellent second-step project. She believed that an initial teacher-guided activity can be foundational to the learning of students. Following that, students can engage in student-guided inquiry after having mastered some basic skills from a non-inquiry activity. To elucidate, she revisited the “Mealworm Activity”. Sara maintained that the first part of the activity created a foundation for the students to be able to carry out the second part of the activity, which Sara considered as an inquiry-based activity.

Sara believed that inquiry and the 5E model were related. “I think that there are differences between the two approaches, but there are also similarities,” (Interview #4, January 30, 2006) she said. Students learning on their own was one similarity Sara believed. Sara explained that 5E was a way to set up a unit that involved the use of inquiry, but was not totally focused on it. “While a teacher never lectures in inquiry-based settings, in 5E, the teacher lectures, and also brings in activities that promote inquiry-based learning,” (Interview #4) she affirmed.

You use inquiry in 5E, but you also use inquiry in other things. They have some things in common: students are discovering things on their own and I think engage and elaborate, that is the whole goal that the students discover things on their own. So that is definitely inquiry, but I think there are some parts of 5E that are not. So, they are similar, like one uses the other, but they are different things. (Interview #4)

Constraints and Needs

Constraints: Sara mentioned that there were both logistical and student related factors that acted as constraints to using inquiry-based activities in her teaching. The main logistical factors were the culture of the school she worked in, and also the early stage of her career. “When I first started, I was provided with a curriculum and a lot of materials such as labs and worksheets developed by other biology teachers. I accepted that because I am new as a teacher,” (Interview #2, October 11, 2005) she said. “But I
also do think that what they had already done is great -- the things they put together. They handed it to me and they are explaining to me how to teach or how they do it at least,” (Interview #2) she explained. She continued,

I think it is great stuff, though it is not inquiry. And personally, and I do not want to take the time to try and rework everything. It is easier on me the way it is, so it is kind of being selfish. I am not going to introduce inquiry into it. I think inquiry-based learning is a good idea, but I think it is a lot of work for the teacher to prepare things that the students can use. (Interview #2)

Students’ base of knowledge and levels of motivation were factors that Sara mentioned as constraints to possible implementation of a mainly inquiry-based curriculum. She said, “At this point, I do not think that I would ever be comfortable with having students carry out student-directed inquiry activities. In my opinion, they do not have sufficient base knowledge to perform inquiry-based activities” (Interview #2, October 11, 2005). Also, she expressed that student’s lack of motivation to initiate work on their own. She explained if she had physical facilities that were excellent, that would not make any difference unless students were motivated to do the work. “I think inquiry-based learning can be achieved in a bare room if the students were truly motivated,” (Interview #2, October 11, 2005) she concluded.

Where things with my students stand now, while teaching, I have to intervene constantly and get them back on task. So, I am inclined to think that if I decide to teach inquiry-based learning I would struggle and it would take forever. I am not sure if it would actually work. (Interview #2)

Needs: Because Sara chose not to use inquiry-based instruction in her teaching, and did not plan to do so in the future, it was not possible to touch on her needs for implementing inquiry-based activities.
Factors That Facilitated Inquiry-Based Activities

Even though Sara stressed that she was not interested in pursuing inquiry-based instruction in her teaching, she still acknowledged the benefits of inquiry to the learning of students, and also acknowledged the value of the inquiry-based focus of the education she received at A-STEP.

“Students engage in inquiry-based learning actively and they take the work more seriously than they do non inquiry-based activities,” (Interview #4, January 30, 2006) Sara said. She said that it puts students in a different mind set – “A more active one as they choose a question that interests them and collect data in whatever manner they choose” (Interview #4). And, “If they fail for some reason or if they could not do a task, then they will need to find out what must be adjusted and do the task over and over until they succeed,” (Interview #4) she concluded. She also stressed that inquiry gave them a chance to behave like professional scientists which could possibly translate to career options.

Sara expressed that she had learned as much in the 15 months in A-STEP as she might have learned in four years of a traditional teacher education program. In A-STEP, she especially valued and got a lot of pleasure out of the student teaching internship experience. In this regard she said,

Being in a classroom under the supervision of a mentor teacher provided a context where I gained actual experience. I was able to transform what I learned in the program to the real world through my interaction with the mentor teacher and students I taught. (Interview #4, January 30, 2006)

Another aspect of the program she greatly appreciated was the knowledge she gained from use of models illustrating inquiry-based activities. “Anything I know about
inquiry-based instruction is what I have learned in A-STEP,” (Interview #4) she affirmed.

A-STEP focused a lot on 5E and inquiry…. I think they kind of drilled it into our heads… we used the documents that were put out by National Science Education Standards…I think, Dr. Johnson modeled some inquiry lessons for us and we prepared a 5E unit which is inquiry…I think as far as teaching in inquiry, that was where we really hit it the most hard. (Interview #2, October 11, 2005)

Prior to her A-STEP experience, Sara said that she felt that she had a very different picture of what science teaching should be like. After taking A-STEP science method courses, she made the decision that inquiry-based instruction was the best way to teach science if possible. “You do not necessarily have to lay out the procedures for [inquiry-based] labs. [The students] can come up with their own procedures. And the models were learned at A-STEP were excellent,” (Interview #4, January 30, 2006) she said. She concluded, “First, a student who carried out activities was guided by the faculty and then became the teacher who modeled her own inquiry-based activity. I think the models were powerful” (Interview #4).

Profile Summary

Sara Bullock, 24, was a high school biology teacher at the time of this study. She had been teaching for two years, after graduating from A-STEP’s ABP tract in 2004. At the time this study was conducted, she did not emphasize inquiry-based teaching. She based her instruction on a curriculum and materials that had been developed and utilized by other biology teachers in the school where she taught. In order to illustrate the points in the lessons she taught and to keep her students motivated, she utilized a variety of strategies, including small-group activities, starting lessons with a warm up question, showing video clips, having students illustrate concepts through drawing, and doing team presentations.
Sara defined inquiry-based instruction as a teaching method allowing students to either solve problems or discover scientific topics on their own. She thought that in inquiry-based learning students choose questions and figure out answers without anyone giving them steps to follow in order to arrive at an answer. Student choice in what they want to study was what Sara considered the determining factor regarding whether an activity was inquiry-based or not.

Sara elaborated on what she called a continuum of inquiry, comprising of different forms of inquiry defined by the level of teacher involvement in the activities. Based on the degree of guidance, she named two ends of this continuum – the fully “teacher-guided” and the fully “student-directed.” She affirmed that inquiry could take a place at any point between the two ends of the continuum. Sara suggested that inquiry-based activities could be effective second-step projects, following preparatory non-inquiry activities. Thus, to successfully perform student-directed inquiry, she believed that students needed to have initial experience in teacher-directed activities.

Sara stressed that she felt constrained by logistical and student factors. The main logistical factors were the culture of the school she worked in, and also the early stage of her career. Students’ base of knowledge and levels of motivation were the factors that Sara mentioned as constraints to possible implementation of a mainly inquiry-based curriculum.

Although Sara stressed that she was not interested in pursuing inquiry-based instruction in her teaching, she acknowledged the benefits of inquiry to the learning of students, and also acknowledged the value of the inquiry-based focus of the education she received in A-STEP.
CHAPTER FIVE

Cross Case Analysis: A-STEP’s Beginning Science Teachers’ Understanding and Implementation of Inquiry

In this chapter, based on the full data set, the teacher profiles, and interviews with A-STEP faculty members presented in Chapter 4, I present four main assertions and relevant supporting evidence. The assertions, which describe the major themes common among the participants’ understanding and implementation of inquiry, are:

1. A-STEP beginning science teachers held incomplete meanings of inquiry compared to A-STEP faculty members view.

2. A-STEP beginning science teachers’ implementations of inquiry-based instruction neither reflect their meaning of inquiry nor inquiry as portrayed in the program.

3. A-STEP beginning science teachers perceived constraints and needs that were similar to the ones recognized by A-STEP faculty members.

4. A-STEP beginning science teachers’ perceived benefits of inquiry for student learning and relied on activities and models used in A-STEP to facilitate their practice of inquiry-based instruction.

In discussing each of the four assertions, I utilize relevant data from participant interviews, my classroom observations, and interviews with A-STEP faculty members, where appropriate, in order to understand the participants’ meaning and implementation of inquiry in relation to A-STEP.
Assertion 1: A-STEP’s Beginning Science Teachers Held Incomplete Meanings of Inquiry Compared to A-STEP Faculty Members View

Teacher participants viewed inquiry as (a) a process of problem solving driven by students, (b) activities carried-out by students generate questions. The views of inquiry that research participants held was incomplete and left out other essential features of inquiry: evidence, explanation, and justification.

In making this assertion, I use the five essential features of inquiry (NRC, 2000) to understand and compare A-STEP’s beginning science teachers’ understanding of inquiry. The five essential features of inquiry consist of: “(1) learner engages in scientifically oriented questions, (2) learner gives priority to evidence in responding to questions, (3) learner formulates explanations from evidence, (4) learner connects explanations to scientific knowledge, and (5) learner communicates and justifies explanations” (p. 29).

I compare the views of inquiry held by beginning science teachers, first. Then, I compare these views of inquiry to A-STEP faculty members’ understanding of inquiry as presented in science method courses.

Two main themes emerged from the data regarding this assertion: First, all participants expressed that inquiry is primarily a student-driven activity aiming to solve a problem. Table 2 provides a summary of the beginning science teachers’ understanding of inquiry. All the research participants recognized inquiry as a process of problem solving. Cindy, unlike the others, emphasized that inquiry is a scientific process of problem solving which is similar to the process that scientists studying the natural world use. In addition, Andrea and Sara understood inquiry as a process leading students to discover certain scientific topics on their own.
Yet, I claim that the overwhelming meaning that the research participants assigned to inquiry was not their understanding of inquiry as a process of problem solving or inquiry as discovery learning, but their meaning of inquiry as student-driven activity. Whether the research participants recognized inquiry as a process of problem solving or inquiry as discovery, they all reasoned that classroom inquiry relies on the initiative of students (i.e., involving students in generating authentic questions and carrying out independent research). Thereby, they all agreed that inquiry-oriented activities are unstructured, meaning that students are not provided with any guidance or very little guidance while carrying out their independent investigations (e.g., identifying a problem, designing an investigation, collecting data, and so forth).

Second, the participants deemed that student-generated questions are the first and foremost feature of inquiry. Unlike others, Cindy thought that students examining their own misconceptions through current literature as another part of inquiry.

Andrea said, “Students have to come up with the questions. Inquiry is not a cookbook with step one, two, three. They have to figure out how to solve the problem on their own” (Interview #2, October 25, 2005). Lisa agreed with Andrea’s view. “According to my understanding, [in inquiry] students are supposed to generate the problem and questions, come up with a procedure, design the experiment and then come up with their own results,” (Interview #2, October 15, 2005) she said. Sara had a similar understanding to that of Andrea and Lisa. Sara stated, “I would say [inquiry] is whenever you choose a question and you figure out the answer, and no one tells you to follow whatever steps toward figuring out the answer” (Interview #1, July 14, 2005).
Three of the participants, Andrea, Cindy, and Sara, also described guided inquiry as activities that relied on teacher guidance. Lisa, on the other hand, did not mention the words guided, teacher-directed inquiry, nor any other word that would have implied guided inquiry. According to the participants, when an activity did not qualify to be called open inquiry (because it was not student-driven) if it included some essential features of inquiry (NRC, 2000), then it was eligible to be called guided inquiry (see Table 2 and Table 3 for more information). However, they regarded these features separately rather than as elements of a whole. For example, if teachers had students draw conclusions based on what they knew and evidence they obtained from data would have made the activity guided inquiry regardless of whether other essential features of inquiry were present.

Cindy, for example, differentiated guided inquiry from inquiry by using a lower case “i” in guided inquiry. She said that having guest lectures was an example of inquiry because students were introduced to new topics, asked questions, and worked together to figure out what the researchers were communicating. “That collaborative approach to understanding new material to me is part of inquiry,” (Interview #4, January 31, 2005) she said.

Similarly, Sara regarded learning from the article “Why Study Photosynthesis?” as an example of guided inquiry. In this activity, it was the teacher who posed the questions, provided resources, and told the students how to answer questions and communicate results. However, “what had made the activity inquiry was that the students had to seek the information…do something on their own,” she said.
Table 2. A-STEP Beginning Science Teachers’ and Faculty Member Meanings of Inquiry and Guided Inquiry

<table>
<thead>
<tr>
<th>Participants/Faculty Members</th>
<th>Meaning of Inquiry</th>
<th>Guided Inquiry</th>
</tr>
</thead>
</table>
| Andrea                      | • Relies on initiative of students  
  • Unstructured—students engage in their own questions, design an experiment, investigate the question  
  • Inquiry = Discovery | • Relies on teacher’s guidance  
  • Teacher helps students to formulate their own paths to the correct answer using leading questions  
  • Teacher tells students how to conduct their tests and what types of things they need to look for to obtain answers |
| Cindy                       | • Relies on initiative of students  
  • Unstructured—students design experiments, collect data, work collaboratively to analyze the data, come to a conclusion, and present findings  
  • Inquiry = The scientific process of problem solving | • Relies on teacher’s guidance  
  • Especially, students deriving conclusions from given data using new tools and procedures they learned  
  • Small activities that do not have all features of inquiry  
  • Requires students working collaboratively |
| Lisa                        | • Relies on initiative of students  
  • Unstructured—students identify a problem and come up with their own ideas and questions to test  
  • Inquiry = Problem solving | N/A  
  (Lisa never mentioned guided inquiry or any other words that would have implied guided inquiry) |
| Sara                        | • Relies on initiative of students  
  • Unstructured—students engage in their own questions, design investigations, utilize their own resources, decide how to answer questions, collecting data, and communicating their results  
  • Inquiry = Problem Solving  
  • Inquiry = Discovery | • Relies on teacher’s guidance  
  • Teacher poses questions, provides resources, and tells students how to answer questions and communicate results  
  • Students have to seek information, find what they need |
| Faculty Members             | • Relies on the essential features of inquiry (NRC, 2000)—Questions, evidence, explanations, justification, and communication  
  • When all essential features of inquiry employed by students | • Relies on the essential features of inquiry (NRC, 2000)—Questions, evidence, explanations, justification, and communication  
  • Degree of teacher involvement in the essentials features places guided inquiry on the continuum of inquiry (NRC, 2000) |
<table>
<thead>
<tr>
<th>Participants</th>
<th>Activity</th>
<th>Inquiry</th>
<th>Why?</th>
<th>Not inquiry</th>
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<tbody>
<tr>
<td>Andrea</td>
<td>Density</td>
<td>• The students discovered density of an unknown on their own</td>
<td>• The students asked the teacher questions</td>
<td>• The activity was not a full scale lab</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• The teacher told the students how to conduct their tests and what types of things they needed to look for to gain answers</td>
<td>• Teacher asked leading questions to help the students formulate their own path to the correct answers rather than the teacher giving them answers</td>
<td>• The activity was neither student originated nor directed</td>
</tr>
<tr>
<td></td>
<td>Forced to Change</td>
<td>• The students were not asked to replicate the activity—due to equipment constraints</td>
<td>• The students did not figure out on their own—teacher told students how to conduct their test, what kind of things they needed to look for, and used leading questions to help students formulate their answers</td>
<td>Cathode-Ray Demonstration</td>
</tr>
<tr>
<td>Cindy</td>
<td>DNA Extraction</td>
<td>• The students started activity by examining their misconceptions and became familiar with current literature on the topic</td>
<td>• The students worked collaboratively, designed experiment, collected data, analyzed the data came to conclusion, and presented their findings</td>
<td>Pipetting Skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• The students worked collaboratively, designed experiment, collected data, analyzed the data came to conclusion, and presented their findings</td>
<td>• Teacher gave the students the statistical tools to make their evaluation</td>
<td></td>
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<tr>
<td>Activity</td>
<td>Description</td>
<td>Notes</td>
<td></td>
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<tr>
<td>Pipetting Skills</td>
<td>• The students worked collaboratively&lt;br&gt;• The students drew conclusions based on what they knew and evidence that they obtained from data</td>
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<tr>
<td>The First Lesson with Guest Lectures</td>
<td>• The students were introduced to new topics&lt;br&gt;• The students asked questions, took information from the posters&lt;br&gt;• The students worked together to figure out what the researchers were communicating</td>
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<tr>
<td>Lisa Mineral Identification Laboratory</td>
<td>• The students generated the problem, came up with the procedure, designed the experiment, and came up with their own results</td>
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<tr>
<td>Why Study Photosynthesis?</td>
<td>• The teacher posed the questions, provided resources, and told the students how to answer questions and communicate results&lt;br&gt;• The students had to something on their own to--seek the information they needed</td>
<td>Photosynthesis Demonstration Experiments&lt;br&gt;• Teacher told the students what they needed to learn&lt;br&gt;• The students were not exploring anything on their own&lt;br&gt;• The teacher told the students what to look for</td>
<td></td>
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<tr>
<td>Mealworm Laboratory (Part II)</td>
<td>• The students had a choice in what they wanted to study--student chose an independent variable to test a hypothesis</td>
<td>Mealworm Laboratory (Part I)&lt;br&gt;• The teacher determined the variables&lt;br&gt;• Students did the activity as a class together</td>
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</table>
Both Professor Anderson and Professor Richardson described inquiry in terms of the essential features of inquiry (NRC, 2000). They agreed that the five essential elements of inquiry are all necessary for inquiry-based activities. However, the views of inquiry and guided inquiry that the research participants held (inquiry is primarily a student-driven activity and that including some separate essential features of inquiry in an activity qualified it as guided inquiry) conflicted with A-STEP faculty members’ meaning of inquiry and their intended outcomes of A-STEP.

Professor Anderson and Professor Richardson outlined various activities and readings\(^3\) that they used in A-STEP instructions to model inquiry and show that inquiry is not necessarily hands-on. One of the activities, the Moon Activity, which I described in Chapter 4, further details how the faculty members made use of an inquiry-oriented approach to teach A-STEP students what inquiry is and is not, as well as teaching the difference between guided versus open inquiry.

The faculty members placed the essential features of inquiry along the continuum of the inquiry (NRC, 2000) and used it to show the variations between teacher-directed and student-directed inquiry. Although the faculty members spent much time and effort in their science methods courses representing classroom inquiry, data analyses revealed that there was a great inconsistency between the beginning science teachers’ understanding of inquiry and the faculty members’ understanding and intended portrayal of inquiry.
Assertion 2: A-STEP Beginning Science Teachers’ Implementation of Inquiry-Based Instruction Neither Reflect Their Meaning of Inquiry nor Inquiry As Portrayed In the Program

The faculty members stressed that they would anticipate that A-STEP interns would be able to make use of some of the inquiry strategies they had taught them. They also felt that the teachers would be able to employ inquiry ranging from teacher-directed partial inquiries to student-directed open inquiries, along the continuum of inquiry. However, the participants’ implementation of inquiry-based instruction did not reflect inquiry as portrayed in the models used by A-STEP faculty members in the program.

Professor Anderson began the Moon Activity by asking students to tell him why they think they see different shapes of the moon. In another activity, the Rusty Nail, Professor Anderson began his instructional sequence by having the students take a nail and put it somewhere at home where they thought it would rust. Two weeks later, the students brought their nails back to class and answered the questions Professor Anderson posed for them.

Although these two activities were different in some ways, they shared common strategies and purposes that modeled inquiry. In starting these two activities, as described, Professor Anderson not only uncovered the teachers’ prior knowledge, but also engaged them in the activity so they could develop questions for their investigations. At the same time, these two activities initiated the first essential feature of inquiry which is “Learner engages in scientifically oriented questions” (NRC, 2000, p. 29).

The rest of these two activities (see “Interview with Faculty Members” section in Chapter 4), fulfilled other essential features of inquiry Students designed investigations,
gathered data, decided what data meant as evidence, came up with explanations based on their evidence, connected their explanations to scientific knowledge, and, finally, communicated and justified their explanations to their classmates. These two activities not only portrayed “open-inquiry,” but also “guided inquiry.”

Following, I discuss some of the activities from my classroom as evidence in comparing the participants’ practices of inquiry versus inquiry as portrayed in A-STEP. First, I argue the activities the participants considered as “open-inquiry,” then I continue with the activities regarded as “guided inquiry” by the participants. Table 3 outlines some of the activities that the participants utilized either during my classroom observations or that they put into practice at some point before my classroom observations both as examples of inquiry-based and non-inquiry based teaching. Table 3 delineates the participants’ reasoning of why they considered an activity inquiry, guided inquiry, or non-inquiry.

Lisa and Cindy both believed that they implemented inquiry-based activities during my classroom observations. The activities they regarded as examples of inquiry-based teaching were the DNA Extraction Laboratory and the Mineral Identification Laboratory (See Table 3).

Lisa believed it was important to engage students in some ways, such as brainstorming, to introduce an activity and considered this as the first step of inquiry. In using such activities, she intended to find out about students’ prior knowledge of the topic and help students generate ideas and questions to investigate in through inquiry.

Lisa regarded the Mineral Identification Laboratory (see Chapter 4-Lisa’s profile for more information) as an example of her inquiry practice because students were the
ones who generated the problem, came up with the procedure, designed the experiment, and came up with their own results. However, the students were not able to generate ideas---Lisa stated that she did not provide detailed instructions to the students on how to carry out the activity. This was enough for Lisa to consider the activity as inquiry.

Lisa wanted to find out about her students’ prior knowledge and have them generate procedures they could then use in later inquiry activities. However, the classroom observations revealed that she was not able to have her students generate ideas to test in the Mineral Identification Laboratory, nor did she utilize the essential features of inquiry because the students did not engage in answering scientifically-oriented questions, data collection, formulation of explanations, connection of explanations to scientific knowledge, and communication and justification of their explanations.

