MCDONALD, JUDITH RICHARDS, Ph.D. A Case Study of Second-Career Alternatively Certified Science Teachers: What Research and Educational Experiences and Understanding of Nature of Science Do They Bring to Classroom Practices? (2008) Directed by Dr. Catherine Matthews. 265 pp.

This multiple case study examined second-career lateral entry middle school science teachers to see what research and educational experiences and understanding of nature of science they bring to their classroom practices. I examined four alternatively certified, second-career middle school science teachers in a large urban southeastern school district. I found in this study that these teachers understanding of nature of science as displayed through their classroom practices was impacted by their scientific research experiences and exposure to direct instruction of nature of science (NOS). This study determined each participants understanding of nature of science through the Views of Nature of Science (VNOS) B Test and found out how they acquired their NOS through a background questionnaire and a semi-structured interview. I observed each classroom to determine if these teachers were implementing NOS classroom practices. This study had mixed results and found that two of the four teachers were more informed about the NOS and demonstrated these practices in their classrooms. This study explains how these teachers acquired their NOS and what practices they demonstrated in their classroom.

A CASE STUDY OF SECOND-CAREER ALTERNATIVELY CERTIFIED SCIENCE TEACHERS: WHAT RESEARCH AND EDUCATIONAL EXPERIENCES AND UNDERSTANDING OF NATURE OF SCIENCE DO THEY BRING TO CLASSROOM PRACTICES?

by

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APPROVAL PAGE

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CHAPTER I

INTRODUCTION

"Education in order to accomplish its ends both for the individual learner and for society must be based upon experience, which is always the actual life-experience of some individual." John Dewey, 1938

There is a severe teacher shortage in the United States. We need more teachers, especially in the fields of mathematics, special education, and science (Ingersoll, 2003; National Commission on Mathematics and Science Teaching for the 21st Century [NCMSTA], 2000). In 2006, in an effort to address this severe teacher shortage, 48 states and the District of Columbia certified individuals through alternative certification programs (Feistritzer, 2006). In 2004-2005, more than 55,000 individuals were certified by non-traditional pathways to become teachers (Feistritzer, 2006). There has been exponential growth in the number of teachers certified through alternative routes and hired to teach in our nation's classrooms. Only 1,000 individuals were certified through alternative programs in 1985. Last year, Texas alone certified 9,967 individuals through alternative programs. These individuals comprised approximately one third of the state's new hires (Feistritzer, 2006).

Alternatively certified teachers (ACTs) are being hired to teach in large numbers in classrooms across the United States. Because the alternative routes to teacher certification are typically shorter, involve less face-to-face instruction, and instead rely more on distance learning, it is important to examine the strengths and weaknesses that these ACTs bring to the profession (Darling-Hammond, Holtzman, Gatlin, & Heilig, 2005).

The purpose of this dissertation was to study four, middle school science ACTs in a large suburban school district in North Carolina. According to Veal (2002), second-career alternatively certified science teachers are an "untapped reservoir" of knowledge. Therefore, the focus of this study was on these second-career teachers' strengths in the middle school science classroom. I attempted to understand how their prior career science experiences and knowledge of science were revealed through their classroom practices.

The rationale for this study is that we are clearly and quickly filling the science teacher gap by hiring alternatively certified science teachers to fill the openings in our middle and high school classrooms. While there is literature that addresses the weaknesses of these teachers (Darling-Hammond, 2000; Laczko-Kerr & Berliner, 2002), there is less literature that focuses on or investigates the strengths that these ACTs bring to their classroom practices. Finally, I argue that we do not know enough about how second-career science teachers translate their experiences and parlay their knowledge into classroom practices.

In this chapter, I present the research questions and briefly describe the research design for this study. The chapter concludes with a concise overview of the organization of the dissertation.

Need for Science Teachers

According to Hussar (1999), by 2008 – 2009, the United States will need approximately 1.7 to 2.7 million new teachers to replace those who retire and to accommodate the estimated growth in the number of school age children (National Research Council [NRC], 1996). The National Commission on Mathematics and Science Teaching for the 21st Century (NCMST, 2000) anticipates that 240,000 mathematics and science teachers will be needed to fill middle and high school classrooms over the next ten years due to retirement, attrition, and job changes. Our nation must focus on science education immediately because of the critical need to fill our science classrooms with the best prepared science teachers our nation has to offer.

Science teachers are among the most difficult to recruit for school districts because the pool of potential candidates is limited, especially for urban and rural school districts (National Science Teachers Association [NSTA], 2005; Council of the Great City Schools, 2000). The National Center for Education Statistics (NCES, 2004) indicated that mathematics and science vacancies were difficult to fill, especially in high poverty, urban schools. In North Carolina, approximately 10,000 teachers leave the public school classroom annually, while the public and private universities in North Carolina graduate only about 5,000 teachers a year, creating a large shortage of teachers annually. According to the 2005 *Fall Teacher Vacancy Report* published by the North Carolina Department of Public Instruction (NCPDI), vacancies in the area of secondary science have increased from 9% in 2002 to 21% in 2003 (NCPDI, 2005). Continually rising, the vacancies in 2005 were reported to have reached an all time high of 25%. Not only will we need to fill all of these teacher vacancies, but new teachers will have to be highly qualified according to the federal law, *No Child Left Behind* (2002).

Highly qualified teachers are those individuals who are well informed in their content areas, according to a checklist provided to school systems by the federal government. The federal checklist mandates that all highly qualified teachers: (a) hold a bachelor's degree from an accredited college or university, (b) hold state teaching certification, and (c) demonstrate competency in their content areas, as defined by the state in which they will be teaching (United States Department of Education, 2004). Competency in the content area can be demonstrated in one of two ways: successfully passing a rigorous state test, or holding an academic major in the content area. Each state has further requirements of its teachers. For example, North Carolina High Objective Uniform State Standard for Evaluation (HOUSSE) requires that all science teachers understand the nature of science and the development of scientific knowledge (Standard 2) and that they understand the historical development of scientific thought and the application of science in society (Standard 3) (NCPI, 2005).

A number of the teacher shortages will be addressed by teachers who enter science classrooms, crossing the threshold of teaching via completing an alternative certification program. Most states allow individuals with bachelor's degrees in science to apply for teaching positions under a provisional or alternative license (according to the report published by NCMST for the 21st Century, 2000). Clearly, ACTs are part of the solution to filling our empty science classrooms. Most school districts across our nation rely on ACTs to help fill these openings.

Many studies have been done that focus on the skills ACTs lack, and these studies typically provide suggestions about how to prepare these ACTS for teaching in the classroom through induction programs (Abell, Arbaugh, Chval, Friedricshen, Lannin, & Volkmann, 2006; Darling-Hammond, 1989; Darling-Hammond, Hudson, & Kirby, 1989; Wilson, Floden, Ferrini-Mundy, 2002; Wong, 2003). In order to plan the best induction programs and to help ACTs succeed as teachers, we need to learn more about the strengths these individuals bring to the classroom.

Undeniably, there is a shortage of science teachers in this country and we must address the urgency of this matter. This study explores the prior science experiences and knowledge that second-career ACTs bring to middle school science classrooms.

Alternatively Certified Teachers (ACTs)

According to Johnson and Kardos (2005), approximately 33 to 48 percent of all teachers come from another line of work prior to entering the field of teaching. The National Center for Alternative Certification (NCAC2004) states that alternative certification was primarily created to meet the needs of teacher shortages in science, mathematics, and foreign language. Additionally the NCAC (2004) states that there is little research on ACTs and what these teachers bring from prior careers to the field of teaching.

Many research studies on ACTs focus on the induction programs and the analysis of the alternative certification programs that ACTs complete (Abell et al., 2006; Darling-Hammond, 1989; Darling-Hammond et al., 1989; Greenwood, 2006). Other studies focus on what the ACTs lack (NCMST, 2000; Ingersoll, 1999). We must closely examine the strengths that ACTs bring to classrooms. We need to know what these teachers transfer from their prior work experiences that helps them to effectively reach students, which in turn helps increase student learning.

We know that good science teachers must have an understanding of content knowledge, pedagogical content knowledge (PCK) and pedagogical knowledge in order to be effective in the classroom (Shulman, 1986). We also know that beginning teachers struggle with classroom management, content knowledge, time management, creating lesson plans, instructing diverse learners, and applying pedagogy within their classrooms (Lederman, 1999; McCann, Johannessen, & Ricca, 2005; Ramano & Gibson, 2006). In one study, second-career ACTs felt as though they were entering the classroom with good content knowledge, real-world knowledge, patience, organizational skills, and collaborative skills (Haggard, Stostad, & Wintterton, 2006).