Cindy, on the other hand, as the first step of inquiry, required the students to review online materials that she considered basic for the understanding of genetics. She deemed that by doing this the students had a chance to examine their own misconceptions through current literature. She also provided the students with three different readings about DNA extraction protocols (see Chapter 4-Cindy’s Profile for more information). Based on the information from these resources, the students were asked to design a protocol to efficiently obtain DNA. During the DNA Extraction activity the students worked in teams with less direction from teacher. Cindy monitored their work and provided them with the help and support they needed in designing and implementing the protocols. She considered her role to be that of a facilitator. During the activity, Cindy stressed the importance of evidence and reminded the students that they needed to record and report every single step taken during the procedure.
Comparatively, except for having students develop scientifically-oriented questions, Cindy was able to utilize other features of inquiry—evidence, explanations, justification, and communication—in the DNA Extraction activity. What Cindy and Lisa did to engage their students in the activities did not fulfill the same purpose that Professor Anderson and Professor Richardson had in their models.

As to implementation of guided inquiry-oriented activities, three of the participants, Andrea, Cindy and Sara, referred to some of the activities as instances wherein they implemented guided inquiry (see Table 3).

Andrea, for example, referred to one of the hands-on activities that I observed, Forced to Change, as an example in which she implemented guided inquiry. In this activity, Andrea first had students read the worksheet (Appendix F—Forced to Change) then let the students loose to conduct the activity. The students followed step-by-step instructions provided in their worksheets to complete the activity. Once the students finished working on the activity, they were to turn in their laboratory reports individually (see Andrea’s Profile in Chapter 4 for more information).

There were a few reasons Andrea felt that she implemented guided inquiry. First, she felt that the students did not have to figure out how to proceed on their own. Second, she told the students how to conduct their tests and what kind of things they needed to look for. Finally, she explained that she used leading questions to help students formulate their answers.

Sara considered her teaching using the article “Why Study Photosynthesis?” as an example of guided inquiry (see Appendix L). The article briefly describes the process of the photosynthesis in nine areas where photosynthesis has direct or indirect effects on
human life. Sara had the students read the article, discuss it, and then make presentations about the most important aspects of photosynthesis as related to that topic area.

According to Sara, what had made the activity guided inquiry was that the students had to seek the information on their own and make presentations.

In activities Andrea, Sara, and Cindy considered as guided inquiry, they failed to see essential features of inquiry as parts of a whole. In these activities they started what they deemed guided-inquiry activities straight from handouts. They based their understanding of whether an activity was inquiry or guided inquiry on two main factors. First, if any activity they implemented was not completely student-driven (i.e., involved students in generating authentic questions and carrying out independent research) then they considered it guided inquiry. Second, in any activity they implemented, if they recognized any one of the essential features of inquiry, then they considered the activity guided inquiry. Additionally, Andrea understood that guided inquiry consisted of activities where she guided students through the activities rather then pointing out the degree of guidance she provided in terms of essential features of inquiry.

In the science methods courses, the central focus of A-STEP’s faculty members was the five essential features of inquiry (see The Views of A-STEP Faculty Members in Chapter 4). Using the essential features of inquiry, they were explicit to their students that inquiry is not necessarily hands-on although it can involve hands-on activities. For example, in one of the science methods courses that Professor Richardson taught, students were exposed to a model—The Galapagos Finches Software—illustrating that inquiry does not necessarily involve hands-on activity and students collecting data. By using the article written by Bybee, Professor Anderson tried to illustrate how different
scenarios could be representative of inquiry. They engaged students in the investigations both by using questions provided by teachers and by having students generate questions to investigate. Finally, the faculty members wanted to make sure that their students would be able to differentiate inquiry from non-inquiry activities. Professor Anderson gave details on two different versions of an activity, cookbook and inquiry, and provided a context for students to develop an understanding of how cookbook laboratories were different from inquiry-oriented activities.

Because the faculty members explicitly detailed the use of inquiry strategies and learning cycles model, it was reasonable for them to expect that A-STEP beginning science teachers would implement inquiry-oriented activities in their own classrooms. However, my classroom observations revealed that the beginning science teachers who participated in this study had not succeeded in making a full transition towards classroom inquiry.

Assertion 3: A-STEP Beginning Science Teachers Perceived Constraints and Needs That Were Similar To the Ones Recognized By A-STEP Faculty Members

In addition to beginning science teachers not having a clear understanding of inquiry-based instruction, Professor Anderson and Professor Richardson acknowledged that beginning science teachers, in general, face logistical and contextual constraints to implementing inquiry. These constraints might include classroom management, time, and inadequate resources as logistical constraints. They considered classroom management to be the main logistical constraint that hampers beginning science teachers’ implementation of inquiry. As to contextual constraints, they called attention to school culture and lack of mentoring. They incorporated strategies that would have helped their students to
overcome these constraints once they began to employ inquiry in their own classrooms (see “Interview with A-STEP Faculty Members” section in Chapter 4). However, despite the efforts that the faculty members made in introducing these strategies, A-STEP beginning science teachers identified constraints to implementing inquiry-oriented activities in their teaching. Even though the definition of inquiry the participants held varied according to Assertion 1, they perceived that their implementation of inquiry was constrained by student characteristics, logistical factors and personal knowledge. However, they perceived student characteristics (e.g., students’ level of knowledge in science and mathematics and level of motivation) and logistical factors as the main constraints.

Sara was definitive in her views regarding students. She did not think that she could ever be comfortable with having students carry out student-directed inquiry activities. In her opinion, students did not have sufficient knowledge to direct inquiry activities. Cindy’s observation was that students had “a math phobia.” She sensed that her students did not like math and therefore did not want to employ math to analyze the results. Lisa’s experience was that students “cannot seem to make the cognitive leap” (Interview #2, October 15, 2005) toward understanding that some inquiry-based activities required.

The teachers regarded student level of motivation as an obstacle to inquiry-based teaching. Each participant explained that their students appeared to be focused on getting high grades and having the right answer, rather than preferring to engage in inquiry-based activities and thereby building knowledge. A comment made by Cindy represented the general sentiment of all four participants. She said that students did not seem to like
experimental settings and complained that they had difficulty with inquiry-based learning. “They call such settings disorganized and that leads them to feel that everything goes above their heads. They say that their learning is not totally accessible and useful to them….That surely affects their level of motivation,” (Interview #3.7, November 30, 2005) Cindy added.

The logistical constraints the participants perceived included shortage of equipment, class size, time, and school culture. Lisa and Andrea believed that class size was a key constraint. Due to this constraint, both Lisa and Andrea decided either to not use inquiry or to use more teacher directed inquiry-based activities.

Three participants out of the four, Andrea, Lisa and Sara, recognized time as another important logistical constraint. Andrea and Lisa believed that inquiry-oriented activities required extra classroom time compared to regular cookbook types of activities. Andrea and Sara also felt that it took more teacher time to prepare for and produce inquiry-based activities than to prepare for and produce traditional activities. Andrea expressed that this was the case to an even greater extent when she was teaching a new class.

In addition, Andrea explained that the sheer volume of material that had to be taught constrained her use of inquiry. Andrea’s view of inquiry, inquiry as student-driven activity that involved students in generating authentic questions and carrying out independent research, limited her implementation. She did not think that such volume of material could be taught through inquiry, given the limited time she had.

Lisa and Sara felt constrained by the culture of the schools where they worked. Inquiry-based instruction was not promoted in their schools. “In the beginning, I tried to
do inquiry with the students, ...but at that time, I had little idea about the students and the school culture,” (Interview #4, February 8, 2006) Lisa said. She added that introducing inquiry-based instruction in a school culture where students were expected to be passive recipients was a challenge that constrained her use of inquiry.

Andrea and Sara also perceived that limitation in their personal knowledge hindered their commitment to inquiry-based teaching. Andrea explained that whenever she taught a subject other than her strong suit of chemistry, she felt constrained when finding and implementing inquiry-based activities. Andrea also recognized that the didactic style with which she had been taught science in college had influenced her own teaching style and constrained her from using inquiry-based activities. Sara believed that being in an early stage of her career was a constraint to using inquiry-based activities in her teaching. Thus, she decided to use the curriculum that had been developed by other biology teachers in her school “just to be safe,” acknowledging that not only was she a new teacher, but also new in the school. All participants believed that they lacked access to field-tested and practical examples of inquiry to help them as beginning teachers.

The constraints and needs that the research participants perceived in their implementation of inquiry were similar to what A-STEP faculty members recognized as the constraints that would face beginning teachers.

The participants reflected on their experiences in A-STEP. They agreed that the program could have given them more practical preparation. Their wish lists varied, however. Andrea, for example, would have preferred to get a copy of each lesson plan that the professors used so that she could implement the lesson plan in her own teaching. She felt this would have helped her because it was difficult for her to do an activity as a
participating student and also concentrate on how the classroom was set up and the activity accomplished by the professor.

Lisa felt that the faculty members in A-STEP were somewhat out of touch with the classroom. She did not think that the faculty members considered the realities of school teachers. She elaborated that she needed to know more about classroom management and specific activities she could have utilized in her classroom rather than knowing about inquiry as theory. Lisa also expressed the frustration with not having sufficient support in transcending her teaching struggles. She emphasized the need for more supportive supervision from A-STEP while she was teaching.

Cindy had concerns comparable to Andrea’s and Lisa’s. She felt there was a disproportionate amount of time, effort and work focused on inquiry during A-STEP courses. In detailing her views, she said that she felt as if the faculty members armed them to be rebels to go out and change the world rather than how to become effective beginning teachers. Cindy also emphasized that her experience as a student teacher with her mentor teacher was quite contradictory to what she had been taught about inquiry in A-STEP. Cindy expressed her frustration by explaining that her mentor teacher remarked that Cindy’s efforts to implement inquiry were useless, and she advised Cindy to be more didactic in her teaching.

Assertion 4: A-STEP Beginning Science Teachers’ Perceived Benefits of Inquiry for Student Learning and Relied On Activities and Models Used In A-STEP to Facilitate Their Practice of Inquiry-Based Instruction

The three main factors that facilitated the research participants’ use of inquiry-based teaching included: (a) their perceived benefit of inquiry to students’ learning; (b)
their reliance on the activities and models used in A-STEP; and (c) their prior work experience.

**Perceived Benefit of Inquiry to Student Learning**

In spite of the constraints that the research participants faced in using inquiry-based teaching methods, all four acknowledged that there were benefits of inquiry-based instruction to student learning. The participants explained that the inquiry approach boosted student learning because the students had control over the activities, owned the process, and actively engaged in the activities. Sara, for example, stressed that she was not interested in pursuing inquiry-based instruction in her teaching. However, she was aware that when her students engaged in inquiry-based activities, they took the work more seriously than they did during non-inquiry-based activities. She concluded that this was the benefit of inquiry to students’ learning. Andrea also explained that inquiry, unlike teacher-centered instruction, requires active participation of students, thus they retain more information and understand science.

All four of the research participants believed that inquiry provided a real-life context for better and more in-depth learning. They realized that inquiry puts students in a different mind-set because they are more active and have control over investigations. They believed that using inquiry not only allowed the students to participate, but also to develop critical thinking skills and maintain high levels of motivation. In spite of the numerous constraints to teaching inquiry in Lisa’s “old-fashioned” school in general, and in her hard-to-control classroom in particular, she assessed that inquiry increased students’ enthusiasm.
In Assertion 3, however, the participants were all agreed that the students’ lack of motivation hampered their practice of inquiry. In light of this, it would seem that the research participants contradicted themselves. However, they did not because they experienced both situations either through separate inquiry activities or in single inquiry activity. Cindy’s experience, for example, with the DNA Extraction activity illustrates how the participants perceived motivation both as a facilitating and hindering factor to their practice of inquiry. Cindy explained that her students did not seem to like experimental settings and that they expressed that they were having difficulty with inquiry-based learning. During my classroom observation of Block 7, I was able to observe some of the frustrations experienced by Cindy’s students. On that day, the students said that their learning was not easy and useful to them because the activities they were performing were disorganized. On the other hand, I also witnessed the enthusiasm and motivation the very same students had while working on their DNA extraction protocols. In recalling one the moments Cindy had with one of the students, she said, “My kids were so excited about writing those protocols. One of them took those protocols to the Biology teacher and said, ‘Look what we did - we wrote our own protocols!’” (Interview #4, January 31, 2006).

Reliance on Activities and Models Used in A-STEP

Prior to their A-STEP experience, the participants said that they felt they had a very different picture of what science teaching should be like. After taking A-STEP science methods courses, they came to a conclusion that inquiry-based instruction was the best way to teach science, if possible. That was true for those who had graduated and those who were still students in the program at the time of the study.
Sara, for instance, expressed that she had learned as much in the 15 months in A-STEP as she might have learned in four years of a traditional teacher education program. “A-STEP taught me that there are many different levels of inquiry. It can be teacher-guided or it can be student-guided” (Interview #1, October 11, 2005) Sara said. She continued, “Anything I know about inquiry-based instruction is what I have learned in A-STEP” (Interview #1, October 11, 2005). Andrea believed that she was a better teacher because A-STEP caused her to reflect on what she had done the year before. As a consequence, she revised her teaching in order to incorporate inquiry-based activities.

In spite of the fact that the research participants expressed dissatisfaction with what they perceived as shortcomings of A-STEP in teaching inquiry-based methods, they all acknowledged that A-STEP was the first place where they were exposed to inquiry. They all agreed that there were many aspects of the program (e.g., use of models and virtual labs, integration of mathematics and science, strategies utilized by the faculty members, and framing of lessons in a context relevant to students) that played important roles in facilitating their practices of inquiry-based instruction. Even though there were common aspects that all the participants discussed, there were also some aspects of the program that participants individually valued.

One of the aspects of the program that all participants greatly appreciated was the knowledge that they gained from use of models illustrating inquiry. Although Lisa did not feel that what she had learned about inquiry in A-STEP was fully useful to her in her classroom, she believed that the strategies used in A-STEP helped her to facilitate her practice of inquiry-based teaching. When teaching inquiry-based activities, Lisa relied on models she had learned during the first science methods course of A-STEP.
Like Lisa, Andrea had been in A-STEP for only a few months and relied on the models used in A-STEP in her practice of inquiry-based instruction. Andrea stated that these models facilitated her inquiry-based teaching because they detailed the steps taken toward implementation of inquiry-based activities. She mentioned the Moon Project as an example of how the program made her think about the process of inquiry and learning. Other projects Andrea recalled were the Rusty Nail activity and the Stream Team project.

Cindy, like all other the participants, reiterated the benefits of A-STEP’s approach to teaching. She acknowledged that A-STEP’s approach had dramatically changed her teaching strategies towards inquiry-oriented instruction. For example, she said that using A-STEP strategies, she had her students combine their data so that they could draw conclusions using explanations formulated from evidence. She also emphasized the interdisciplinary aspect of A-STEP. Cindy mentioned that she never thought of mathematics and science as integral, but rather had seen them as two different subjects, even though she had used mathematics all the time in her professional career. Learning to integrate mathematics and science was another factor facilitated by A-STEP that Cindy appreciated.

Work Experience

Three of the participants, Andrea, Cindy and Lisa, held a variety of jobs in the field of science, industry and education prior to their enrollment in A-STEP. However, only Andrea and Cindy stated that their prior work experiences facilitated their practice of inquiry.

Cindy stated that her previous work experience facilitated her practice in two ways. First, she said that she was aware that there are many approaches that one can
choose to carry out any given activity. Therefore, she did not limit the format of her student’s work. Second, she stated that she drew on her previous work experience to teach students good laboratory and technical skills (e.g., evaluating evidence accurately in order to make a conclusion).

Andrea explained that whenever she saw a connection between the subject she was teaching and her prior work experience, she brought it to the attention of her students to connect it with her students’ real-life experiences. Thus, she felt that her first-hand experience with chemistry as practiced in the chemical industry facilitated her practice of inquiry-based instruction.

Conclusion

All research participants acknowledged that A-STEP was the first place where they learned about inquiry. After the experiences they had with inquiry, they all came to a conclusion that inquiry-based instruction was the best way to teach science, if possible. Whether the research participants perceived constraints or articulated their frustration with what they had learned in the program about inquiry, there were three main factors that facilitated the research participants’ use of inquiry-based teaching: (a) their perceived benefit of inquiry to students’ learning; (b) their reliance on the activities and models used in A-STEP; and (c) their prior work experience as it related to their teaching field.
CHAPTER SIX: DISCUSSION, CONCLUSIONS, AND IMPLICATIONS

The purpose of this study was to: (a) understand how beginning science teachers recruited from various science disciplines and prepared in an ATCP implemented inquiry during their initial years of teaching; (b) describe constraints and needs that these beginning science teachers perceived in implementing inquiry-based science instruction; and (c) understand the relation between what they learned in their ATCP and their practice of teaching science through inquiry. One overarching and five sub-questions guided the study during the phases of data collection, data analysis, and organization of findings. The overarching question was: How do alternative certification science teachers in A-STEP understand and implement inquiry-based instruction in their beginning years of teaching? The sub-questions were:

1. What do alternatively certified beginning science teachers mean by classroom inquiry?
2. How do alternatively certified beginning science teachers implement inquiry-based instruction in their teaching?
3. What do alternatively certified beginning science teachers perceive as constraints, challenges, and needs for implementing inquiry-based instruction?
4. What do alternatively certified beginning science teachers perceive as factors that facilitate their implementation of inquiry-based instruction?
5. How are alternatively certified beginning teachers’ experiences of teaching science through inquiry related to what they learn in their ATCP?

This chapter consists of: (a) a summary of the findings in relation to the sub-questions; (b) a discussion of findings with regard to the literature reviewed in Chapter

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Two; (c) a conclusion explaining how the study adds to the literature regarding beginning science teachers’ views and practice of inquiry-based instruction; (d) an implications section for those who are active in promoting inquiry-based instruction at any level, including science educators involved in the design of teacher education programs (traditional and alternative) and teaching science methods courses at all levels (preservice, induction, and professional development programs); and (e) a section of recommendation for future research.

Summary of the Findings

In examining views of inquiry, I first presented the views of inquiry that the research participants held, and then I compared their views with A-STEP faculty members’ views of inquiry. The cross-case analysis of data revealed that the research participants believed that classroom inquiry relies on the initiative of students, involves students in generating authentic questions and carrying out independent research. Moreover, if an activity was not student-driven, but included some essential features of inquiry (NRC, 2000), the participants named the activity as “guided inquiry.” In this view of inquiry, they regarded essential features of inquiry separately rather than as elements of a whole. The views of inquiry held by research participants were not only incomplete as compared to the five essential features of inquiry (NRC), but also inconsistent with A-STEP faculty members’ meaning of inquiry and with their intended goals.

In examining the research participants’ practice of inquiry, I made use of interviews, artifacts, and classroom observations. Three research participants, Andrea, Cindy, and Linda, described themselves as student-centered, striving to implement inquiry-oriented activities. Although Sara mentioned that she adopted a more traditional
approach in teaching, she referred to a few activities that took place either before or during my classroom observations as examples of her practice of inquiry. A-STEP faculty members anticipated that A-STEP interns would be able to make use of some of the strategies they had used in A-STEP courses to employ inquiry ranging from teacher-directed guided inquiry to student-directed open inquiry, along the continuum of inquiry.

A-STEP interns’ implementation of inquiry-based instruction did not reflect inquiry as portrayed in the models used by A-STEP faculty members in the program. The participants’ actions revealed that they had not succeeded in making a full transition towards classroom inquiry from teacher-centered traditional instruction. Their practice was closer to teacher-centered styles than inquiry-based. The research participants were not able to employ the essential features of inquiry as parts of the whole, whether they used open or guided inquiry.

In spite of the efforts that A-STEP faculty members took to prepare students, A-STEP interns perceived constraints and needs in their practice of inquiry-based teaching. The perceived constraints and needs were similar to the ones recognized by A-STEP faculty members. The research participants perceived that their implementation of inquiry was constrained by student characteristics (e.g., students’ level of knowledge in science and mathematics and level of motivation), logistics (e.g., shortage of equipment, class size, time, and school culture), and personal factors (didactic background experiences and teaching a subject they had not majored in). The research participants drew attention to their limited practical knowledge in implementing inquiry-oriented activities. They also believed that they lacked access to field-tested and practical examples of inquiry across the continuum of inquiry.
Although the research participants perceived constraints and needs in using inquiry-based teaching methods, all four participants agreed that there were some factors that facilitated their practice of inquiry. The three main factors that facilitated their use of inquiry-based teaching included: (a) their perceived benefit of inquiry to students’ learning; (b) their reliance on the activities and strategies used in A-STEP; and to a lesser degree (c) their prior work experience in science.

Discussion

While structuring this section, I revisit Chapter Two (Literature Review), Chapter Four (Teacher Profiles and the Views of Faculty), and Chapter Five (Cross-case Analysis of Findings). The purpose here is to compare the findings of this study with research studies discussed in Chapter Two in order to provide a perspective on whether this study fulfilled the promise of helping to contribute to the literature about beginning science teachers’ understanding and implementation of inquiry-based teaching. My findings on beginning science teachers’ meaning and practice of inquiry confirm earlier studies in many aspects. However, there is uncertainty because of the participants’ enrollment status in A-STEP (see Figure 1). Following, I argue the similarities and differences between the reviewed literature and the research findings.

Researchers have revealed that there is a deficiency in teachers’ understanding of inquiry across all levels of education (e.g., Brown et al., 2006; Brown & Melear, 2006; Colburn, n/a; DeBoer, 2004; Harwood et al., 2002; Holliday, 2004; Keys & Bryan, 2001; Simmons et al., 1999). According to these researchers, teachers not only demonstrated a wide variety of conceptions of inquiry (i.e., inquiry as discovery learning and any sort of hands-on activities), but also considered inquiry as student-driven activities, involving
students in generating questions and carrying out independent research, with either less or no teacher intervention.

The beginning ATCP science teachers in this study demonstrated incomplete views and misconceptions about what constituted inquiry, such as inquiry goals “hands-on” and “discovery”. These views are similar to the ones discussed in the literature. The participants deemed that inquiry involves students generating authentic questions and carrying out independent research on their own with little or no teacher guidance. They regarded student-generated questions as the first and foremost feature of inquiry, followed by designing investigations and collecting data. However, they left out the other essential features of inquiry (i.e., formulating explanation from evidence, connecting explanations to scientific knowledge, and communicating and justifying explanations) (NRC, 2000).

Likewise, the research participants held an incomplete view of guided inquiry, a term they used to represent activities that were not qualified to be “open inquiry” by research participants. What made an activity guided inquiry was the fact that it was not student-driven, but included teacher input as guidance to students throughout. The research participants did not consider all essential features of inquiry as parts of a whole while labeling an activity as guided inquiry. Rather, they viewed each essential feature separately. To illustrate, if an activity included only one of the essential features of inquiry such as communication of results, the research participants viewed this activity as guided inquiry even if the instruction did not represent other essential features of inquiry (i.e., question, evidence, explanation, and justification). This view of guided inquiry did
not reflect the inquiry continuum as discussed by the NRC (2000), nor as concluded in the research studies that I reviewed.

I did not find any studies that compared students’ views of inquiry to their science methods instructors’ views of inquiry upon completion of a program (e.g., teacher education, induction, or professional development). However, some research studies have examined the views of participants, including beginning and expert teachers, about inquiry upon completion of a program (e.g., Keys & Kennedy, 1999; Koballa et al., 2005; Simmons et al., 1999; Wallace & Kang, 2004; Windschitl, 2003). In this study, I compared the research participants’ views of inquiry alongside their science methods instructors’ views of classroom inquiry. The findings revealed their views of inquiry clashed in that the faculty members’ views of inquiry and their teaching reflected the essential features of inquiry.

Some of the research connected the deficiency in science teachers’ views of inquiry with a number of factors originating from previous science learning experiences (e.g., Grossman et al., 1989; Hubbard & Abell, 2005; Koballa et al., 2005; Lee & Krapfl, 2002; Lortie, 1975; Luft & Patterson, 2002; Roth, 1999; Windschitl, 2003). The results of this study confirm this finding. None of the research participants had experienced inquiry teaching either as an undergraduate or graduate student prior to enrollment in A-STEP. They had only experienced teacher-centered science instruction as students in the past. Andrea, for example, recognized that the didactic teaching style with which she had been taught science in college had constrained her from using inquiry-oriented activities. It is also important to mention that A-STEP was the first place where the participants heard of and learned about inquiry as a teaching method.
Several researchers argue that a comprehensive view of inquiry is not the key to implementation of inquiry-based activities. They point to the relative relation between teachers’ practice of inquiry and their past experiences (as undergraduate students exposed to inquiry-oriented science courses, professional work experiences, and number of science methods courses taken in teacher education program) and support they received during induction years (mentoring, induction programs, and school culture) (e.g., Grossman et al., 1989; Koballa et al., 2005; Lee & Krapfl, 2002; Luft & Patterson, 2002; Roth, 1999; Windschitl, 2003). In addition, a number of researchers claimed that teachers’ inquiry role identities significantly affect their practice of inquiry (i.e., Crawford, 1999, 2000; Eick & Dias, 2005; Eick & Reed, 2002; Kagan, 1992; Windschitl). Teachers who had positive experiences with science as inquiry in the past and who had access to a strong support system and strong teacher identity roles, were more likely to practice inquiry-based teaching compared to their counterparts.

Three beginning science teachers in this study, Andrea, Cindy, and Lisa, viewed their teaching practice as reform-oriented and student-centered. Sara, on the other hand, stated that, in her practice, she incorporated inquiry here and there rather than describing her style either as teacher- or student-centered. The classroom observations of the participants, however, revealed inconsistencies between stated beliefs and practices. The observational data also unveiled that their practice did not reflect inquiry as portrayed by the NRC (2000) nor were they able to fully transform what they had learned in A-STEP about inquiry into their practice.

In many cases, the findings confirm the earlier studies that examined science teachers’ practice of inquiry. However, because of the participants’ backgrounds the
findings a bit inconclusive with previous research findings. Following, I discuss the ambiguity in making assertions about the research participants’ practice of inquiry in relation to the earlier studies discussed.

First, although all research participants did not have inquiry experiences as undergraduate students, three of the participants, Andrea, Cindy, and Lisa, had a variety of professional work experiences prior to their enrollment in A-STEP. Andrea had held a variety of positions in industry (engineer, process engineer, senior engineer, and staff financial analyst, to name few), for over 25 years. Cindy had worked in the field of biotechnology and medical bio-technology for seven years. Lisa had worked in the field of poultry and as an ESL teacher for a number of years and held a master’s degree in agriculture. Sara, on the other hand, entered A-STEP straight out of her undergraduate degree program.

The research participants did not have inquiry experiences in the past, which might have hindered their practices and made them to revisit their prior experiences as K-16 students once they began to teach (Brown & Melear, 2006; Eick & Dias, 2005; Koballa et al., 2005; Salish I Research Collaborative, 1997; Simmons et al., 1999). On the other hand, it was evident that there was a positive relation between the participants’ practices and their professional work experiences. Two of the participants, Andrea and Cindy, acknowledged that their prior work experiences facilitated their inquiry teaching practices. Although Cindy had a comparable work experience to Andrea, her view and practice of inquiry were broader and more in line with what she learned in A-STEP. But, Cindy had graduated from the program and Andrea was in her second semester at time this study conducted.
Some researchers have linked beginning science teachers’ practice of inquiry with the number of science methods courses taken (Roehrig & Luft, 2006; Lumpe et al., 2000). However, in this study, although all four research participants recognized the role of the models and activities used in A-STEP (as a facilitating factors to their practice), it is difficult to assert that the number of science methods courses taken influenced their inquiry practices. All A-STEP students took 3-4 science methods courses. It would only be possible for me to make the assertion after Andrea and Lisa graduated from the program. At the time of the study, Andrea and Lisa were taking their second science methods course. It is also important to mention that all the participants, regardless of their status, criticized the focus of science methods courses. They believed that method courses put too much emphasis on inquiry-based teaching as the only means of teaching science.

Second, all four research participant perceived constraints and needs as they attempted to make use of inquiry-based teaching. The perceived constraints (e.g., Adams & Krockover, 1997; Crawford, 1999; Crawford et al., 2005; Eick & Dias, 2005; Luft & Patterson, 2002; Roehrig & Luft, 2004) and needs (Abd-El-Khalick, 2004; Adams & Krockover, 1997; Crawford, 2000; Eick & Dias, 2005; Eick & Reed, 2002; Loughran, 1994; Luft & Patterson, 2002; Roehrig & Luft, 2004, 2006; Salish I Research Project, 1997; Simmons et al., 1999) were similar to those found by researchers studying beginning science teachers’ practice of inquiry. The constraints were: (a) logistical, including lack of equipment, time, and class size; (b) student constraints, including motivation and students’ level of knowledge in science and mathematics; and (c) school culture. The perceived needs included: (a) classroom management, (b) pedagogical skills, (c) practical knowledge, (d) and support. It is important to mention that these were the
same constraints recognized by A-STEP faculty members and which they had attempted to address in their science methods courses.

Third, all research participants acknowledged that they did not receive the support they needed in order to implement inquiry. Indeed, the schools where participants taught neither promoted nor valued inquiry approaches. School culture, apparently, hindered both Lisa’s and Sara’s practice of inquiry. Lisa believed she was the only teacher who tried to introduce inquiry, to teaching science in a school where didactic teaching style was valued and expected of teachers. She was assessed by her principal as having classes that were not well managed and was discouraged from implementing inquiry-oriented activities. Similarly, Sara was introduced to teacher-centered curriculum materials in her school settings and encouraged by other science teachers to use the same materials they had used for years. Knowing that she was not going to be able to receive any support and help if she implemented inquiry-oriented teaching, and that she would have had to develop her own inquiry-oriented curriculum, Sara decided to use approaches followed by her colleagues.

Finally, teachers idealized their roles as “teacher as facilitator” or “teacher as guide.” These roles are contrast to what Crawford (2000) reported as the roles of science teachers in inquiry-based classrooms: model, mentor, collaborator, learner, motivator, diagnostician, guide, innovator, experimenter, and researcher.

Although all research participants held incomplete views of inquiry and were not able to fully translate the lessons of A-STEP into their practice, among the four participants, Cindy overall was different. Not only did Cindy hold a broader view of inquiry, but her practice of inquiry also reflected inquiry as portrayed in the program.
more fully than other participants. She understood that inquiry was the scientific process of problem-solving as practiced by scientists. She deemed that students could develop scientific thinking processes and learn about the nature of science only if they engage in inquiry-oriented activities. Though Cindy perceived needs and constraints in her practice of inquiry, she did not receive pressure from her colleagues or from the administrative staff to implement a certain teaching style. She was determined to use inquiry approaches and held positive feelings towards inquiry-oriented teaching. It was evident that she revisited her past experiences where she carried out scientific researches in the field of bio-technology while implementing inquiry-based activities. She also acknowledged the role of the models and activities used in A-STEP as facilitating factors to her practice. It appears that Cindy’s views were broadened by these experiences. Cindy’s disposition towards inquiry affirms Wallace and Kang’s (2004) statement that the belief sets that promoted inquiry are private and based on the individual teacher’s notion of successful science learning.

In conclusion, this study provides evidence that subject matter knowledge and teachers’ verbal ability are not the determining factors of successful teaching as debated by advocates of deregulation agenda (Ballou & Podgursky, 1999, 2000; Cochran-Smith & Fries, 2001; Hawley, 1990; Kanstroroom & Finn, 1999; Schaefer, 1999; Zeichner, 2003). Although A-STEP is an ATCP, it is structured in favor of the professionalization agenda to produce highly-qualified, reform-minded teachers who would value inquiry-based instruction (Darling-Hammond, 1992, 1998, 2000b, 2000c; Hewson et al., 1999; NCTAF, 1996, 1997; Shen, 1997). On the other hand, the study also reveals that regardless of the structure of a teacher education program, participants can complete it
without fully understanding or practicing what it takes to be a highly-qualified science teacher.

In this research, I looked at beginning science teachers’ understanding and practice of inquiry-based instruction, factors that facilitated and constrained their understanding and use of inquiry, and science methods course instruction in A-STEP. Thereafter, I made several claims based on the data set. It is evident from the findings reported that preparing beginning science teachers to use more inquiry-oriented teaching approaches is complex.

I maintain that science teachers’ understanding and practice of inquiry-based teaching is not only linked to their science teacher preparation program. The findings revealed that teacher learning is situated in three different contexts of learning. Figure 2 provides a visual representation of these contexts of teacher learning. Teachers’ understanding and practice of inquiry is a product of the context of prior experiences, the context of teacher education, and the context of school culture. As Figure 2 symbolizes, each of these context have elements that can hinder or promote science teachers’ understanding and practice of inquiry in their classrooms.

The first segment of the contexts for teacher learning is the context of prior experiences. This context corresponds to research participants’ prior experiences including K-12 schooling (especially high school), undergraduate and sometimes graduate science coursework, and work experiences. These prior experiences influence individuals as they enter ATCPs and teaching experiences. These prior experiences shape the meanings and practices of inquiry of beginning science teachers.
The second part of the context of teacher learning is teacher education. In the case of this study, this context represents the A-STEP program. This context the teacher preparation program curriculum, which includes courses taught by science faculty, science education faculty, other education faculty. Teacher preparation programs include coursework in subject specific pedagogy and teaching and field experiences (some of which are supervised by a university supervisor). The teaching and field experience component is shared between the teacher education context and the final context in the figure.

The last piece of the model, the school culture context, symbolizes the work place of the teachers, both in ACP-based field experiences and in their own classrooms. The school culture context includes, mentor teachers, school curriculum, classroom and school facilities, other science teachers, other teachers, expectations of the principal and the science department, and students. The school context is the most complicated context because it is where all three contexts meet and where teachers begin to put their knowledge and beliefs into practice in major ways.

Beginning science teachers in this study carried their prior experiences such as K-12 schooling, undergraduate and graduate education, and work experiences to A-STEP. Coming into A-STEP, each teacher already had an identity, and held knowledge, beliefs, and attitudes toward teaching their subjects. In the context of teacher education, the teachers constructed new knowledge and beliefs about inquiry-based science instruction. Following or in conjunction with the context of teacher education, the teachers found themselves in another context, the school culture. There different elements and players had expectations for science teaching that might have differed from those of A-STEP.
Teachers’ knowledge and beliefs about inquiry-based instruction were further influenced by these elements of the school culture context.

Figure 2. Context of Teacher Learning

Teacher understanding and practice of inquiry is built via a complex set of influences before, during, and after the ATCP. Each of these influences present implications for science teacher preparation and for continuing research into science teacher knowledge and practice of classroom inquiry.
Conclusions

In this study, I attempt to understand alternatively certified beginning science teachers’ views and implementation of inquiry. The combination of beginning science teachers views of classroom inquiry and their practices of inquiry-based activities greatly enrich our understanding. I learned that the beginning science teachers in this study held incomplete views of inquiry. These views of inquiry did not reflect inquiry as described in NRC (2000) - essential features of inquiry, - nor did they reflect views of faculty members involved in teaching science methods courses.

In regard to the research participants practice of inquiry, although the research participants described themselves as reform-oriented, there were inconsistencies between their views and practices. I found that the research participants’ practice of inquiry did not reflect inquiry either as outlined by essential features of inquiry (NRC, 2000) or inquiry as modeled in activities used in A-STEP.

I also examined the research participants’ perceived constraints, needs, and facilitating factors. Their perceived constraints included logistical and student constraints and school culture. The perceived needs included classroom management, pedagogical skills, practical knowledge, discipline, successful grade-specific models of inquiry, and access to a strong support system. Prior professional work experience, models and activities used in A-STEP, and benefits of inquiry to student learning were the declared factors that facilitated the research participants’ practice of inquiry-based teaching.

*What Is The Significance of This Study In Relation to The Research?*

In the final section of Chapter Two, I discussed three gaps in the literature in relation to alternatively certified beginning science teachers. In discussing the first gap, I
drew attention to the limited number of empirical studies on alternative certification beginning science teachers’ views and practices of inquiry-based teaching. Some scholars, e.g. Keys and Bryan (2001) and Koballa et al. (2005), presented positions on additional research agendas to examine teacher beliefs about inquiry, teacher knowledge base for implementing inquiry, and teacher inquiry practices. This study provides empirical evidence to these agendas.

The second gap was that exclusive concerns with filling the teacher shortage has diverted attention away from understanding the needs, constraints, and classroom performance of beginning science teachers recruited through alternative certification programs. This study provides evidence about beginning science teachers’ perceived needs, constraints, and classroom practices, not just their retention in the field.

Finally, the third gap was the need to examine beginning science teachers’ practices of inquiry with respect to what they learned in their ATCP. Therefore, in conducting this study, I examined beginning science teachers’ experiences of teaching science through inquiry as it compared to an intended teacher education curriculum.

Implications

The findings of this study suggest several implications for science educators who: (a) are involved in teaching science methods courses, (b) design both traditional teacher education and alternative teacher certification programs, and (c) design and implement of professional development programs.

The findings of this study imply that teacher educators should take into consideration preservice teachers’ incoming views of inquiry while organizing their teaching goals. Individuals enrolling in ATCPs have different backgrounds and
experiences that had shaped their views of inquiry. Science educators could instigate this process by engaging preservice teachers in discussions about classroom inquiry. This first movement to uncover preservice teachers’ preconceptions of inquiry could significantly shed light on further efforts taken by science educators to promote inquiry in their science methods courses.

The results of this research confirm that the research participants’ incomplete views of inquiry constrained their practices of inquiry. To promote inquiry in all level of education practitioners need to recognize broader views of inquiry that include the essential features of inquiry (NRC, 2000). There are several strategies I propose to counter incomplete views of inquiry that beginning teachers hold.

First, data analyses revealed that the excessive amount of inquiry-based teaching integrated in the science methods courses did not help A-STEP interns to develop a complete view of inquiry. Indeed, the science methods courses made A-STEP interns to think inquiry was the only teaching method that they needed to employ in their teaching. Thus, the study suggests, in teaching science methods courses, science educators should integrate fewer inquiry-oriented activities in which students can explore inquiry in depth. In order to facilitate beginning science teachers’ practices of inquiry-oriented teaching, it is essential to recognize that beginning science teachers who are expected to implement inquiry-based teaching would also need to have knowledge and skills of other teaching strategies besides knowledge and skills required for inquiry-based instruction. So, it is imperative that science educators provide effective and interactive alternative teaching methods to their students. The case of Ms. Kennedy discussed in Chapter Two (Keys & Kennedy, 1999) is a good science teacher education example of how both inquiry and
other teaching methods can be employed. Ms. Kennedy blended inquiry questions arising in context with ongoing lesson plans designed to teach or explore science concepts. She also employed other teaching methods in her teaching.

Second, science educators must explicitly deconstruct and explain models of inquiry-based activities they use in their science methods courses. Science educators can provide copies of activities for their students and show how different parts of these activities meet the essential features of inquiry as outlined by NRC (2000). Students can also depict how each piece of an inquiry-oriented activity is integrated with the whole while comparing them against essential features of inquiry. Science educators should strive to contradict the common misconceptions about inquiry such as inquiry goals hands-on or inquiry as discovery.

Another implication that the study put forward is the necessity of understanding of how different classroom inquiry possibilities can be situated along the continuum of inquiry proposed by NRC (see NRC, 2000, Table 2-6, p. 29). In addition, science educators can also use the two dimensional continuum of inquiry built on NRC’s continuum of inquiry by Brown et al. (see Brown et al., 2006, Figure 1, p. 799) to broaden their students’ understanding of inquiry. Brown et al. provided several examples of different classroom inquiry possibilities that fall in different locations on the inquiry continuum.

The findings of the study suggest that A-STEP interns would have benefited from inquiry-oriented activities used in science methods courses by A-STEP faculty if they were subject and grade-level specific. Thus, this study urges science educators to engage students in subject and grade-level specific inquiry activities relative to their teaching
assignments in order to provide a context for them to see how inquiry worked in a context that might be somewhat similar to their teaching context.

Although this study revealed that A-STEP interns’ incomplete view of inquiry constrained their practices, the context of their teaching also influenced their inquiry practices. Learning to teach through inquiry within a community of practice that supports the use of inquiry-based teaching with an experienced teacher is important for beginning teachers to develop early practical knowledge and competency in practice. The research findings demonstrate that beginning science teachers of both ALT and APB tracks lacked this support or were explicitly restricted by their school culture. Mentor teachers, colleagues, and school administrators, either can promote or de-value classroom inquiry. If the goal of science teacher educators is to facilitate the use of inquiry among beginning teachers, then science teacher educators need to ensure that interns are matched with mentor teachers who value and practice inquiry. They need to establish an active network of support among different parties who share the goal of reform-oriented science teaching and help. Induction programs would further support the development of practical knowledge needed to support beginning science teachers’ inquiry practices. Science educators could support beginning science teachers by providing them with practical field-tested subject and grade level specific example of inquiry-based teaching during their induction years.

Finally, the findings of this research confirm that the participants’ early experiences with non-inquiry based teaching during their undergraduate years significantly influenced their practices. Thus, I recommend that science educators
collaborate with college science faculty in developing undergraduate science courses that comply reform-minded practice.

Directions for Future Research

It was the main objective of this study to understand how science teachers in an alternative certification program, A-STEP, understood and implemented inquiry-based instruction in their beginning years. However, there are several areas that are still open to research.

The research participants did not have the same professional work experiences before entering A-STEP nor were that at the same point in the program at the time of the study. Therefore, to better understand beginning science teachers’ experiences of inquiry, I believe that we need additional research to compare the views and practices of teachers from different backgrounds and at the different points in their programs.

In this study, I did not have an opportunity to find out about participants incoming views of inquiry as they began their first science methods course. Having an understanding of their incoming views would be beneficial. Similarly, it is necessary to follow these teachers after a few years to see whether there is a change in their approaches to teaching science. Therefore, I believe that longitudinal studies are needed to examine how teachers’ views and practices of inquiry change over a period of time, from entering teacher education programs, through several years of teaching.

Another goal of this study was to compare the research participants’ experiences of teaching science through inquiry to what they learned in A-STEP. While comparing the research participants’ experiences of inquiry to the faculty members’ views and practices, I relied only on faculty interview data. Unlike the classroom observations that took place
in the research participants’ classes, I did not have a chance to observe the faculty members teaching the research participants about inquiry. Thus, additional research could provide insights into the settings where preservice teachers experience inquiry-based teaching and how they learn in those settings.

Figure 2 illustrates the complexity of the preparation that took place in A-STEP. This study was limited to understanding the context of the science methods courses and science education faculty components. The role of the other elements in A-STEP remain unexamined in the context of teacher education. Therefore, what is needed is more in-depth case studies of program components in relation to the context of the teacher preparation program. Such studies would build the knowledge base about the impact of different aspects of teacher preparation on beginning science teachers’ understanding and practice of inquiry.

For example, more research is needed on the consequences of who supervises intern teachers engaged in field experiences. In what ways does it make a difference whether the supervisor is a science education faculty, a graduate student, or a school district personnel? Of course, examples of questions related to the context of teacher preparation are too numerous to be considered by any individual researcher. Greater attention to the components of the context of teacher education as parts of a whole will enable us to better understand the science teachers’ developing understanding and practice of inquiry-based teaching.

Similarly, the components of other context areas--prior experiences and school culture--need to be examined closely. These two context areas are not any less important than the context of teacher education. In fact, because all three contexts inform each
other, research connecting these contexts will make possible to gain a better insight about science teachers’ understanding and practice of inquiry-based teaching, if they are all studied in detail.

These recommendations for future research are aligned with the recommendations that Zeichner (2005) proposed in the final chapter of *the Studying Teacher Education: The Report of the AERA Panel on Research and Teacher Education*. In this chapter, A Research Agenda for Teacher Education, Zeichner recommended research on several topics. Among these topics, he emphasized the importance of context in teacher education. He suggested that teacher education researchers, “Conduct research on teacher educators, teacher education students and graduates, and on the instructional context in teacher education…Conduct research on teacher education curriculum, instructional practices, and organizational arrangements within programs” (Zeichner, pp. 747-748). The model presented in Figure 2 helps define some of the contexts in which new science teacher education research can be conducted.

Epilogue

As of today, October 8, 2006, I am able to verify that three of the research participants out of four are still teaching. I was not able to verify whether Lisa was still teaching, but I found out that she was not teaching in the school where she used to teach nor did she complete her teaching education program. I recently learned that Sara decided to pursue a degree in law and she is awaiting acceptance to law school. Therefore, this year, which is her third year of teaching, is going to be her last year teaching.
REFERENCES


FOOTNOTES

1 Mark Gagnon was a former Science teacher. He taught science to grades 4-8. Mark involved in professional development programs that were about inquiry-based teaching both as a participant and a designer. At the time of this study he was working on his Ph.D. in science education.

2 Interview #3.1 means that quote from the first classroom observation of the third interview series

3 E.g., one of the segments of the course readings included a section about teaching and doing scientific inquiry. Some of these readings were:
APPENDIXES
Appendix A: Program of Study

Professional Education Core
TDP 7070 Overview of Teaching I 4 credits
TDP 7080 Overview of Teaching II 4 credits
C&I 7560 Reading in the Content Area 2 credits

Field-Based Internship
C&I 8942 Advanced Internship (taken 2-4 semesters) 8 credits

Content Courses
Mathematics Content
Mathematics content courses to include geometry, algebra, and/or statistics

Science Content
Phys 7085 Exploring Physics 3 credits
Bio Sc 8002 Environmental Analysis 3 credits

Content Education Sequence
(For Dual Math Certification, students will take the Secondary sequence, add 7410, and carry out internships at both the middle and secondary levels)

Secondary Mathematics Education Sequence
C&I 8861 Teaching, Learning, and Research in Middle and Secondary School Mathematics I 3 credits
C&I 8862 Teaching, Learning, and Research in Middle and Secondary School Mathematics II 3 credits
C&I 8863 Teaching, Learning, and Research in Middle and Secondary School Mathematics III 3 credits
C&I 8893 Integrating Instruction in Science and Mathematics 2 credits

OR

Middle Level Mathematics Education Sequence
C&I 8861 Teaching, Learning, and Research in Middle and Secondary School Mathematics I 3 credits
C&I 8862 Teaching, Learning, and Research in Middle and Secondary School Mathematics II 3 credits
C&I 8893 Integrating Instruction in Science and Mathematics (Grade 5-12) 2 credits
TDP 7410 Teaching, Engaging, and Assessing Middle-Level Students (TEAMS) 3 credits

OR
### Secondary Science Education Sequence

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<td>C&amp;I 8718</td>
<td>Teaching, Learning and Research in Middle and Secondary School Science II</td>
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<td>C&amp;I 8719</td>
<td>Teaching, Learning and Research in Middle and Secondary School Science III</td>
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<tr>
<td>C&amp;I 8893</td>
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### Middle Level Science Education Sequence

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<td>C&amp;I 8893</td>
<td>Integrating Instruction in Science and Mathematics (Grade 5-12)</td>
<td>2</td>
</tr>
<tr>
<td>TDP 7410</td>
<td>Teaching, Engaging, Assessing Middle-Level Students (TEAMS)</td>
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The Alternative Certification Program (ALT) is designed for individuals with an undergraduate degree in math, science, or a related area who are hired by a school district under a Missouri Temporary Authorization Certificate and teach at the same time they complete their certification program. ALT students attend 2 concentrated summer sessions on the MU campus and spend 2 school years as full-time teachers, during which they are part of a learning community with other interns, mentor teachers, and MU faculty members. (2 years; 35 credits)

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<tr>
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<td>TDP 7070 (4 credits) Overview of Teaching I</td>
<td>C&amp;I 8717 (3 credits) Teaching, Learning and Research in Middle and Secondary School Science I</td>
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<td></td>
<td>TDP 7080 (4 credits) Overview of Teaching II</td>
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| **Academic Year #1, Fall (5 credits)** | | |
| C&I 8862 (3 credits) Teaching, Learning, and Research in Middle and Secondary School Mathematics II | C&I 8942 (2 credits) Advanced Internship | C&I 8718 (3 credits). Teaching, Learning and Research in Middle and Secondary School Science II |

| **Academic Year #1, Winter (5-8 credits)** | | |
| C&I 8863 (3 credits) Teaching, Learning, and Research in Middle and Secondary School Mathematics III (secondary only) | 7560 (2 credits) Reading in the Content Areas | C&I 8719 (3 credits) Teaching, Learning and Research in Middle and Secondary School Science III (secondary only) |
| | C&I 8942 Advanced Internship (2 credits) | |

| **Summer #2 (5-8 credits)** | | |
| Mathematics course (Geometry, Algebra, or Statistics) (3 credits) | C&I 8893 (2 credits) Integrating Mathematics and Science Instruction TDP 7410 (3 credits) TEAMS (middle level only) | Science course (PHYS 7085 Exploring Physics) (3 credits) |

| **Academic Year #2, Fall and Winter (7 credits)** | | |
| Mathematics course (Geometry, Algebra, or Statistics as needed) (3 credits) | C&I 8942 Advanced Internship (2 credits fall, 2 credits spring) | Science course (BioSci 8002 Environmental Analysis) (3 credits) |
The Accelerated Post-Baccalaureate Program (APB) is designed for individuals with an undergraduate degree in math, science, or a related area who desire a high quality teacher preparation program in an accelerated time frame. APB students attend 2 concentrated summer sessions on the MU campus and spend 1 school year interning at a partner school, during which they are part of a learning community with other interns, mentor teachers, and MU faculty members. (15 months, 35 credits)

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<td>C&amp;I 8942 (6 credits) Advanced Internship</td>
<td>C&amp;I 8719 (3 credits) Teaching, Learning and Research in Middle and Secondary School Science III (secondary only)</td>
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<td>Math content course (3 credits) (middle only)</td>
<td>Science course (BioSci 8002 Environmental Analysis) 3 credits</td>
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<td>C&amp;I 8893 (2 credits) Integrating Mathematics and Science Instruction</td>
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Appendix B: Consent Forms

Teacher Consent Form

Southwestern Bell Science Education Center
303 Townsend Hall
Columbia, MO 65211-2400
VOICE (573) 529-1869
FAX (573) 441-0046
Email: ad3h6@mizzou.edu

College of Education
Department of Learning, Teaching, & Curriculum

_______, 2005

Dear Participant,

This letter seeks permission for your participation in a non-funded dissertation project entitled, “Alternative Certification Science Teachers’ Understanding and Implementation of Instruction in Their Beginning Years of Teaching” This letter outlines the purpose, procedures, duration, and benefits and risks of your participation with this project, as well as addressing the issues of confidentiality, voluntary participation and the approval for studying human subjects.

Purpose of Research
The purpose of this study is to understand the experiences of teachers in during the first years of teaching. Specifically, I want to understand how teachers of an alternative teacher certification program teach science in their beginning years.

Specific Procedures to be used for the Entire Study
I will collect the following data: (a) at least three maximum four interviews depending on my satisfaction with collected data --The first interview will be held during the summer session of 2005 while you are on campus. The remaining interviews will take place in the fall semester of the academic year of 2005 that you are assigned teaching position--; (b) observational field notes and video taping (only instructor/teacher: the video tapes will be stored in my home office for three years; The classroom observation will take place from beginning of a unit to the end of it which may take 4-5 lessons; I will be the one having access to data, but for the purpose of accurate data analysis I may share my data with my advisor, committee members, and peer debriefer); (c) unobtrusive data such as copies of lesson plan, documents, or descriptions of classroom tools; and (d) a single interview in the fall semester of 2005 with a number of faculty members teaching method courses to the participant in the alternative teacher certification program.

Duration of Participation
July 2005 to August 2006 for data collection.

Benefits to the Individual
I expect that this project will be beneficial to your professional development as a teacher, by helping you think about science teaching and learning in new ways.

Risks to the Individual
The risks anticipated are no greater than those encountered in every day life. Your performance in the program will not be affected by your participation. Your participation is voluntary, and you have the right to terminate your participation at any time.

Confidentiality
Regarding the collection of observational data, a pseudonym will be assigned to any data originating from you; thus your personal identity will be held confidential. You will not be included by name in any future report resulting from this study, unless you wish otherwise.

Voluntary Nature of Participation
Your participation in this study is voluntary. If you do agree to participate, you can withdraw your participation at any time without penalty.

Human Subject Statement
This project has been reviewed and approved by the University of Missouri-Columbia Human Subjects Review Board. The Board believes the research procedures adequately safeguard your privacy, welfare, civil liberties, and rights. If you have any questions, you may reach me at (573) 529-1869. For additional information regarding human subjects participation in research, please contact the University of Missouri-Columbia IRB office at (573) 882-9585.

If you are willing to participate in this project, please complete the consent form below.

Sincerely,

Abdulkadir Demir
Doctoral Candidate  Sandra Abell
Professor

Consent Form

I, ________________________________ agree to participate in the research project entitled “Alternative Certification Science Teachers’ Understanding and Implementation of Instruction in Their Beginning Year of Teaching” conducted by Abdulkadir Demir, a doctoral candidate in the College of Education, Department of Learning, Teaching, & Curriculum at the University of Missouri – Columbia.
I understand that:

• My participation is voluntary and that I must be 18 years of age to participate.
• My identity will be kept confidential.
• I will not need to provide personal background information other than past teaching experiences.
• I understand that all interviews will be audio-taped.
• I understand that classroom observations will be video-taped.

I have read the letter above and am aware that I may contact Abdulkadir Demir [(573) 441-0046; E-mail: Ad3h6@mizzou.edu] with any questions and concerns or contact the Office of IRB, Institutional Review Board.

Campus IRB Contact Information
Phone: 573-882-9585
Fax: 573-884-0663
483 McReynolds
University of Missouri
Columbia, MO 65211

I consent to the use of research data as described above and understand that I am free to withdraw consent and to discontinue participation in the study at any time.

_____________________________ ______________________________
Participant’s Signature Date

_____________________________
Participant’s Name
Dear Participant,

This letter seeks permission for your participation in a non-funded dissertation project entitled, “Alternative Certification Science Teachers’ Understanding and Implementation of Inquiry-Based Instruction in Their Beginning Years of Teaching.” This letter outlines the purpose, procedures, duration, and benefits and risks of your participation with this project, as well as addressing the issues of confidentiality, voluntary participation and the approval for studying human subjects.

Purpose of Research
The purpose of this study is to understand the experiences of teachers in during the first years of teaching. Specifically, I want to understand how teachers teach science and what challenges, constraints, and needs they perceive in an alternative teacher certification program. The purpose of interview I want to conduct with you is to gain an understanding of your view of inquiry.

Specific Procedures to be used for the Entire Study
I will use a single semi-structured interview to collect data from you. However, the following data will be collected from alternatively certified science teachers of the program: (a) at least three maximum four interviews depending on my satisfaction with collected data --The first two interviews will be held during the summer session of 2005 while they are on campus. The remaining interviews will take place in the fall semester of the academic year of 2005 that they are assigned teaching positions--; (b) observational field notes; and (c) unobtrusive data such as copies of lesson plan, documents, or descriptions of classroom tools.

Duration of Participation
July 2005 to August 2006 for data collection.

Benefits to the Individual
After collecting data through interview, classroom observation, and artifacts I will share my findings with you, which might help you think about your teaching practice.
Risks to the Individual
We perceive no risks to you from participating in this study.

Confidentiality
Regarding the collection of observational data, a pseudonym will be assigned to any data originating from you; thus your personal identity will be held confidential. You will not be included by name in any future report resulting from this study, unless you wish otherwise.

Voluntary Nature of Participation
Your participation in this study is voluntary. If you do agree to participate, you can withdraw your participation at any time without penalty.

Human Subject Statement
This project has been reviewed and approved by the University of Missouri-Columbia Human Subjects Review Board. The Board believes the research procedures adequately safeguard your privacy, welfare, civil liberties, and rights. If you have any questions, you may reach me at (573) 529-1869. For additional information regarding human subjects participation in research, please contact the University of Missouri-Columbia IRB office at (573) 882-9585.

If you are willing to participate in this project, please complete the consent form below.

Sincerely,

Abdulkadir Demir
Doctoral Candidate

Sandra Abell
Professor

Consent Form

I, ________________________________ agree to participate in the research project entitled
“Alternative Certification Science Teachers’ Understanding and Implementation of Inquiry-Based Instruction in Their Beginning Year of Teaching” conducted by Abdulkadir Demir, a doctoral candidate in the College of Education, Department of Learning, Teaching, & Curriculum at the University of Missouri – Columbia.

I understand that:
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• My identity will be kept confidential.
• I will not need to provide personal background information other than past teaching experiences.
• I understand that all interviews will be audio-taped.

I have read the letter above and am aware that I may contact Abdulkadir Demir [(573) 441-0046; E-mail: Ad3h6@mizzou.edu] with any questions or concerns.
I consent to the use of research data as described above and understand that I am free to withdraw consent and to discontinue participation in the study at any time.

Participant’s Signature

Date

Participant’s Name
Appendix C: Interview Questions

Interview #1

1. What can you tell me about yourself?
   a. How old are you?
   b. What can you tell me about your educational background?
   c. What was your major?
   d. When did you graduate?
2. What can you tell me about your previous work experience?
   a. What did you do?
   b. How long did you work?
   c. Where did you work?
   d. What reason(s) did make you to leave?
3. What experiences have you had doing science research?
4. How do you think those experiences compared to what scientists do?
5. What teaching experience have you had in teaching science prior enrolling in A-STEP?
   a. When was the last time you taught a subject?
   b. Where did you teach?
   c. What grade level did you teach?
   d. How long did you teach?
   e. Do you have any tutoring or Sunday school experience?
6. In your opinion, what are the most important qualities that a science teacher should have in teaching science?
   a. What can you tell me about your own qualities in teaching science?
7. What can you tell me about your goals, as a new science teacher, to help your students learn science?
8. What kind of teaching strategies are you planning on using next semester (in teaching science)?
   a. Why?
9. What do you think you need to learn to teach science more effectively?
10. In your opinion, what are the best ways for the students to learn?
   a. Why do you think those are the best way?
   b. How do integrate those ways into your teaching?
Interview #2

General Questions
1. What can you tell me about your teaching assignment, school, and community etc.?
2. I would like to get a general sense of your teaching experience. How has it been going?
   a. What can you tell me about what has been most rewarding aspect of your teaching so far? Why has that been rewarding?
   b. How about the most challenging aspect of your teaching so far? Why?
      1. How do you handle these challenges?
      2. How about challenges you have been facing in instructions?
3. I would like you to walk me through a science topic you have taught recently.
   a. What was the topic?
   b. What were your objectives for student learning? Why did you select these objectives?
   c. How did you decide what to teach?
   d. How did you begin your lesson?
   e. How did you teach the topic?
      1. What was the first thing you did?
      2. What role did your students have?
      3. What role did students have in designing the procedure?
   f. How did you prepare to teach the topic?
      1. What can you tell me about instructional materials or resources that helped you teach the topic?
   g. How did you feel about how the lesson(s) played out?
      1. To what extent do you feel you met the learning objectives?
   h. How did the students respond?
   i. What did you think students learned?
   j. In what ways, if any, your past experiences (past career) and what you learned in A-STEP about teaching a lesson helped you facilitate your teaching to teach the topic?
   k. What can you tell me about the difficulties you think you experienced in teaching the topic?
      1. What would you do differently in teaching the same topic in the future? Why?
      2. In your opinion, was there any other way to better teach this topic? Why? or Why not?

Inquiry Questions
1. What does teaching science through inquiry mean to you?
2. In your opinion, what distinguishes inquiry from other instructional methods? Why?
   a. How teaching science through inquiry is different from the way you had taught science before?
3. What would inquiry learning look like if I were to encounter in your classroom? In a lab for that class?
4. Do you think your lesson in teaching the topic incorporated inquiry? In what ways? Why? Why not?
   a. If yes, what was your role?
5. What were some of the constraints, if any, for implementing inquiry-based activities in teaching this topic?
   a. Tell me about the constraints that you believe that you have in implementing inquiry-based activities in your classroom, in general.
6. Why would you prefer to use inquiry in your teaching? Why would not you prefer?
7. How often and in what ways do you integrate inquiry based-instruction in your classroom?
a. How do you search for ideas about incorporating inquiry based experiences into your curriculum?
   i. How do you identify and use resources outside the school for your inquiry based activities?
b. Is it possible to teach all topics using an inquiry approach in your subject? Why? or Why not?
c. What can you tell me about how experiences you had with inquiry in A-STEP helped you understand how to teach by inquiry?

8. What do you think students learn about science while involving in inquiry-based activities?
   a. What kind of opportunity does inquiry based curriculum provide to learners?
   b. How do you assess students learning in inquiry based activities?

9. How do you create a setting that is flexible and supportive of science inquiry?
   a. What kind of accommodations do you make to make inquiry equally accessible to every student regardless of his/her background such as culture, language, physical ability, emotional status etc.?
   b. What factors do you need to pay attention to?
Interview #3 Series

Pre-Classroom Observations

1. I would like you to tell me a bit about the students in this class
   a. Their ability
   b. How do they compare to students in the school as a whole?
   c. Are there any students with special needs in this class?
   d. Are there any students for whom English is not their first language?
   e. Are there any students with learning disabilities?
2. I would like you to tell me about the unit that you are going teach?
3. What are your goals for this unit, i.e. what do you intend for students to learn?
   a. How and why did you choose these instructional goals?
4. Is there anything about this particular class that led you to plan this unit this way?
5. What is the relation of this unit to other units you teach this year?
   a. What have the students experienced prior to this?
   b. What do you expect the students to know already?
6. Have you taught this unit before? If yes, Are you planning on teaching this unit any different then how you taught it before?

Before Each Lesson

1. I would like you to tell me a bit about the lesson that you are going teach?
   a. What are your goals for this lesson?
   b. How do you plan to teach it?
   c. What do you intend for students to learn after this lesson?
2. How do you plan to assess students’ learning?
3. What resources are you planning on using to teach this unit?

After Each Lesson

1. What was the specific purpose of today’s lesson?
2. How do you feel about how the lesson played out?
3. What do you think the students gained from today’s lesson?
4. Did you make modifications to your lesson plan during the lesson? If so, what were they, and what motivated these changes?
5. What is the next step for this class in this unit?
6. Why did you to teach the lesson the way you did?
7. Is there anything particular that led you to plan this lesson this way?
8. How different was today’s lesson from how you have taught it before?
9. What would you do differently to improve this lesson in the future?
10. I noticed….. what were the reasons behind that?
11. If any, in what ways do you think your lesson used inquiry? Why? Why not?
12. What were some of the factors that you paid attention to create a setting that was flexible and supportive of science inquiry in teaching this lesson?
13. What were some of the constraints, if any, for implementing inquiry in teaching this lesson?
Post Observations

1. How did you determine whether your students achieved the learning goals you set? Why did you select this/these methods? How do you plan to use the results?
2. Did your students learn what you intended them to learn?
3. How effective do you think your assessment strategies were? Would you make any changes in your approach to assessment? If so, what changes would you make and why?

Program Questions

1. Tell me about your experience in A-STEP?
   a. What can you tell me about your expectations of A-STEP prior enrolling to the program? To what degree have your expectations been met so far?
   b. What has been/was the most challenging aspect of A-STEP?
   c. What has been/was the most rewarding aspect of A-STEP?
2. How has A-STEP affected your current practice in science teaching?
   a. Tell me about your teaching methods before A-STEP?
      i. Tell me about the things you believe that you missed while teaching science in the past? Why?
   b. What have you learned about science teaching in A-STEP?
      i. In what ways do you use that knowledge?
      ii. In what ways did you use that knowledge in teaching the unit I observed?
   c. Can you give me an example of how you revised your teaching since you started teaching? Why did you that?
   d. What do you wish you had gotten in A-STEP that would help you teach better?
   e. What have you learned about inquiry in A-STEP?
      i. How do you use what you learned about inquiry in the program in teaching science?
      ii. In what ways did you use that knowledge in teaching the unit I observed?
3. Tell me about courses where you think you learned about inquiry teaching?
   a. What can you tell me about the strength and weakness of these courses?
   b. What did you enjoy the most about these courses?
   c. In what ways do you think these courses were beneficial?
   d. In what ways these courses helped you think about your past experience with teaching?
   e. Can you give me an example of how you revised your teaching after taking these courses?
   f. How much of have you been using what you have learned in these courses this semester?
4. In your opinion, what are the strength and weakness of A-STEP?
5. What kind of help do you receive now from A-STEP for your teaching?
6. What advice do you have for A-STEP faculty to improve the program?
Faculty Members Interview Questions

1. What are your goals in teaching method course(s) to A-STEP teachers?
2. How do you craft these goals into your teaching?
3. What is your definition of inquiry-based instruction?
   a. In your opinion, how much teaching science through inquiry is important? Why?
4. What kind of knowledge and skills do you believe that a beginning science teacher should have to use inquiry-based instruction in his/her science teaching?
5. How do you teach these knowledge and skills to beginning science teachers in your method courses?
   a. How do you help beginning science teachers to create settings flexible and supportive of science inquiry?
6. In general, what are the most perceived constraints that beginning science teachers face in implementing inquiry-based instruction? Why?
7. What can you tell me about A-STEP’s beginning science teachers’ views of inquiry in teaching science prior to taking your course?
   a. What are their perceived constraints and needs for implementing inquiry-based instruction?
   b. How do you find out what they know and don’t know to be able teach them what they need?
   c. What kind of activities or sources do you use to challenge their views of inquiry in teaching science?
8. What would you expect that A-STEP’s beginning science teachers know about inquiry-based instruction subsequent to your course?
   a. To what degree do you believe that A-STEP’s science teachers are capable of implementing inquiry-based instruction in their teaching? Why?
   b. If you were to encounter in one of your student’s classroom or lab, how much of inquiry-based instruction would you expect to see?
9. What would you expect that A-STEP’s beginning science teachers perceive as constraint(s) in implementing inquiry-based instruction, after graduation? Why?
   a. What kind of support do faculty members provide or strategies are in place for beginning A-STEP teachers to overcome these constraints?
10. Tell me about activities that you use to model/teach inquiry based instruction? (Moon activity, Nail)
11. What do you teach your students about 5E?
   a. What do you expect them to be able tell about 5E and its relation with Inquiry?
September 26, 2005

Dear [Name],

I am a doctoral student pursuing my degree in Science Education at University of Missouri-Columbia in the department of Learning, Teaching, and Curriculum. In the fall semester of 2005, I would like to conduct some classroom observations to collect data for my research within your system with the intention of acquiring valuable information that may be used to better improve the design and implementation of alternative teacher certification programs, ATCPs.

My research proposal centers on “Alternative Certification Science Teachers’ Understanding and Implementation of Instruction in Their Beginning Years of Teaching”. Understanding the beginning years of teaching will help informing teacher preparation programs, traditional and alternative. Improved ATCPs will strengthen teachers’ PCK and produce highly-qualified science teachers. Therefore, I hope the results of this study will lead to refining inquiry-based pedagogy at all levels of education.

I would like to conduct classroom observation with science teacher, [Name], assigned a teaching position in your school. [Name] is also enrolled in an ATCP, A-STEP: An Alternative Science Teacher Education Program, at the University of [Name]. I am planning on watching [Name] in the same classroom while teaching a unit from beginning to the end. I am expecting the length of the classroom observation to be about a week or so. Throughout my classroom observations, I will immerse myself in the research settings as an onlooker observer who completely separates himself or herself from the research settings as spectator does. In addition, I am planning on video taping [Name] while lecturing. The video tapping will not involve any student.

I am seeking your permission to do my classroom observation at Mrs. Roberson class to gain understanding of her use of inquiry-based instruction. Please feel free to contact my doctoral advisor, Dr. Sandra Abell at (573) 884-9033 or AbellS@missouri.edu. If you have any questions, you may reach me at (573) 529-1869 or ad3h6@mizzou.edu. Thank you for considering my request.

Sincerely,

Abdulkadir Demir
Appendix E: Syllabuses of A-STEP Science Methods Courses

Title: Teaching, Learning and Research in Middle and Secondary School Science I
Course Number: C&I 8717

Credit Hours: 3 hours
Professor: Dr. Mark J. Volkmann
Office: 321D Townsend
Office Hrs: M & W 1-3 or by appt.
Students: Required Post Bac Middle and Sec Majors
Ph: (573) 884-9738
Time: M-F 8:00 a.m. – 12:00 p.m. (Summer)
E-mail: volkmannmj@missouri.edu

Prerequisite: Admittance to Post-Baccalaureate Program in Middle and/or Secondary Education.

Course Description: Emphasizes the philosophy and nature of science, students' preconceptions and classroom interactions for successful science teaching in the middle and secondary school. Includes learning about the science teaching standards, students' conceptions of science, and the influence of students' conceptions of science on science learning.

Purpose: This course is the first in a 4-course sequence of subject-specific teaching and learning courses in the post-baccalaureate science teacher certification program. It reflects the TDP Conceptual Framework Design Principles: 1) it is organized around problems of science teaching practice, 2) it provides opportunities for reflection on science teaching and learning, and 3) it includes authentic performance evaluations related to specific standards for your development as a science teacher (see below).

As part of the science teaching sequence, this course is built around 4 goal areas (the nature of science, the nature of science learning, the nature of science teaching, and developing your teaching philosophy). However, the emphasis in this first course is placed on learning about the nature of science, the nature of scientific inquiry and classroom inquiry, students' conceptions and explanations about a variety of scientific phenomenon.

Course Outcomes: If you have participated in this course in a complete and competent manner, your understanding of middle and high school science education will expand in the following ways. You will develop an understanding of:

1. The Nature of Science. Future science teachers will develop a deeper understanding of the nature of science; the meaning of theory, principle, and law; the tentativeness of scientific knowledge; the role of "truth" in science; and the nature of inquiry. (Mo-Step Indicator #1)
2. The Nature of Science - Scientific Inquiry. Future science teachers will gain experience and develop a deeper understanding of how scientists investigate natural phenomenon through inquiry. (Mo-Step Indicator #1)
3. The Nature of Science Learning - Students' Conceptions of Science. Future science teachers will gain experience and develop a deeper understanding of students' conceptions and explanations about a variety of scientific phenomenon. (Mo-Step Indicator #2)
4. The Nature of Science Teaching - Classroom Inquiry. Future science teachers will reflect on how science teachers model and support school science inquiry. (Mo-Step Indicator #2)
5. The Nature of Science Teaching - Conceptual Change Instructional Models. Future science teachers will become aware of instructional models that focus on conceptual change. (Mo-Step Indicator #2)
6. The Nature of Science Teaching - Science Teaching Technology. Students will learn how to use web-based technology to record data and communicate information. (Mo-Step Indicator #11)
7. **The Nature of Science Teaching - Equity.** Students will become aware of equity issues in science teaching and ways to address them. (Mo-Step Indicator #3)

8. **Philosophy of Science Teaching.** Future science teachers will articulate their emerging philosophy of science teaching and learning and publish it on the internet. (Mo-Step Indicator #9 & #11)

**Required Texts and Materials**

The following research articles compose a packet of readings aimed at helping students connect the practice of teaching science to the practice of researching science education.


The following books are purchased by students or are available on-line at no charge. These books address the following themes of the course:


**On-line Readings:** (These readings are used throughout the sequence of graduate science methods courses.)

- Classroom Assessment and the National Science Education Standards. Available: [http://www.nap.edu/books/030906998X/html/](http://www.nap.edu/books/030906998X/html/)
Course Policies

Discussion and Participation: Class sessions are intended to be interactive. Therefore, your contributions to discussion are considered important and desirable. You are expected to come to class prepared to raise questions from the readings and to report on assignments for the course. During the course, you may be given additional assignments to enrich class discussion.

Attendance: Class time is used for the purpose of discussing issues and performing activities. Missed class time results in missed learning. For this reason, 5% will be deducted from your final grade for each absence.

Academic Honesty: Academic honesty is fundamental to the activities and principles of a university. All members of the academic community must be confident that each person’s work has been responsibly and honorably acquired, development, and presented. Any effort to gain an advantage not given to all students is dishonest whether or not the effort if successful. The academic community regards academic dishonesty as an extremely serious matter, with serious consequences that range from probation to expulsion. When in doubt about plagiarism, paraphrasing, quoting, or collaboration, consult the course instructor.

ADA Statement: If you need accommodations because of a disability, if you have emergency medical information to share with me, or if you need special arrangements in case the building must be evacuated, please inform me. To request academic accommodations (for example, a notetaker), students must also register with Disability Services, AO38 Brady Commons, 882-4696. It is the campus office responsible for reviewing documentation provided by students requesting academic accommodations, and for accommodations planning in cooperation with students and instructors. Please see me privately after class, or at my office (321D Townsend Hall). If you need accommodations because of a disability, if you have emergency medical information to share with me, or needed and consistent with course requirements. Another resource, MU's Adaptive Computing Technology Center, 884-2828, is available to provide computing assistance to students with disabilities. For more information about the rights of people with disabilities, please see http://ada.missouri.edu/ or call 884-7278.

Projects, Assignments, and Grading Procedures

Projects: There are four projects and these projects drive the daily work. Therefore, a description of the sequence of the projects provides an overview of the class. Each project is described in detail and a linked grading rubric is available for each at this web site: http://www.missouri.edu/~mjvz63/T410/Projects.html.

1. The Inquiry Project: Students take part in an inquiry activity as they investigate the phases of the moon. Students record their moon observations in a journal, share observations with other students, develop questions to investigate, and develop explanations that are based on class findings.

2. The Preconceptions Project: Students design a pre-instructional analysis tool for high school students to complete that will define their current understanding of a science concept. Students share analyses and work with others to develop a power point presentation to share in class.

3. The Assessment of Preconceptions Lesson Plan: Students develop a discrepant event demonstration as a diagnostic assessment of student understanding about a science concept and present it during class or to another university classroom.

4. The Web-Philosophy Project: Students write, and re-write their beliefs about science, learning, and teaching. These beliefs are compared to course readings and activities. By the
end of the semester, you will develop a concise on-line philosophy statement that is informed by current research.

The final grade will be based on your point total (accumulated from the course activities and projects) as compared to this distribution of points on the following:

<table>
<thead>
<tr>
<th>Assignment or Project</th>
<th>% of Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class activities, attendance, and reading reactions</td>
<td>25%</td>
</tr>
<tr>
<td>The Inquiry Project</td>
<td>20%</td>
</tr>
<tr>
<td>The Preconceptions Project</td>
<td>30%</td>
</tr>
<tr>
<td>The Assessment of Preconceptions Lesson Plan</td>
<td>10%</td>
</tr>
<tr>
<td>The Web-Philosophy Project</td>
<td>15%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
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</tbody>
</table>

**Grading Criteria**: Letter grades will be awarded in 10% increments. For example, an ‘A’ will be awarded to students earning 90% of the points, a ‘B’ to students earning 80% of the points, etc. The project expectations are described in detail in each project assignment. The grading criteria (see below) describe the basis for distinguishing between different levels of student performance. I used these criteria and student input to design rubrics for each course project. All project descriptions and rubrics are available on-line.

<table>
<thead>
<tr>
<th>Letter Grade</th>
<th>Description</th>
<th>% Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>An “A” project will be excellent in content, organization, development, and style. All project components are addressed in clear and concise language with few if any mistakes in diction, grammar, spelling or punctuation. An “A” project contains a statement of purpose or a sharply defined thesis statement that answers the question implicit in the assignment. The project content provides evidence that supports all aspects of the thesis. The organization is logical and easily followed; paragraphs are developed with pertinent examples and/or citations. Thinking is well organized, insightful, and easily understood.</td>
<td>90 % or higher</td>
</tr>
<tr>
<td>B</td>
<td>A “B” project will be very good in content, organization, development and style. All project components are addressed in clear and concise language with few if any mistakes in diction, grammar, spelling or punctuation. A “B” project contains a statement of purpose or a thesis statement that answers the question implicit in the assignment. The project content provides some evidence that supports the thesis. The organization is logical and easily followed; paragraphs are developed with pertinent examples and/or citations. The student’s thinking is organized, but parts may be unclear.</td>
<td>80 % or higher</td>
</tr>
<tr>
<td>C</td>
<td>A “C” project will be adequate in content, organization, development and style. All project components are addressed, superficially. There are some mistakes in diction, grammar, spelling or punctuation. A “C” project answers the question implicit in the assignment. Evidence is provided that superficially supports the answers. The organization is logical but difficult to follow, paragraphs may be disconnected (missing transitions). Pertinent examples and/or citations are provided. Student thinking may be unclear.</td>
<td>70 % or higher</td>
</tr>
<tr>
<td>D</td>
<td>A “D” project will be inadequate in content, organization, development and style. Some project components are not addressed. There are several mistakes in diction, grammar, spelling or punctuation. A “D” project fails to answer the question implicit in the assignment. Little evidence is provided that supports the answers.</td>
<td>60 % or higher</td>
</tr>
</tbody>
</table>
The organization is illogical and difficult to follow--paragraphs are disconnected. Pertinent examples and/or citations are missing. Student thinking is unclear.

F

An “F” project will be unacceptable in content, organization, development and style. Many of the project components are not addressed. There are multiple mistakes in diction, grammar, spelling or punctuation. An “F” project fails to answer the question implicit in the assignment. Very little or no evidence is provided that supports the answers. The organization is illogical and difficult to follow--paragraphs are disconnected. Pertinent examples and/or citations are missing. Student thinking is unclear.

Below 60

Course Schedule – Topics and Readings

This course is offered in an alternative format – 4.5 hours per day over a period of 10 consecutive days in summer session II. Students begin two activities before classes begin: observations of the moon and reading T. Rex and the Crater of Doom.

<table>
<thead>
<tr>
<th>Class</th>
<th>Topic and Activity</th>
<th>Readings</th>
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<tbody>
<tr>
<td></td>
<td>Card Sort Activity on the Nature of Science</td>
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<tr>
<td></td>
<td>Discuss moon observations and begin the inquiry of the moon.</td>
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<tr>
<td></td>
<td>Discuss chapters 2 &amp; 3 of T. Rex and the Crater of Doom to develop a shared understanding of the nature of science and scientific inquiry.</td>
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<td></td>
<td>Discuss students’ conceptions of science.</td>
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<td></td>
<td>Discuss chapter 4 &amp; 5 of T. Rex and the Crater of Doom to develop a shared understanding of science and scientific work.</td>
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<td></td>
<td>Focus on the ideas students bring to the classroom about the earth, sun, and moon.</td>
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<td></td>
<td>Investigate student ideas about living and nonliving, nutrition, and photosynthesis.</td>
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<td></td>
<td>Develop interviews of students’ ideas in science.</td>
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<td></td>
<td>Examine the National Science Education Standards</td>
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<td></td>
<td>Prepare interview to investigate students pre-conceptions in science.</td>
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<tr>
<td></td>
<td>• Investigate ways that teachers can elicit students’ misconceptions.</td>
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<tr>
<td></td>
<td>• View video of ways to teach photosynthesis</td>
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<tr>
<td></td>
<td>• Develop a consensus about scientific and classroom inquiry.</td>
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<tr>
<td></td>
<td>• Discuss students ideas about photosynthesis.</td>
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<td></td>
<td>• Analyze the moon study for inquiry and for the 5E instructional model.</td>
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<tr>
<td></td>
<td>• Investigate the variety of meanings of “science for all”.</td>
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<tr>
<td><strong>10</strong></td>
<td>• Design a web page philosophy</td>
<td></td>
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<tr>
<td></td>
<td>• Learn about professional organizations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Complete a course evaluation.</td>
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</tbody>
</table>
Title: Teaching, Learning and Research in Middle and Secondary School Science II  
Course Number: C&I 8718  
Credit Hours: 3 hours  
Professor: Dr. Mark J. Volkmann  
Office: 321D Townsend  
Office Hrs: M & W 1-3 or by appt.  
Students: Required Post Bac Middle and Sec Majors  
Ph: (573) 884-9738  
Time: Saturdays 9:00 – 4:00 (Fall)  
E-mail: volkmannmj@missouri.edu  
Prerequisite: Admittance to Post-Baccalaureate Program in Middle and/or Secondary Education and C&I 8717.

Course Description: Emphasizes instructional strategies and classroom interactions for successful science teaching in the middle and secondary school. Includes analysis of curriculum resources and management methods for the science classroom.

Course Outcomes: This course is the second in a 4-course sequence of subject-specific teaching and learning courses in the post-baccalaureate science teacher certification program, and part of Phase II of the Teacher Development Program (TDP). It reflects the TDP Conceptual Framework Design Principles: 1) it is organized around problems of science teaching practice, 2) it provides opportunities for reflection on science teaching and learning, and 3) it includes authentic performance evaluations related to specific standards for your development as a science teacher (see below).

As part of the science teaching sequence, this course is built around 4 goal areas (the nature of science, the nature of science learning, the nature of science teaching, and developing your teaching philosophy). However, the emphasis in this second course is placed on developing instructional strategies and evaluating curriculum materials consistent with how students learn science, what the standards say, and what we know about best practice and inquiry-based instruction.

Expected Learning Outcomes: By the end of the course, you will have achieved the following outcomes within four broad goal areas, linked to the Missouri Standards for Teacher Education Programs (MoSTEP, see http://dese.mo.gov/divteachqual/teached/standards.htm):  
1. What is science? (MoSTEP 1.2.1, 1.2.10)  
   • Continue to build your understanding of the nature of science and scientific inquiry through participating in an investigation of a local problem that involves science and society.  
2. How do learners learn science? (MoSTEP 1.2.2, 1.2.3)  
   • Consider the implications of how people learn (e.g., prior knowledge, transfer, expert/novice knowledge, metacognition, motivation) on science teaching.  
3. How do teachers teach science? (MoSTEP 1.2.4, 1.2.5, 1.2.6, 1.2.7, 1.2.8)  
   • Build a repertoire of science teaching and assessment strategies effective within the 5E model that reflect an inquiry-based approach.  
   • Learn effective strategies for classroom interaction and classroom management in whole-class and small group settings.  
   • Analyze science curriculum using a curriculum analysis tool.  
4. Philosophy (MoSTEP 1.2.9, 1.2.11)  
   • Continue to reflect upon and refine your personal philosophy of science teaching and learning in a web-based format.

Required Texts and Materials  
Reading Packet: A packet of articles from science teaching journals such as The Science Teacher and Science Scope.
Required Books:
- *NSTA Pathways to the National Science Education Standards* (Middle school or high school version)
- *Who Really Killed Cock Robin*, Jean Craighead George

On-line Readings: (These readings are used throughout the sequence of graduate science methods courses.)
- Classroom Assessment and the National Science Education Standards. Available: [http://www.nap.edu/books/030906998X/html/](http://www.nap.edu/books/030906998X/html/)

Course Policies

**Discussion and Participation:** Class sessions are intended to be interactive. Therefore, your contributions to discussion are considered important and desirable. You are expected to come to class prepared to raise questions from the readings and to report on assignments for the course. During the course, you may be given additional assignments to enrich class discussion.

**Attendance:** Because this course is highly interactive, your attendance at the 5 campus-based Saturday sessions is required. Missing one Saturday session would be the equivalent of missing 1/5 of a regular campus-based course, or about 2 weeks of instruction. Although each case will be considered on an individual basis, the general policy will be to lower a student’s grade by one letter for each on-campus session missed.

**Academic Honesty:** Academic honesty is fundamental to the activities and principles of a university. All members of the academic community must be confident that each person’s work has been responsibly and honorably acquired, development, and presented. Any effort to gain an advantage not given to all students is dishonest whether or not the effort if successful. The academic community regards academic dishonesty as an extremely serious matter, with serious consequences that range from probation to expulsion. When in doubt about plagiarism, paraphrasing, quoting, or collaboration, consult the course instructor.

**ADA Statement:** If you need accommodations because of a disability, if you have emergency medical information to share with me, or if you need special arrangements in case the building must be evacuated, please inform me. To request academic accommodations (for example, a notetaker), students must also register with Disability Services, AO38 Brady Commons, 882-4696. It is the campus office responsible for reviewing documentation provided by students requesting academic accommodations, and for accommodations planning in cooperation with students and instructors. Please see me privately after class, or at my office (321D Townsend Hall). If you need accommodations because of a disability, if you have emergency medical information to share with me, or needed and consistent with course requirements. Another resource, MU's Adaptive Computing Technology Center, 884-2828, is available to provide computing assistance to students with disabilities. For more information about the rights of people with disabilities, please see [http://ada.missouri.edu/](http://ada.missouri.edu/) or call 884-7278.

**Projects, Assignments, and Grading Procedures**
Projects: There are four projects and these projects drive the daily work. Therefore, a description of the sequence of the projects provides an overview of the class. Detailed descriptions of these projects are provided through the on-line course syllabus. Each project is described in detail and a linked grading rubric is available for each at this web site: http://www.missouri.edu/~mjvz63/8900/Projects.html.

1. Class Participation—Virtual and On-Campus: This class will be highly interactive and will require your active and thoughtful participation in activities and discussions.
   A. Participation in on-line discussions
   B. Participation in on-line collaborative inquiry project
   C. Attendance and participation in campus-based classes

2. Streams Project. You will investigate a local stream and think about strategies for integrating local resources and social issues into your science teaching. You will write the “Explain” and “Elaborate” lessons for the unit we began in class with “Engage” and “Explore.”

3. Teaching Strategies Assignments. This project will help you become familiar with a science teaching strategies to use throughout the 5E model. You will create a lesson plan for each of the following:
   a. Discrepant event demonstration
   b. Laboratory conversion (cookbook to inquiry)
   c. Interactive Lecture PowerPoint

4. Curriculum Analysis Project. This project will help you to synthesize your ideas about best practice in science teaching and learning through the evaluation of science curriculum materials. You will write an instructional materials analysis and evaluation, as well as make suggestions for improving the materials.

5. Teaching Philosophy Statement: For your final portfolio, and as you begin the job search process, you will be asked to formulate a philosophy statement. This assignment will ask you to reevaluate and refine the philosophy statement you developed in your first science methods course, and add web-based evidence statements.

<table>
<thead>
<tr>
<th>Assignments</th>
<th>Due Date</th>
<th>% of Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class Participation—Virtual and On-Campus</td>
<td>Throughout</td>
<td>20%</td>
</tr>
<tr>
<td>Streams Project</td>
<td>Class 2</td>
<td>15%</td>
</tr>
<tr>
<td>Teaching Strategies Assignments (3)</td>
<td>Class 3 and Class 4</td>
<td>30% (10% each)</td>
</tr>
<tr>
<td>Curriculum Analysis Project</td>
<td>Class 5</td>
<td>25%</td>
</tr>
<tr>
<td>Teaching Philosophy Statement</td>
<td>Finals Week</td>
<td>10%</td>
</tr>
</tbody>
</table>

Grading Criteria

Letter grades will be awarded in 10% increments. For example, an 'A' will be awarded to students earning 90% of the points, a 'B' to students earning 80% of the points, etc. The project expectations are described in detail in each project assignment. The grading criteria (see below) describe the basis for distinguishing between different levels of student performance. I used these criteria and student input to design rubrics for each course project. All project descriptions and rubrics are available on-line.

<table>
<thead>
<tr>
<th>Letter Grade</th>
<th>Description</th>
<th>% Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>An “A” project will be excellent in content, organization, development, and style. All project components are addressed in clear and concise language with few if any mistakes in diction, grammar, spelling or punctuation. An “A” project contains a statement of purpose or a sharply defined thesis statement that answers the question implicit in the assignment. The project content provides evidence that supports all aspects of the thesis. The organization is logical and easily followed; paragraphs are developed with pertinent examples and/or citations. Thinking is well organized, insightful, and easily understood.</td>
<td>90 % or higher</td>
</tr>
<tr>
<td>B</td>
<td>A “B” project will be very good in content, organization, development and style.</td>
<td>80 % or higher</td>
</tr>
<tr>
<td>Grade</td>
<td>Description</td>
<td>Minimum Score</td>
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<tr>
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</tr>
<tr>
<td>A</td>
<td>All project components are addressed in clear and concise language with few if any mistakes in diction, grammar, spelling or punctuation. A “B” project contains a statement of purpose or a thesis statement that answers the question implicit in the assignment. The project content provides some evidence that supports the thesis. The organization is logical and easily followed; paragraphs are developed with pertinent examples and/or citations. The student’s thinking is organized, but parts may be unclear.</td>
<td>higher</td>
</tr>
<tr>
<td>C</td>
<td>A “C” project will be adequate in content, organization, development and style. All project components are addressed, superficially. There are some mistakes in diction, grammar, spelling or punctuation. A “C” project answers the question implicit in the assignment. Evidence is provided that superficially supports the answers. The organization is logical but difficult to follow, paragraphs may be disconnected (missing transitions). Pertinent examples and/or citations are provided. Student thinking may be unclear.</td>
<td>70 % or higher</td>
</tr>
<tr>
<td>D</td>
<td>A “D” project will be inadequate in content, organization, development and style. Some project components are not addressed. There are several mistakes in diction, grammar, spelling or punctuation. A “D” project fails to answer the question implicit in the assignment. Little evidence is provided that supports the answers. The organization is illogical and difficult to follow--paragraphs are disconnected. Pertinent examples and/or citations are missing. Student thinking is unclear.</td>
<td>60 % or higher</td>
</tr>
<tr>
<td>F</td>
<td>An “F” project will be unacceptable in content, organization, development and style. Many of the project components are not addressed. There are multiple mistakes in diction, grammar, spelling or punctuation. An “F” project fails to answer the question implicit in the assignment. Very little or no evidence is provided that supports the answers. The organization is illogical and difficult to follow--paragraphs are disconnected. Pertinent examples and/or citations are missing. Student thinking is unclear.</td>
<td>Below 60</td>
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</table>

**Course Schedule – Topics and Readings**

This course is offered in an alternative format. The 45 contact hours are divided into 30 hours during 5 Saturday meetings and an additional 15 hours of on-line instructional time.
Calendar of Readings

<table>
<thead>
<tr>
<th>Class</th>
<th>Topic</th>
<th>Readings</th>
</tr>
</thead>
</table>
| 1     | Course introduction  
Write your current philosophy  
Investigate the Flat Branch stream, using it as an example of problem-based learning that is modeled in terms of the 5E’s. | How People Learn, Chapters 1-3 (online)  
Who Really Killed Cock Robin |
| 2     | Inquiry Revisited – 5E  
Teaching and Assessment Strategies for “Engage” and “Explore”  
- Standards  
- Discrepant Events  
- Inquiry-based laboratories | Reading packet  
Pathways  
Streams Project due |
| 3     | Teaching and Assessment Strategies for “Explain” and “Elaborate”  
- Discussions  
- Interactive lecture  
- Cases  
- Cooperative learning | Reading packet  
Pathways  
Discrepant Event Demonstration due  
Laboratory Conversion due |
| 4     | Adapting instruction for learners with special needs and talents  
Curriculum Analysis, Selection, and Adaptation | Reading packet;  
Guiding Curriculum Decisions;  
Selecting Instructional Materials (online)  
Lecture PowerPoint due |
| 5     | Teaching and Assessment Strategies for “Evaluate”  
Reading, writing, and speaking in science  
Safety in the science class  
Your current teaching philosophy | Reading packet  
Pathways  
Curriculum Analysis Project is due.  
Web-based philosophy (due finals week) |

<table>
<thead>
<tr>
<th>Topic</th>
<th>Secondary Reading</th>
<th>Middle Level Reading</th>
</tr>
</thead>
</table>
| A. Science and Real World Issues Critiques and Evidence PBL | EDThoughts: pp. 62-63; 76-77  
TST, May 2002: Trimarchi  
TST, April 2001: Scott et al.  
PBL: TST, Jan 2002: Uyeda et al. | EDThoughts: pp. 62-63; 76-77  
SS, Feb 2001: Koenig  
SS, Feb 2002: Davis & Kirkpatrick  
PBL: SS, March 1999, Burruss |
| B. Inquiry | EDThoughts, pp. 13-17  
Bybee, 2002  
TST, Feb 2002, Martin-Hansen | EDThoughts, pp. 13-17  
Bybee, 2002  
SS, March 2000, Colburn |
| C. Misconceptions and Conceptual Change | EDThoughts, pp. 84-85  
TST, Nov. 2002: Talanquer | EDThoughts, pp. 84-85  
SS, Nov/Dec 1999: Mascazine & McCann |
| D. Teaching Strategies  
1. Lecture  
2. Lab  
3. Cooperative learning (CL) | EDThoughts, pp. 18-23  
1. Lecture: TST, Jan 2002: Trimarchi  
2. Labs: TST, Feb 2003: Chin  
3. CL: TST, April 2003: Pratt | EDThoughts, pp. 18-23  
1. Lecture: TST, Jan 2002: Trimarchi  
2. Labs: SS, May 2003: Flick  
3. CL: TST, April, 2003: Pratt |
### E. Issues of Diversity and Science Learning

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<tr>
<th></th>
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<th></th>
<th>EDThoughts, pp. 2-3, 8-9, 86-87</th>
<th>EDThoughts, pp. 8-9, 86-87</th>
</tr>
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</table>

### F. Curriculum Mapping

<table>
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<tr>
<th></th>
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<th>EDThoughts: pp. 45-51, 54-55</th>
<th>EDThoughts: pp. 45-51, 54-55</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SS, April 2002: deClark</td>
<td>SS, April 2002: deClark</td>
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<tr>
<td></td>
<td></td>
<td>Book: <em>Guiding Curriculum Decisions</em></td>
<td>Book: <em>Guiding Curriculum Decisions</em></td>
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<td></td>
<td>Online: <em>Selecting Instructional Materials</em></td>
<td>Online: <em>Selecting Instructional Materials</em></td>
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### G. Reading, Writing, and Science

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<tr>
<th></th>
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<th>EDThoughts, pp. 52-53</th>
<th>EDThoughts, pp. 52-53</th>
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### H. Advice to Beginning Science Teachers

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<tr>
<td>TST, Sept 2002: Snyder &amp; Stroot</td>
<td>SS, March 2000: Goodnough</td>
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### I. Safety

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<tr>
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<th>EDThoughts, pp. 24-25</th>
<th>EDThoughts, pp. 24-25</th>
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<tbody>
<tr>
<td>TST, April 2001: Gerlovich et al.</td>
<td>TST, April 2001: Gerlovich et al.</td>
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</tbody>
</table>
Title: Teaching, Learning and Research in Middle and Secondary School Science III
Course Number: C&I 8719

Credit Hours: 3 credits
Professor: Dr. Mark J. Volkmann
Office: 321D Townsend
Office Hrs: M & W 1-3 or by appt.
Students: Required Post Bac Middle and Sec Majors
Ph: (573) 884-9738
Time: Saturdays 9:00 – 4:00 (Winter term)
E-mail: volkmannmj@missouri.edu
Prerequisite: Admittance to Post-Baccalaureate Program in Middle and/or Secondary Education and C&I 8717 and C&I 8718

Course Description: Emphasizes technology-based science instruction, inquiry-based curriculum development, formative and summative assessment, web-based philosophy for successful science teaching in the middle and secondary school. Includes analysis of curriculum resources and management methods for the science classroom.

Course Outcomes: This course is the third in a 4-course sequence of subject-specific teaching and learning courses in the post-baccalaureate science teacher certification program, and part of Phase II of the Teacher Development Program (TDP). It reflects the TDP Conceptual Framework Design Principles: 1) it is organized around problems of science teaching practice, 2) it provides opportunities for reflection on science teaching and learning, and 3) it includes authentic performance evaluations related to specific standards for your development as a science teacher (see below).

As part of the science teaching sequence, this course is built around 4 goal areas (the nature of science, the nature of science learning, the nature of science teaching, and developing your teaching philosophy). However, the emphasis in this third course is placed on developing expertise with inquiry-based, technology-assisted instruction, short and long term lesson planning, formative and summative assessment, and what we know about best practice and inquiry-based instruction.

Expected Learning Outcomes: By the end of the course, you will have achieved the following outcomes within four broad goal areas, linked to the Missouri Standards for Teacher Education Programs (MoSTEP, see [http://dese.mo.gov/divteachqual/teached/standards.htm](http://dese.mo.gov/divteachqual/teached/standards.htm)):

1. **What is science?** Enhance your understanding of the nature of science and scientific inquiry by engaging, as a learner, in a technology-enhanced science inquiry project and by adapting existing curriculum to inquiry. (Mo-Step Indicator #1, #8, #11)

2. **How do learners learn science?** Consider the implications of how people learn (e.g., prior knowledge, transfer, expert/novice knowledge, metacognition, motivation) on science teaching. Design an inquiry-based curriculum unit using a constructivist learning theory (the 5E instructional model)(Mo-Step Indicator #2).

3. **How do teachers teach science?** Explore and evaluate a variety of teaching strategies and resource material, including technology tools, for supporting science learning. In addition, you will become familiar with procedures for maintaining a safe classroom environment (Mo-Step Indicator #1, #2, 5, 6, 9, 11). Design an inquiry-based curriculum unit using a constructivist learning theory (the 5E instructional model), the Missouri Science Frameworks/Grade Level Expectations, and National Science Inquiry Standards (Mo-Step Indicator #1, 2, 4, 5, 6, 8, 9). Design pre-instructional assessments, as well as formative and summative assessments (Mo-Step Indicator #8).

4. **What is your philosophy of science education?** Articulate your beliefs about the nature of science, science learning and teaching through an evidence-based philosophy paper (Mo-Step Indicator #7, 9).
Required Texts and Materials

Required Texts:
- *NSTA Pathways to the National Science Education Standards* (Middle school or high school version)

On-line Readings: (These readings are used throughout the sequence of graduate science methods courses.)
- Classroom Assessment and the National Science Education Standards. Available: [http://www.nap.edu/books/030906998X/html/](http://www.nap.edu/books/030906998X/html/)

Course Policies

Discussion and Participation: Class sessions are intended to be interactive. Therefore, your contributions to discussion are considered important and desirable. You are expected to come to class prepared to raise questions from the readings and to report on assignments for the course. During the course, you may be given additional assignments to enrich class discussion.

Attendance: Because this course is highly interactive, your attendance at the 5 campus-based Saturday sessions is required. Missing one Saturday session would be the equivalent of missing 1/5 of a regular campus-based course, or about 2 weeks of instruction. Although each case will be considered on an individual basis, the general policy will be to lower a student’s grade by one letter for each on-campus session missed.

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emergency medical information to share with me, or needed and consistent with course requirements. Another resource, MU's Adaptive Computing Technology Center, 884-2828, is available to provide computing assistance to students with disabilities. For more information about the rights of people with disabilities, please see http://ada.missouri.edu/ or call 884-7278.

Projects, Assignments, and Grading Procedures

Projects: There are four projects and these projects are interconnected with the activities done within the class meetings. Detailed descriptions of these projects are provided through the on-line course syllabus. Each project is described in detail and a linked grading rubric is available for each at this web site:

1. Science As Inquiry: Finch Project - The purpose of this project is to engage, as a science learner, in an extended 5-E mini-unit, as a model for your curriculum unit and assessment project.

2. Resource File – The purpose of this project is twofold: 1) to become familiar with a variety of teaching resources; and 2) to build a collection of teaching resources for a specific science topic. This project is sequenced prior to the curriculum unit, with the intent that you will design your curriculum unit from your resource file.

3. Curriculum Unit with Assessments - The purpose of this project is to learn how to develop a Unit Plan. You will do this by designing a series of lessons and assessments about a topic of your choice in terms of the 5E instructional model. You will teach this unit in your internship.

4. Teaching Philosophy Statement - The purpose for writing a statement of your teaching philosophy is to help you develop a solid foundation for future decisions about what is science, how students learn, and how one should teach science. This assignment asks you to reevaluate and refine the philosophy statement you developed in your first science methods course, and add web-based evidence statements.

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Due Date</th>
<th>% of Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class Participation, Professional Involvement,</td>
<td>Throughout</td>
<td>20%</td>
</tr>
<tr>
<td>Peer Teaching &amp; Minor Assignments, and on-line</td>
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<tr>
<td>discussion. There will be a sign-up sheet for</td>
<td></td>
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<tr>
<td>peer teaching dates.</td>
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<td></td>
</tr>
<tr>
<td>Science As Inquiry: Finch Project</td>
<td>Class 2</td>
<td>10%</td>
</tr>
<tr>
<td>Resource File</td>
<td>Class 3</td>
<td>15%</td>
</tr>
<tr>
<td>Curriculum Unit with Assessments</td>
<td>Class 4</td>
<td>25%</td>
</tr>
<tr>
<td>Assessments Portfolio</td>
<td>Class 5</td>
<td>20%</td>
</tr>
<tr>
<td>Teaching Philosophy Statement</td>
<td>Finals Week</td>
<td>10%</td>
</tr>
</tbody>
</table>

Grading Criteria

Letter grades will be awarded in 10% increments. For example, an 'A' will be awarded to students earning 90% of the points, a 'B' to students earning 80% of the points, etc. The project expectations are described in detail in each project assignment. The grading criteria (see below) describe the basis for distinguishing between different levels of student performance. I used these criteria and student input to design rubrics for each course project. All project descriptions and rubrics are available on-line.

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<th>% Equivalent</th>
</tr>
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<tbody>
<tr>
<td>A</td>
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<td>90 % or higher</td>
</tr>
</tbody>
</table>
followed; paragraphs are developed with pertinent examples and/or citations. Thinking is well organized, insightful, and easily understood.

B
A “B” project will be very good in content, organization, development and style. All project components are addressed in clear and concise language with few if any mistakes in diction, grammar, spelling or punctuation. A “B” project contains a statement of purpose or a thesis statement that answers the question implicit in the assignment. The project content provides some evidence that supports the thesis. The organization is logical and easily followed; paragraphs are developed with pertinent examples and/or citations. The student’s thinking is organized, but parts may be unclear.

80 % or higher

C
A “C” project will be adequate in content, organization, development and style. All project components are addressed, superficially. There are some mistakes in diction, grammar, spelling or punctuation. A “C” project answers the question implicit in the assignment. Evidence is provided that superficially supports the answers. The organization is logical but difficult to follow, paragraphs may be disconnected (missing transitions). Pertinent examples and/or citations are provided. Student thinking may be unclear.

70 % or higher

D
A “D” project will be inadequate in content, organization, development and style. Some project components are not addressed. There are several mistakes in diction, grammar, spelling or punctuation. A “D” project fails to answer the question implicit in the assignment. Little evidence is provided that supports the answers. The organization is illogical and difficult to follow--paragraphs are disconnected. Pertinent examples and/or citations are missing. Student thinking is unclear.

60 % or higher

F
An “F” project will be unacceptable in content, organization, development and style. Many of the project components are not addressed. There are multiple mistakes in diction, grammar, spelling or punctuation. An “F” project fails to answer the question implicit in the assignment. Very little or no evidence is provided that supports the answers. The organization is illogical and difficult to follow--paragraphs are disconnected. Pertinent examples and/or citations are missing. Student thinking is unclear.

Below 60

Course Schedule – Topics and Readings
This course is offered in an alternative format. The 45 contact hours are divided into 30 hours during 5 Saturday meetings and an additional 15 hours of on-line instructional time. Students will read The Beak of the Finch before the beginning of class in the winter term.

<table>
<thead>
<tr>
<th>Class</th>
<th>Topic and Activity</th>
<th>Readings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
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<td></td>
</tr>
<tr>
<td>line resources, and assessment.</td>
<td><a href="http://www.nap.edu/books/030906998X/html/">http://www.nap.edu/books/030906998X/html/</a></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Micro teaching demonstrations of assessment practices. Assessment Portfolio due Web-based Philosophy is due during finals week</td>
<td></td>
</tr>
</tbody>
</table>
Integrating Instruction in Science and Mathematics  
C&I 8893 – Summer 2006

**Course Description:** This course is designed to help future middle and secondary mathematics and science teachers enhance grade 5-12 student understanding of the connectedness of mathematics and science, thereby deepening student understanding. In this course, future teachers will gather and analyze data through scientific investigations, exploring the assumptions, advantages, and disadvantages of various mathematical models. The purpose of this course is to learn ways to coordinate science and mathematics instruction.

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volkmannmj@missouri.edu             lanninj@missouri.edu
Office hours: by appointment

**PURPOSE, GOALS, AND DISPOSITIONS ~ C&I 8893**

This course is the final in a 4-course sequence of subject-specific teaching and learning courses in the post-baccalaureate mathematics and science teacher certification program, and part of Phase II of the Teacher Development Program (TDP). It reflects the TDP Conceptual Framework Design Principles: 1) it is organized around problems of science and mathematics teaching practice, 2) it provides opportunities for reflection on science and mathematics teaching and learning, and 3) it includes authentic performance evaluations related to specific standards for your development as a mathematics or a science teacher.

**Course Goals C&I 8893**

By the end of the course, you will have achieved the following goals, linked to the Missouri Standards for Teacher Education Programs for future (grade 5-12) science and mathematics teachers (MoSTEP):

1. **Nature of mathematics and science:** develop a deeper understanding and reflect on the similarities and differences associated with the nature of mathematics and the nature of science. (MO-Step Indicators: 1.2.1, 1.2.9)
2. **Models:** construct and revise mathematical models to answer questions about phenomena and develop a deeper understanding of the power and assumptions of mathematical models used in scientific investigations and apply this knowledge to instructional situations. (MO-Step Indicators: 1.2.1, 1.2.2, 1.2.4, 1.2.5, 1.2.8)
3. **Predictions:** use knowledge to identify and explain observations, or changes, in advance, (make predictions), examine the certainty of predictions, and apply this knowledge to instructional situations (MO-Step Indicators: 1.2.1, 1.2.9)
4. **Interdisciplinary Connections:** develop an understanding of the connections among mathematics and science standards, concepts, curricula, and corresponding topics/skills. (MO-Step Indicators: 1.2.1, 1.2.4, 1.2.9)
5. **Real World Connections:** use mathematics to analyze evidence and data to explain real world phenomena

**POLICIES AND EXPECTATIONS ~ C&I 8893**

Class Participation: Class sessions are intended to be interactive. Therefore, your contributions to discussion are considered important and desirable. You are expected to come to class prepared to raise questions from the readings and to report on assignments for the course. During the course, you will be
given additional assignments for homework to enrich class discussion. These assignments count as part
of your participation/activity grade and will assist you in the completion of your class projects.

Attendance: Class time is used for the purpose of discussing issues and performing activities. Missed class
time results in missed learning. For this reason, 5% will be deducted from your final grade for each
absence. Pre-arranged absences will be handled on a case-by-case basis.

C&I 8893 – GRADES, CRITERIA, ACADEMIC INTEGRITY, & SPECIAL NEEDS

The final grade will be based on your point total (accumulated from the course activities and projects) as
compared to this distribution of points on the following:

<table>
<thead>
<tr>
<th>Activities and Projects</th>
<th>Points</th>
<th>Due Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class activities, attendance, and reading reaction</td>
<td>10</td>
<td>Everyday</td>
</tr>
<tr>
<td>Reading Reactions</td>
<td>20</td>
<td>Provided in Class</td>
</tr>
<tr>
<td>Project #1</td>
<td>30</td>
<td>June 14</td>
</tr>
<tr>
<td>Project #2</td>
<td>40</td>
<td>June 21</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Letter grades will be awarded in 10% increments. For example, an 'A' will be awarded to students earning
90% of the points, a 'B' to students earning 80% of the points, etc. The project expectations are described
in detail in each project assignment. The grading criteria (see below) describe the basis for distinguishing
between different levels of student performance. These criteria and student input will be used to design
rubrics for each course project. All project descriptions and rubrics are available on-line.

Academic Honesty: Academic honesty is fundamental to the activities and principles of a university. All
members of the academic community must be confident that each person’s work has been responsibly and
honorably acquired, development, and presented. Any effort to gain an advantage not given to all students
is dishonest whether or not the effort if successful. The academic community regards academic dishonesty
as an extremely serious matter, with serious consequences that range from probation to expulsion. When in
doubt about plagiarism, paraphrasing, quoting, or collaboration, consult the course instructor.

Important Notes: (1) Students having disabilities which might affect their work (in or out of class) should
check with us as soon as possible. MU can make a variety of arrangements that help insure equal
opportunity. It is your right and we are glad to work with you on this. (2) Also, keep in touch with MU’s
Office of Disability Services, A038 Brady Commons, 882-4696. For information on resources for students
with disabilities, click on “Disability Resources” on MU’s homepage. (3) If you have emergency medical
information to share with us, or if you need special arrangements in case the building must be evacuated,
please inform us immediately. You may talk with us privately after class, or at our offices—212 Swallow
Hall and 200 Swallow Hall.
## Grading Criteria:

<table>
<thead>
<tr>
<th>Letter Grade</th>
<th>Description</th>
<th>% Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>An “A” student will actively participate in class, providing insightful comments that add to whole-class and small-group discussions in substantive ways. All coursework is completed in a manner that demonstrates a deep understanding of the connections between mathematics and science. Ideas are logically organized in the coursework and clearly communicated using concise language. All work is completed on time.</td>
<td>90 % or higher</td>
</tr>
<tr>
<td>B</td>
<td>A “B” student will actively participate in class, providing comments that add to either whole-class or small-group discussions in substantive ways. All coursework is completed in a manner that demonstrates a generally strong understanding of the connections between mathematics and science. Ideas are generally logically organized in coursework and clearly communicated using concise language. All work is completed on time.</td>
<td>80 % or higher</td>
</tr>
<tr>
<td>C</td>
<td>A “C” student will rarely participate in class, providing comments that add to either whole-class or small-group discussions in substantive ways. Some coursework is completed in a manner that demonstrates an initial understanding of the connections between mathematics and science. Ideas are somewhat organized in the work and generally clearly communicated. Some work is not completed on time.</td>
<td>70 % or higher</td>
</tr>
<tr>
<td>F</td>
<td>An “F” student does not actively participate in class or distracts from the general purpose of class discussions. Most coursework is completed in a manner that demonstrates little understanding of the connections between mathematics and science. Ideas are generally disorganized in coursework. Some or most of the work is not completed on time.</td>
<td>Below 60</td>
</tr>
</tbody>
</table>

### PROJECTS ~ C&I 8893

**Class Participation:** This class is highly interactive and requires your active and thoughtful participation in activities and discussions. Be prepared for each class meeting! Read and complete written work before class.

**Project #1:** The purpose of this project is to explain how mathematics is used to explain a specific natural phenomenon using a mathematical model.

**Project #2:** The purpose of this project is for future science teachers to identify mathematics concepts used to explain science and for future mathematics teachers to identify science concepts used to anchor mathematics and for both to demonstrate appropriate instruction relative to the other’s discipline.

**Project #1: Intersections of Scientific and Mathematical Conceptual Models**

- **Due Date:** June 14, 2006
- **Project Point Value:** 30 pts out of 100 pts

**Overview:** What do science and mathematics contribute to our understanding of the world? Science and mathematics provide thoughtful and elegant explanations of the natural world. These explanations
represent theoretical creations that provide explanations to a wide array of questions. Take for example Einstein’s equation for special relativity.

\[ E = mc^2 \]

This equation represents a theoretical explanation for where the sun's energy comes from. It states that the quantity of energy contained in a particle is the mass of that particle times the speed of light squared. This equation is introduced to grade school students, it appears in middle school science textbooks, but it is not explained until students reach high school physics. This mathematical model provides a simple and elegant answer to the age-old scientific question: What is the source of the sun’s energy? This explanation of the sun's energy is the essence of how science and mathematics work together.

Purpose: The purpose of this project is to explain a specific natural phenomenon using a mathematical model.

Directions: The finished project should explain the phenomenon using a mathematical model. The science and mathematics you use must be at the same conceptual level as the students you plan to teach. The finished product should consist of a written explanation and an oral presentation. The written and the oral explanations should contain the following components:

1. The context – frame your project in terms of a real world phenomenon that involves the use of mathematics to model an explanation. Your selected question must address a science and mathematics GLE for the age level you plan to teach.
2. The early conceptions – give a history of the incorrect explanations for this phenomenon.
3. The assumptions – list and explain the underlying ideas that serve as a basis for the model.
4. The model explanation - explain the mathematical and scientific concepts that are employed to address the question. Include representations that should be used to help students develop understanding. Describe how the model draws upon the assumptions to address this real-world question and how you would help students make sense of the mathematics as you construct the model.

The written portion should be handed in at the time you and your partner give your oral presentation. The length of your written and oral presentations are dependent on the question you select and the depth of your explanation. Some projects may be less than 5 pages long and others may be longer. The quality of the paper is not a function of its length. The quality is dependent on how well you address the components listed above.

Project #2: Intersections of Science and Mathematics in Instructional Materials
Due Date: June 21, 2006
Project Point Value: 40 pts (out of 100 pts)
Overview: As a science or mathematics teacher, you will have the opportunity to teach lessons that includes knowledge from the other's domain. When these common concepts are surrounded by conflicting terminology and inconsistent approaches, students get confused and learning becomes compartmentalized. The purpose of this course is to avoid these circumstances by working together to align goals, strategies, terminology, and increase student success. In this project you will clarify how science teachers and mathematics teachers work together.

Purpose: The purpose of this project is to develop lessons involving overlapping science and mathematics content.

Directions: You will work in cross-disciplinary pairs to identify overlapping content, discuss how the content might be taught, and offer friendly criticism to assist one another in the production of a high quality lesson.

1. Form cross-disciplinary pairs. We will assign pairs to work together.
2. Select a text from the instructional materials provided in the classroom that you would consider using (or you are actually going to use) in your future classroom.
3. Exchange textbooks with your Cross-Discipline Buddy (CDB). Use post-it-notes to flag potential overlapping concepts where your disciplinary knowledge is being taught in the other's text.
4. Return the text to your CDB. Check the flagged points of overlap and select one or two to discuss with your buddy as potential for lesson development.
5. Choose one. Make a photocopy of the textbook materials that are pertinent to the concept and to the lesson you will design.
6. The Lesson Plan. Your plan should address the following (please use these subdivisions as an organizational framework for your written project):
   A. What science and mathematics concepts will you teach? Give a full description of each.
   B. What science and mathematics GLEs will be addressed by this plan?
   C. Give a brief description of the engage step (how you will engage students in the study of this topic) and the explore step (how you will help them explore preliminary explanations).
   D. Give a deeper description of the explain step. The direction of the lesson should be clear from a statement of the goals you want to achieve. The backbone of the lesson should focus on what is happening from minute to minute in the classroom. As the lesson unfolds, describe each instructional strategy you plan to use and how that strategy helps students to achieve your goals. Provide any handouts you would use. Tell what you will be doing and how you expect the students to respond. Tell how you will assess what students are learning.
   E. Reflection. Describe how the mathematics meshes with the science instruction and/or how the science meshes with the mathematics instruction.
   F. Your finished project should include a photocopy of the textbook pages that are associated with your lesson, science and mathematics GLEs, a brief description of the initial engagement and exploration steps, several paragraphs describing the all aspects of the explain step, and a reflection describing science and mathematics integration.

Resources:

- Missouri Grade Level Expectations for Mathematics
- Missouri Grade Level Expectations for Science
- The NCTM Principles and Standards - Trial offer
- The NSES Standards
- How People Learn: Brain, Mind, Experience, and School
- Inquiry and the National Science Education Standards
TEXTS
On-line Required Reading:

6. Huntley Article
7. Science Grade Level Expectations for Missouri
8. Math Grade Level Expectations for Missouri

On-line Optional Reading:

Appendix F: Forced to Change Hand-out From Andrea

3–2 Explore

Forced to Change

In this activity you will explore the force of a magnetic field.

Materials (per group)

3/8" and 3/4" steel ball bearings  sheet of white paper
sheet of cardboard  sheet of carbon paper
strong bar magnet  books

Procedure

1. Set up a ramp on the floor by placing a couple of books under one end of the sheet of cardboard.
2. Place the sheet of carbon paper on top of the white paper and lay the papers at the base of the lower end of the ramp.

3. Roll the smaller ball bearing down the ramp. Note where the ball bearing lands by labeling the ink smudge on the white paper.
4. Roll the larger ball bearing down the ramp and mark where it lands.
5. Have one person hold the magnet at the base of the ramp as shown in the diagram. The ball bearings should fly by one pole of the magnet as they exit the ramp.
6. Roll one of the ball bearings down the ramp and mark where it lands on the carbon paper. Repeat the activity five times with each size ball bearing.
7. Move the magnet to the other side of the ramp and repeat step 6.

Questions

1. Before you added the magnet, was there any difference in the way the two ball bearings rolled down the ramp? Explain.
2. What effect did the magnet have on the path of each of the ball bearings?
3. Form a conjecture about why the magnet affected the two ball bearings differently.
Lab #3
Introduction to Spectrophotometry

Objective: To investigate the relationship between the amount of light absorbed by a solution, and the concentration of an analyte in that solution.

Note: This does not require a full write up at this time. Write the procedure, capture your data, and show how you and your lab partner determined your dilution factors. Complete your graph, and write down the answers to questions #10 and #11.

Procedure:
1. Observe the teacher’s demonstration of proper use of the spectrophotometer.
2. With your lab partner, set out 5 100mL beakers. Make sure that the beakers are clean.
3. Combine all 8 tubes which would hold dilution #1 from the serial dilution lab. Complete this for all 5 dilutions.
4. Stir all five mixtures, so they are homogeneous.
5. Zero the spectrophotometer using DI water.
6. Starting with the most dilute solution, record the absorbance of the combined solution at 630 nm.
7. Calculate the approximate total dilution factor of the solution when compared to the stock solution. To do this, you can average all 8 dilutions (4 from each student.)
8. Enter your five data points on the class summary.
9. Make a graph comparing concentration (compared to the stock) and absorbance.
10. Does your graph have a pattern?
11. Does the class graph show a pattern?
Appendix H: Instructions for DNA Extraction Laboratory from Cindy

Lab #4
Extracting DNA—designing your own experimental protocol Day #1

You will do this procedure with a partner. The partners may turn in one set of the pre-lab activities; however each partner will be responsible for her/his own lab notebook.

You have been asked to design a protocol to efficiently obtain DNA as part of a demonstration for your fellow high school students. Efficiency will be measured by percent yield. The DNA you extract will be analyzed later in the year.

Pre-Lab
1) Think about the structure of eukaryotic cells. Draw a simple diagram of an animal cell, and a plant cell. What barriers have to be overcome in order to isolate DNA from animal cells? Plant cells? Are there other potential sources of DNA that have not been listed?

2) Read through the attached protocols. Note how the protocols are similar and different.

3) Read the print out of the discussion group regarding DNA extraction.

4) What are the 3 major things which must be accomplished in order to extract DNA? Make a table, with these a column for each of the major steps. Go through each protocol, and extract the procedure and reagents required to accomplish that major task.

5) Confer with your lab partner to design your experiment. What aspect of DNA extraction are you going to investigate with your protocol? Why do you think that aspect may have an impact on your percent yield?

6) Working with your partner, design an experimental protocol. The protocol must have a hypothesis, DNA source, reagents, equipment, safety precautions, procedure, and the data to be collected. You must have this procedure approved prior to proceeding.

You will have access to the following:
Source for DNA—you can make a reasonable request

- Enzymatic contact cleaner
- Isopropyl alcohol (90%)
- EDTA
- Sodium Chloride
- Sodium Acetate
- Hot plate
- Thermometer
- Detergent—you can make a reasonable request
- Glass stirring rod

Cheese cloth
Ethyl alcohol (anhydrous)
Ice
Meat tenderizer

If there are other materials which you would like, please ask the instructor before you start designing the experiment. She may or not be able to provide the materials for you, but it doesn’t hurt to ask in the design phase.
Lab #4 Extracting DNA—running your own experimental protocol

Day #2

Your lab book will be checked prior to you starting your experimental protocol. Objective/hypothesis, procedure, and materials must be in your notebook. There must also be data tables ready to record relevant data. You will be allowed to proceed after your notebook has been checked, and all of these items are present.

Complete your experimental protocol. If you find that you have to deviate from your protocol it is okay—as long as you record it correctly into your laboratory notebook. Make sure to thoroughly explain what you changed from your original procedure, and why.

Record all raw data necessary to do your final calculations, complete a full lab write up, and answer the additional questions below.

When you have isolated your DNA sample, store it in a microcentrifuge tube with your team initials on it. This will be kept for further analysis. Make sure to clean your lab area completely.

Calculate your percent recovery for each experimental protocol. Add your results to the class listing. In addition to analyzing your results, you will also be responsible for comparing your data to that of your classmates.

To complete you lab write up, refer to the Laboratory Notebook Guidelines which were distributed at the beginning of the year. This is also available on Blackboard under course documents/notebook write up.

In addition to the requirement listed under the Laboratory Notebook Guideline, answer the following questions:

1) Did the variable you investigated affect the percent of DNA recovery? If not, explain why you think you did not see an effect. If so, how much did your variable affect your percent recovery? How confident are you that the effect is due to your variable? How would you change your experiment to further investigate this difference?

2) Is there a difference between the percent recoveries of each lab team? How large is the difference between the teams? To what would you attribute the differences? How confident can you be as to the reason for the differences between the teams? Outline how you would determine the source for differences between team’s recoveries.

3) Your original task was to create an efficient protocol, based on percent recovery. Based on your data, the data of your classmates, and your knowledge of experimental design, outline the next experiment you would conduct on the route to creating an efficient protocol. Assume that you would have all 3 teams at your disposal. Include your hypothesis, materials, procedure, and list the data that would need to be collected in order to support or refute your hypothesis.
Appendix I: Fingerprint from Graphite Activity from Lisa

Pencil Parts Have Other Uses
Major copper producing countries: United States, Chile, Canada, Poland, Zaire, Zambia
Major copper producing states in U.S.: Arizona, New Mexico, Utah, Michigan, and Montana.
Uses of copper: 41% in building construction, 24% in electrical and electronic products, 13% in industrial machinery and equipment, 12% in transportation and 10% in other general products.

Major zinc producing countries: Australia, Canada, China, Mexico, Peru, United States.

Uses of zinc: 46% in construction, 20% in transportation, 11% in machinery, 11% electrical uses, and 12% in other uses such as paints, batteries, rubber, medicines, lubricants.

Clays are produced in most states, except: Alaska, Delaware, Hawaii, Rhode Island, Vermont, and Wisconsin.
Main types of clay: kaolin, ball clay, fire clay, bentonite, fuller's earth, and common clay.

Uses of clays: paper making, glass, dinnerware, bathroom fixtures, floor & wall tile, kitty litter and other absorbents, medicines, and various foods.

Pencil Facts
Lead pencils contain no lead.
Graphite is extremely soft and smudges anything with which it comes in contact.
Graphite feels greasy or slippery to the touch.
The less clay mixed with graphite, the softer and blacker the lead will be.
Wood cases for most pencils are made of incense cedar, a North American tree of the cypress family.
The word pencil comes from the Latin peccellus, which means little tail or little brush.
The English made the first graphite pencils in the mid-1500's.
The Germans were the first to enclose the graphite in a wood case, about 1650.
In 1795, Nicolas Jacques Conte of France developed a pencil-making process that manufacturers still use today.
In 1812, William Monroe of Concord, Mass., sold the first American-made pencils to a Boston hardware dealer.
Eberhard Faber, an American businessman, built the first mass-production pencil factory in the United States in 1861.

More than 2 1/2 billion pencils are sold each year in the United States alone—about 11 pencils for each person in the country.

Activity: Fingerprint from graphite
Materials
- one sheet of scratch paper
- a soft graphite pencil (No. 2)
- five pieces of cellophane tape (each 2" long)
- a damp, soapy paper towel & a dry paper towel
- trace each student's hand for recording sheet

Experiment:
1. Use the side of a soft graphite pencil to apply a thick coating of graphite to a small section of the scratch paper. Rub the fingertips to be printed over the graphite. Make sure that the graphite covers the entire first joint of the finger—from the tip to the joint line.
2. Firmly press the graphite-coated fingertip on a piece of cellophane tape that has been placed adhesive side up on a desk or table. Slowly peel the tape from the finger. Place the tape in the correct space on the recording sheet.
3. Before printing each fingertip, apply more graphite.
4. After printing, each fingertip should be wiped clean with a soapy paper towel and dried to prevent graphite residue from smearing the next fingerprint.

You will also learn that graphite is a lubricant. Why is that?
Appendix J: Mineral Identification Activity from Lisa

Mineral Identification Lab Name _______________ Group ____________
Sample Number __________ Mineral/rock name _______________
Use the same sample for each test, example H-1 or same rock

<table>
<thead>
<tr>
<th>Color</th>
<th>Streak</th>
<th>Density</th>
<th>Crystal shape</th>
<th>Hardness</th>
<th>Luster</th>
<th>Acid test/other</th>
</tr>
</thead>
<tbody>
<tr>
<td>black</td>
<td></td>
<td>0 gm/ml</td>
<td>cubic</td>
<td>1</td>
<td>metallic</td>
<td>reaction</td>
</tr>
<tr>
<td>blue</td>
<td></td>
<td>1 gm/ml</td>
<td>orthorhombic</td>
<td>2</td>
<td>non-metallic</td>
<td>magnetic</td>
</tr>
<tr>
<td>clear</td>
<td></td>
<td>1.5 gm/ml</td>
<td>hexagonal</td>
<td>3</td>
<td>brilliant</td>
<td>florescent</td>
</tr>
<tr>
<td>gray</td>
<td></td>
<td>2 gm/ml</td>
<td>monoclinic</td>
<td>4</td>
<td>glassy</td>
<td>none</td>
</tr>
<tr>
<td>green</td>
<td></td>
<td>2.5 gm/ml</td>
<td>tetragonal</td>
<td>5</td>
<td>silky</td>
<td></td>
</tr>
<tr>
<td>orange</td>
<td></td>
<td>3 gm/ml</td>
<td>triclinic</td>
<td>6</td>
<td>dull</td>
<td></td>
</tr>
<tr>
<td>pink</td>
<td></td>
<td>3.5 gm/ml</td>
<td>not present</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>red/brown</td>
<td></td>
<td>4 gm/ml</td>
<td></td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>violet</td>
<td></td>
<td>4.5 gm/ml</td>
<td></td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>white</td>
<td></td>
<td>5 gm/ml</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yellow/gold</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Density formula: First find the volume of the sample. Final volume minus the initial volume _______ ml - _______ ml = _______ ml

D = mass/volume _______ gms / _______ ml = _______ gm/ml

Texture description ______________________
Texture print

264
TEST 3 samples for each test. They must be the same samples each station.

**Hardness** ~ Based on Mohs Scale of Hardness

Scratching tools:
- fingernail (2.2)
- copper penny (3.5)
- pocket knife or common nail (5.2)
- piece of glass (5.5)
- quartz (7)
- piece of corundum (9)

Notes for testing:
- Each mineral can scratch the minerals with lower hardness ratings.
- Each mineral can scratch itself.
- Don't press hard, normal scratching should do.
- Weathered surfaces are softer.
- Corners or edges of crystals are softer.
- Small pieces seem softer than large pieces.
- When you scratch, take a close look at the scratch line - which often looks white. Is it really a scratch or is it a powder line made from the tool you used because it was softer than the item you were trying to scratch.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
<th>Mineral example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 SOFT</td>
<td>Easily crumbles. Can be scratched with a fingernail (2.2).</td>
<td>Talc</td>
</tr>
<tr>
<td>2</td>
<td>Can be scratched with a fingernail (2.2).</td>
<td>Gypsum</td>
</tr>
<tr>
<td>3</td>
<td>Can be scratched with a copper penny (3.5).</td>
<td>Calcite</td>
</tr>
<tr>
<td>4</td>
<td>Can be scratched with common nail.</td>
<td>Fluorite</td>
</tr>
<tr>
<td>5</td>
<td>Can be scratched with a piece of glass (5.5).</td>
<td>Apatite</td>
</tr>
<tr>
<td>6</td>
<td>Mineral of hardness 6 or more will scratch glass.</td>
<td>Feldspar - Orthoclase</td>
</tr>
<tr>
<td>7</td>
<td>Can be scratched with quartz crystal</td>
<td>Quartz</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Topaz</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Corundum</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Diamond</td>
</tr>
</tbody>
</table>
TEST 3 samples for each test They must be the same samples each station

Density
Find the density of 3 samples
1. Use the scale to find the mass of the sample.
2. Use the graduated cylinder to find the volume
   a. First check the volume without the sample (initial volume)
   b. Put the sample in the cylinder
   c. Subtract the initial volume from the final volume to find the sample’s volume.
   d. Record your information on the sheet and do the calculations

Luster
  1. observe the luster of the sample
  2. record your observation
Other tests

TEST 3 samples for each test. They must be the same samples each station

Acid test
1. Put two drops of acetic acid on the sample. Wait 15 seconds and record the reaction

Magnetic test
1. Use the magnet
2. Observe if there is an attraction to the sample. (you may "feel" the magnetic pull)

Florescence
1. Put the sample under the light.
2. Observe if there is any florescence
TEST 3 samples for each test. They must be the same samples each station.

Color
1. Observe the color of the sample.

Crystal Shape
1. Observe the crystal shape. Draw it in the blank space on the lab sheet if unsure of shape name.

Streak
1. Rub the sample on the porcelain tile observe the color.
2. Record the color.

Texture
1. Rub the sample with graphite rock.
2. Put a piece of tape on the sample (like we did with our finger prints)
3. Pull of the tape and put on the lab sheet
4. Describe the texture on the sheet.
Appendix K: Photosynthesis Demonstration Experiments from Sara

BIOLOGY
Photosynthesis Demonstration Experiments

Directions: Follow along with the experiments and demonstrations on photosynthesis. Complete all study questions.

EXPERIMENT #1: Blue Water
1. With a partner, set up the following experiment. One person MUST wear safety glasses.

a. Fill each of three test tubes 1/3 full of water. Add two droppers' full of Bromthymol Blue to the water in the test tubes, and place them in the rack.

Bromthymol Blue is a dye that indicates a change in the pH (acidity) of the solution. The water that has the blue color has a pH of about 8. When the blue color changes to yellow, the solution has a pH of about 6, and is slightly acidic. When carbon dioxide is added to the water it forms carbonic acid and the pH of the water decreases. When the carbon dioxide leaves the water the color will return to a bluish color.

b. Place a straw in one test tube. The person with the safety glasses should gently blow air into the test tube until the solution in the test tube turns yellowish. Make sure that you have a folded paper towel over the top of the test tube to prevent splashing.

c. Do this same procedure to another test tube.

d. Obtain a short sprig of Elodea aquarium plant and push it into one of the yellowish test tubes with the glass stirring rod. Placed all three test tubes in the rack about 12 inches from the lamp. Turn the lamp on and direct it at the test tubes. Return to your seat.

2. Knowing the function of Bromthymol Blue, why did the color of the water change to a yellowish color after the student blew in the tube?

3. After about 20 minutes in front of the light, what has happened to the color of both yellow test tubes?

4. What does this illustrate about one of the required substances for photosynthesis?

5. Why was the blue test tube needed in this activity?
6. Why was the second yellow tube needed...the one without the plant?

7. Which of the following titles is the most appropriate for this demonstration?
   a. The Conversion of Carbon Dioxide to Oxygen in Photosynthesis
   b. Carbon Dioxide as a Product of Photosynthesis
   c. The Need for Oxygen for Photosynthesis
   d. Photosynthesis and the Uptake of Carbon Dioxide

8. Explain why you chose the answer that you did.

9. Return the sprig of Elodea to the container in the front of the room. Rinse out the three test tubes and return them to the rack.

PHOTOSYNTHESIS EXPERIMENT # 2  Test Tube Trap

1. Observe the apparatus on display on the front counter. As it is described to you, make a quick sketch of the apparatus in the space below.

2. The upside down test tube is a kind of trap. What is it trapping from the beaker of water with the elodea in it? Where did this substance come from?
3. An identical apparatus has been in the dark in a cabinet in the prep room where there is no light at all. What is the purpose for this extra ‘set-up’ in the dark? (What will this demonstrate?)

4. Which title is the most appropriate for this demonstration?
   b. The Importance of Light in Photosynthesis.
   c. The Production of Oxygen in Photosynthesis.
   d. Glucose as a Reactant in Photosynthesis.

5. Explain why you chose the title that you did.

EXPERIMENT 3: Boiled Geranium

Background information: This geranium plant has been in the dark for two days. At the time when the plant was taken out of the dark
   4 leaves were wrapped with aluminum foil
   4 leaves were fitted with a special mask with an X cut in it.
   And obviously there are many leaves with no mask or foil
So, in effect, the leaves wrapped completely with the foil are still in the dark, and those with the mask will have a portion of the leaves exposed to light.

1. What are the three test conditions in this experiment?

2. Sketch what the leaves with the mask look like...showing the shape of the hole in the masks.
3. For the next 4 hours, the geranium was under the plant lights. Let's look to see what happened to the leaves that were covered or masked, and compared them to the leaves that were uncovered.

a. Remove one regular leaf, one completely covered leaf, and one masked leaf.
b. Remove the covers and masks carefully and boil the leaves in boiling water for a few minutes, then boil the leaves in alcohol for a few minutes to remove all of the chlorophyll.
c. Immerse the boiled leaves in iodine solution. If the leaves turn dark then starch is present in the leaves. (Remember, that starch is a whole bunch of glucose molecules together.)
d. Examine the leaves and draw a sketch of each leaf after it has been treated with the iodine.

<table>
<thead>
<tr>
<th>Regular leaf</th>
<th>Covered leaf</th>
<th>Masked leaf</th>
</tr>
</thead>
</table>

4. Recall that photosynthesis produces glucose, which is the molecule that stores the energy captured in the photosynthesis process. Plants can easily convert glucose to starch, which really is "concentrated" glucose since starch is really just a lot of glucose molecules bonded together into a long chain molecule.

a. Why did the regular leaf have starch in it?

b. Explain the absence of starch in the covered leaf.

c. Why did some of the masked leaf contain starch?

d. How could you tell where there was starch and where there wasn’t starch?
5. Why was it necessary to put the plant in the dark for 2 days prior to putting the masks on the leaves?

6. How do the observed patterns in the masked/covered leaves indicate the effect of light in the photosynthesis process?

7. Which of the following would be the best title (better than Boiled Geraniums) for this demonstration experiment?
   a. The Production Of Glucose In Photosynthesis.
   b. Starch Decomposition By Boiling
   c. Photosynthesis and the Release of Oxygen
   d. Photosynthesis: Carbon Dioxide and the Formation of Starch.

8. Explain why you chose the answer that you did in number 7 above.
Appendix L: Why Study Photosynthesis? from Sara

Why Study Photosynthesis?

Devens Gust, Ph.D.
Professor of Chemistry and Biochemistry
Center for the Study of Early Events in Photosynthesis

What is photosynthesis?

Photosynthesis is arguably the most important biological process on earth. By liberating oxygen and consuming carbon dioxide, it has transformed the world into the hospitable environment we know today. Directly or indirectly, photosynthesis fills all of our food requirements and many of our needs for fiber and building materials. The energy stored in petroleum, natural gas, and coal all came from the sun via photosynthesis, as does the energy in firewood, which is a major fuel in many parts of the world. Thus, being the case, scientific research into photosynthesis is vitally important. If we can understand and control the intricacies of the photosynthetic process, we can learn how to increase crop yields of food, fiber, wood, and fuel, and how to better use our lands. The energy-harvesting secrets of plants can be adapted to man-made systems which provide new, efficient ways to collect and use solar energy. These same natural "technologies" can help point the way to the design of new, faster, and more compact computers, and even to new medical breakthroughs. Because photosynthesis helps control the makeup of our atmosphere, understanding photosynthesis is crucial to understanding how carbon dioxide and other "greenhouse gases" affect the global climate. In this document, we will briefly explore each of the areas mentioned above, and illustrate how photosynthesis research is critical to maintaining and improving our quality of life.

Photosynthesis and food. All of our biological energy needs are met by the plant kingdom, either directly or through herbivorous animals. Plants in turn obtain the energy to synthesize foodstuffs via photosynthesis. Although plants draw necessary materials from the soil and water and carbon dioxide from the air, the energy needs of the plant are filled by sunlight. Sunlight is pure energy. However, sunlight itself is not a very useful form of energy; it cannot be eaten, it cannot turn dynamo, and it cannot be stored. To be beneficial, the energy in sunlight must be converted to other forms. This is what photosynthesis is all about. It is the process by which plants change the energy in sunlight to kinds of energy that can be stored for later use. Plants carry out this process in photosynthetic reaction centers. These tiny units are found in leaves, and convert light energy to chemical energy, which is the form used by all living organisms. One of the major energy-harvesting processes in plants involves using the energy of sunlight to convert carbon dioxide from the air into sugars, starches, and other high-energy carbohydrates. Oxygen is released in the process. Later, when the plant needs food, it draws upon the energy stored in these carbohydrates. We do the same. When we eat a plate of spaghetti, our bodies oxidize or "burn" the starch by allowing it to combine with oxygen from the air. This produces carbon dioxide, which we exhale, and the energy we need to survive. Thus, if there is no photosynthesis, there is no food. Indeed, one widely accepted theory explaining the extinction of the dinosaurs suggests that a comet, meteor, or volcanic material into the atmosphere that the amount of sunlight reaching the earth was severely reduced. This in turn caused the death of many plants and the creatures that depended upon them for energy.
Photosynthesis and energy. One of the carbohydrates resulting from photosynthesis is cellulose, which makes up the bulk of dry wood and other plant material. When we burn wood, we convert the cellulose back to carbon dioxide and release the stored energy as heat. Burning fuel is basically the same oxidation process that occurs in our bodies; it liberates the energy of "stored sunlight" in a useful form, and returns carbon dioxide to the atmosphere. Energy from burning "biomass" is important in many parts of the world. In developing countries, firewood continues to be critical to survival. Ethanol (grain alcohol) produced from sugars and starches by fermentation is a major automobile fuel in Brazil, and is added to gasoline in some parts of the United States to help reduce emissions of harmful pollutants. Ethanol is also readily converted to ethylene, which serves as a feedstock to a large part of the petrochemical industry. It is possible to convert cellulose to sugar, and then into ethanol; various microorganisms carry out this process. It could be commercially important one day.

Our major sources of energy, of course, are coal, oil, and natural gas. These materials are all derived from ancient plants and animals, and the energy stored within them is chemical energy that originally came from sunlight through photosynthesis. Thus, most of the energy we use today was originally solar energy!

Photosynthesis, fiber, and materials. Wood, of course, is not only burned, but is an important material for building and many other purposes. Paper, for example, is nearly pure photosynthetically produced cellulose, as is cotton and many other natural fibers. Even wool production depends on photosynthetically derived energy. In fact, all plant and animal products including many medicines and drugs require energy to produce, and that energy comes ultimately from sunlight via photosynthesis. Many of our other materials needs filled by plastics and synthetic fibers which are produced from petroleum, and are thus also photosynthetic in origin. Even much of our metal refining depends ultimately on coal or other photosynthetic products. Indeed, it is difficult to name an economically important material or substance whose existence and usefulness is not in some way tied to photosynthesis.

Photosynthesis and the environment. Currently, there is a lot of discussion concerning the possible effects of carbon dioxide and other "greenhouse gases" on the environment. As mentioned above, photosynthesis converts carbon dioxide from the air to carbohydrates and other kinds of "fixed" carbon and releases oxygen to the atmosphere. When we burn firewood, ethanol, or coal, oil and other fossil fuels, carbon dioxide is consumed, and carbon dioxide is released back to the atmosphere. Thus, carbon dioxide which was removed from the atmosphere over millions of years is being replaced very quickly through our consumption of these fuels. The increase in carbon dioxide and related gases is bound to affect our atmosphere. Will this change be large or small, and will it be harmful or beneficial? These questions are being actively studied by many scientists today. The answers will depend strongly on the effect of photosynthesis carried out by land and sea organisms. As photosynthesis consumes carbon dioxide and releases oxygen, it helps counteract the effect of combustion of fossil fuels. The burning of fossil fuels releases not only carbon dioxide, but also hydrocarbons, nitrogen oxides, and other trace materials that pollute the atmosphere and contribute to long-term health and environmental problems. These problems are a consequence of the fact that nature has chosen to implement photosynthesis through conversion of carbon dioxide to energy-rich materials such as carbohydrates. Can the principles of photosynthetic solar energy harvesting be used in some way to produce non-polluting fuels or energy sources? The answer, as we shall see, is yes.

Why study photosynthesis?

Because our quality of life, and indeed our very existence, depends on photosynthesis, it is essential that we understand it. Through understanding, we can avoid adversely affecting the process and precipitating environmental or ecological disasters. Through understanding, we can also learn to control photosynthesis, and thus enhance production of food, fiber and energy. Understanding the natural process, which has been developed by plants over several billion years, will also allow us to use the basic chemistry and physics of photosynthesis for other purposes, such as solar energy conversion, the design of electronic circuits, and the development of medicines and drugs. Some examples follow.

Photosynthesis and agriculture. Although photosynthesis has interested mankind for eons, rapid progress in understanding the process has come in the last few years. One of the things we have learned is that overall, photosynthesis is relatively
inefficient. For example, based on the amount of carbon fixed by a field of corn during a typical growing season, only about 1 - 2% of the solar energy falling on the field is recovered as new photosynthetic products. The efficiency of uncultivated plant life is only about 0.2%. In sugar cane, which is one of the most efficient plants, about 8% of the light absorbed by the plant is preserved as chemical energy. Many plants, especially those that originate in the temperate zones such as most of the United States, undergo a process called photospiration. This is a kind of "short circuit" of photosynthesis that wastes much of the plant's photosynthetic energy. The phenomenon of photospiration including its function, if any, is only one of many riddles facing the photosynthesis researcher.

If we can fully understand processes like photospiration, we will have the ability to alter them. Thus, more efficient plants can be designed. Although new varieties of plants have been developed for centuries through selective breeding, the techniques of modern molecular biology have speeded up the process tremendously. Photosynthesis research can show us how to produce new crop strains that will make much better use of the sunlight they absorb. Research along these lines is critical, as recent studies show that agricultural production is leveling off at a time when demand for food and other agricultural products is increasing rapidly.

Because plants depend upon photosynthesis for their survival, interfering with photosynthesis can kill the plant. This is the basis of several important herbicides, which act by preventing certain important steps of photosynthesis. Understanding the details of photosynthesis can lead to the design of new, extremely selective herbicides and plant growth regulators that have the potential of being environmentally safe (especially to animal life, which does not carry out photosynthesis). Indeed, it is possible to develop new crop plants that are immune to specific herbicides, and to thus achieve weed control specific to one crop species.

**Photosynthesis and energy production.** As described above, most of our current energy needs are met by photosynthesis, ancient or modern. Increasing the efficiency of natural photosynthesis can also increase production of alcohol and other fuels derived from agriculture. However, knowledge gained from photosynthesis research can also be used to enhance energy production in a much more direct way. Although the overall photosynthesis process is relatively wasteful, the early steps in the conversion of sunlight to chemical energy are quite efficient. Why not learn to understand the basic chemistry and physics of photosynthesis, and use these same principles to build man-made solar energy harvesting devices? This has been a dream of chemists for years, but is now close to becoming a reality. In the laboratory, scientists can now synthesize artificial photosynthetic reaction centers which rival the natural ones in terms of the amount of sunlight stored as chemical or electrical energy. More research will lead to the development of new, efficient solar energy harvesting technologies based on the natural process.

The role of photosynthesis in control of the environment. How does photosynthesis in temperate and tropical forests and in the sea affect the quantity of greenhouse gases in the atmosphere? This is an important and controversial issue today. As mentioned above, photosynthesis by plants removes carbon dioxide from the atmosphere and replaces it with oxygen. Thus, it would tend to ameliorate the effects of carbon dioxide released by the burning of fossil fuels. However, the question is complicated by the fact that plants themselves react to the amount of carbon dioxide in the atmosphere. Some plants appear to grow more rapidly in an atmosphere rich in carbon dioxide, but this may not be true of all species. Understanding the effect of greenhouse gases requires a much better knowledge of the interaction of the plant kingdom with carbon dioxide than we have today. Burning plants and plant products such as petroleum releases carbon dioxide and other byproducts such as hydrocarbons and nitrogen oxides. However, the pollution caused by such materials is not a necessary product of solar energy utilization. The artificial photosynthetic reaction centers discussed above produce energy without releasing any byproducts other than heat. They hold the promise of producing clean energy in the form of electricity or hydrogen fuel without pollution. Implementation of such solar energy harvesting devices would prevent pollution at the source, which is certainly the most efficient approach to control.

**Photosynthesis and electronics.** At first glance, photosynthesis would seem to have no association with the design of computers and other electronic devices. However, there is potentially a very strong connection. A goal of modern electronics
research is to make transistors and other circuit components as small as possible. Small devices and short connections between them make computers faster and more compact. The smallest possible unit of a material is a molecule (made up of atoms of various types). Thus, the smallest conceivable transistor is a single molecule (or atom). Many researchers today are investigating the intriguing possibility of making electronic components from single molecules or small groups of molecules. Another very active area of research is computers that use light, rather than electrons, as the medium for carrying information. In principle, light-based computers have several advantages over traditional designs, and indeed many of our telephone transmission and switching networks already operate through fiber optics. What does this have to do with photosynthesis? It turns out that photosynthetic reaction centers are natural photochemical switches of molecular dimensions. Learning how plants absorb light, control the movement of the resulting energy to reaction centers, and convert the light energy to electrical, and finally chemical energy can help us understand how to make molecular-scale computers. In fact, several molecular electronic logic elements based on artificial photosynthetic reaction centers have already been reported in the scientific literature.

Photosynthesis and medicine. Light has a very high energy content, and when it is absorbed by a substance this energy is converted to other forms. When the energy ends up in the wrong place, it can cause serious damage to living organisms. Aging of the skin and skin cancer are only two of many deleterious effects of light on humans and animals. Because plants and other photosynthetic species have been dealing with light for ages, they have had to develop photoprotective mechanisms to limit light damage. Learning about the causes of light-induced tissue damage and the details of the natural photoprotective mechanisms can help us find ways to adapt these processes for the benefit of humanity in areas far removed from photosynthesis itself. For example, the mechanism by which sunlight absorbed by photosynthetic chlorophyll causes tissue damage in plants has been harnessed for medical purposes. Substances related to chlorophyll localize naturally in cancerous tumor tissue. Illumination of the tumors with light then leads to photochemical damage which can kill the tumor while leaving surrounding tissue unharmed. Another medical application involves using similar chlorophyll relatives to localize in tumor tissue and thus act as dyes which clearly delineate the boundary between cancerous and healthy tissue. This diagnostic aid does not cause photochemical damage to normal tissue because the principles of photosynthesis have been used to endow it with protective agents that harmlessly convert the absorbed light to heat.

Conclusions

The above examples illustrate the importance of photosynthesis as a natural process and the impact that it has on all of our lives. Research into the nature of photosynthesis is crucial because only by understanding photosynthesis can we control it, and harness its principles for the betterment of mankind. Science has only recently developed the basic tools and techniques needed to investigate the intricate details of photosynthesis. It is now time to apply these tools and techniques to the problem, and to begin to reap the benefits of this research.

--Written by and Copyright ©1996 Devers Gust, Professor of Chemistry and Biochemistry, Arizona State University
Appendix M: Mealworm Laboratories from Sara

BIOLOGY                                Name__________________________
Experimental Design                                                                  Date____  Period____

MEALWORM LAB

Purpose:
It is the purpose of this inquiry to review the major components and concepts of experimental design. You will be using a larva of an arthropod, commonly known as a mealworm. Here we will gather data (make some observations) through experimentation in an effort to learn more about how mealworms behave and respond to their environment. This inquiry is split into three parts: Getting to know your mealworm, completing the experiment, and data analysis.

PART I: GETTING TO KNOW YOUR MEALWORM
TREAT THESE AND ALL LIVING CREATURES WITH CARE.

1. Working with your partner, pick up a mealworm and a few sheets of damp toweling from the counter. Spend 5-10 minutes getting to know your mealworm. Record 5 qualitative and 5 quantitative observations about mealworms and their behaviors in the space below.

OBSERVATIONS

Qualitative

1)  
2)  
3)  
4)  
5)  

Quantitative

1)  
2)  
3)  
4)  
5)
PART II: THE EXPERIMENT

1. The independent variable for this experiment is surface texture. We will use six different kinds of sandpaper for the different test groups.

   Range of Sandpaper Grit Size: 36 — 220

   In this activity we will observe the rate of movement of mealworms on these surfaces. Our dependent variable will be how far the mealworm travels in one minute. You and your partner will be assigned one of six surface textures.

2. For this experiment, what will be independent variable?

   For the class: ____________________  For your group: ____________________

3. For this experiment, what is the dependent variable?

   For the class: ____________________  For your group: ____________________

4. Write a hypothesis that predicts how the distance a mealworm will travel may be affected by the surface it is on. (This hypothesis is a statement that makes a prediction or an explanation and should include both the dependent and independent variables)

5. Get the materials you need to perform your experiment.
   Materials Include: Sandpaper, mealworm, string, ruler, paper towel, stop watch

6. Procedure: Using the assigned surface type, measure the distance that your mealworm will travel in one minute. Record the distance in centimeters. Complete six trials. Record the data that you collected on the table below.

   The distance mealworm #1 traveled on ___________ in one minute.  The distance mealworm #2 traveled on ___________ in one minute.

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Distance Traveled (cm)</th>
<th>Trial #</th>
<th>Distance Traveled (cm)</th>
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<tbody>
<tr>
<td>1</td>
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<td>6</td>
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</tbody>
</table>

7. Determine the average distance traveled on your sandpaper grit type.
Average distance: ________________________

8. Record all of your groups’ data in the appropriate location on the board. **(Do not put your average distance on the board.)**

9. In the data table below, record all of the data for all six test conditions in our class. Then average the data for each grit size.

Title:

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Grit Size</th>
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<tr>
<td>Average Distance</td>
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</tbody>
</table>

10. Make a graph of the averages from the data above. This will be a line graph with the independent variable on the x axis (horizontal), and the dependent variable on the y (vertical) axis. **Follow the rules below for a properly designed graph.**

   1. Make sure that you make the graph large enough so that it takes up most of the sheet of graph paper.
   2. Make sure that you have a title for the graph that briefly states the data contained on the graph.
   3. Make sure that you label the axes of the graph with proper variable name and the units that were used to measure the variable.

280
4. Make sure that when you scale the axes of the graph that your numbers and spacing are of even increments on both axes.
5. Make sure that you label the curves or bars on the graph with the appropriate test condition (or make a key or legend).

Part III: DATA ANALYSIS

Use the graphs that you made to analyze the data. Answer the following data analysis questions.

11. Study the graph of the results for the entire class. What trends are evident in the data? Write a three sentences that describe these trends. If no trends or patterns are evident in the data, then describe the absence of a trend.

12. Write a one-sentence statement that summarizes your belief about the movement of mealworms on different surface textures.

13. Does the data collected by the class support the hypothesis that you wrote in #4? Explain.

14. How confident are you that the data we collected accurately represents the movement of mealworms over these surface types? Explain why you are confident, or why you are not confident in the data that the class collected.

15. What sources for error may have been present in our experiment that would cause the data that we collected to be questionable? List many.

16. What else besides surface texture may have caused the observed results?

17. What have you shown with this experiment? How do you know this for sure?

18. Compare your lab group average to the class average for the same surface type. If your average is very different, what may cause this difference?

19. Why is having many measurements of mealworm movement in one minute better than just a few? (How does having many measurements strengthen any conclusion that you may form?)

20. Why is having 7 or 8 mealworms to measure better than one or two mealworms? (How does having many mealworms to use strengthen any conclusion that you may form?)
BIOLOGY
Mealworm Lab—Part 2

Now that you are familiar with the Mealworms, you will get to conduct an experiment where YOU will choose the independent variable. The dependent variable will remain the same—**distance a Mealworm travels in one minute**. Fill out each section of this sheet carefully in order to accurately design your experiment.

1. What is the independent variable for your experiment?
2. What is the dependent variable for your experiment?
3. Write a possible title for this experiment. It should be concise and accurately describe what is being studied.
4. Write the purpose of the investigation. (This should be a statement of what is being tested / investigated.)
5. Write an appropriate HYPOTHESIS. REMEMBER: A hypothesis should be a prediction of the how the dependent variable will be affected by the independent variable, or in other words, a prediction of how the DV and IV are related.
6. List the materials that will be needed to conduct the experiment.
7. Write a SIMPLE but ACCURATE procedure for the investigation.
8. Draw appropriate data tables for the investigation. Make sure your data tables have all the necessary components.
9. **CONDUCT YOUR EXPERIMENT!!**
10. Write the data you collect in the experiment in the above data table(s).
11. Write down any extra observations that you made, but that did not necessarily fit into the data table.
12. Graph the data you collected in your data tables, so that you can detect any trends. These graphs should be attached to the back of this packet.
13. What trends do you see in the data?
14. Do these trends support or refute your hypothesis?
15. What are possible reasons for the trends (or the lack of trends) in your data?
16. Is there any data that does not fit? If so, explain that data AND explain possible causes for that data.
17. Summarize the relationship determined in the investigation between the independent and dependent variables.
VITA

Abdulkadir (Kadir) Demir born and raised in Batman-Turkey, where he completed his elementary and middle school education. He finished high school in Ankara-Turkey and pursued a bachelor degree in Biology Teaching from Gazi University in the same city. After college he returned to his hometown where he taught biology, environmental education, and general science to grades 6-11. Having worked for three years, he was selected by the Turkish Ministry of Education to study in US to obtain a Ph.D. in science education.

Kadir received two master’s degrees—one in science education and one in educational technology. He continued with a Ph.D. in science education at the same institution, University of Missouri-Columbia (MU). During the time Kadir spent at MU he worked closely with Dr. Sandra Abell on several different projects and researches. Kadir is currently working at University of Toledo as postdoctoral fellow.