Second-career alternatively certified science teachers are likely entering the classroom with a lot of skills and knowledge. Individuals who change careers often transfer prior knowledge from their previous jobs (Chambers, 2002). This is more likely the case if they have worked in the scientific community. For example, a scientist must have a strong working knowledge of the discipline and of how knowledge is produced in the discipline (*content knowledge and real-world knowledge*), an understanding that problem solving takes time (*patience*), skills to organize multiple projects, skills to interpret data and tasks (*organizational skills)*, and the ability to work and communicate well with others (*collaborative skills)*. Alternatively certified science teachers often bring real-world science with them to the classroom, which includes an understanding of how scientific knowledge is formed (Veal, 2002). Veal (2002) suggests that every school district needs to take advantage of ACTs because they offer an "untapped reservoir of knowledge." (p. 56)

The skills and knowledge listed above are often lacking in less informed, traditionally-educated science teachers (Lederman, Lederman, & Abd-El-Khalick, 2006). However, these skills are necessary for good science teaching, according to a variety of accreditation agencies. The National Council for Accreditation of Teacher Education (NCATE) states in Standard 1 that: "Candidates preparing to work in schools as teachers or other professional school personnel know and demonstrate the content, pedagogical, and professional knowledge, skills, and dispositions necessary to help all students learn." The standard continues to detail the knowledge that each teacher candidate must possess by stating, "Teacher candidates have in-depth knowledge of the subject matter that they plan to teach as described in professional, state, and institutional standards. They demonstrate their knowledge through inquiry, critical analysis, and synthesis of the subject." Additionally, Interstate New Teacher Assessment and Support Consortium (INTASC) states that beginning teachers must understand PCK, "The teacher understands the central concepts, tools of inquiry, and structures of the discipline he or she teaches and can create learning experiences that make these aspects of subject matter meaningful for students."

Nature of Science and Standards-Based Science Teaching

Science educators have argued that in order to teach according to the science standards put forth by the *National Science Education Standards (NSES)* (NRC, 1996) and *Science for All Americans* (AAAS, 1990), teachers must have a strong understanding of the nature of science (NOS) (Lederman, 1992; Matthews, 1998; McComas, 2004). According to the *NSES* (NRC, 1996), all science teachers need to understand that science is (a) a collaborative venture requiring a sense of community, (b) flexible and changeable, (c) a human endeavor, (d) influenced by society, culture, and politics, (e) for all people, an observable phenomenon, and (f) inquiry-based to foster understanding of how scientific knowledge is produced. Another standards-based document, *Science for All Americans* (AAAS, 1990), sets forth the basis of scientific literacy as understanding how scientific knowledge is formed through the understanding of NOS. The nine tenets or principles of the NOS state that science is: (a) organized into patterns, (b) tentative, (c) durable and builds upon prior knowledge, (d) not able to answer all questions, (e) observable, (f) logical, yet creative, (g) explanatory and predictive of phenomena, (h) a human endeavor, and (i) social, cultural, and political in nature. If science teachers understand that science is an observable, socially constructed discipline that is produced by humans, then some researchers would contend that these teachers are more likely to achieve standards-based goals set forth by NSES (NRC, 1996) and the recommendations for qualified teachers suggested in *Science for All Americans* (AAAS, 1990).

Why is it important to have a sophisticated understanding of NOS when teaching science? Teachers who are fully aware of and comprehend NOS, while using explicit, reflective instruction, have students who are more scientifically literate (Akerson, Abd-El-Khalick, & Lederman, 2000; Cunningham, 1995; Khisfe & Abd-El-Khalick, 2002). In addition, Wong (2002) stated that teachers who have a greater understanding of NOS and use NOS strategies in their classrooms have a greater chance of demonstrating that science:

- exemplifies a rational perspective on the world (Lederman, 1992)
- translates into students becoming better thinkers (Wong, 2002)
- develops a scientific approach to life's problems and assists students in becoming more active participants in a democratic society (Matthews, 1994)
- creates students who are more informed consumers of scientific information in a world that is quick paced and technologically savvy (Lederman, 1999)
- interests students in science as a career by making it alive, exciting and fun (Wong, 2002)
- utilizes the scientific method that changes in order to keep up with developing technology (Duschl, 1988).

The central principles or tenets of NOS are adapted from the standards-based documents, *NSES* (NRC, 1996) and *Science for All Americans* (AAAS, 1990). Most science education researchers agree that the central principles of NOS include how scientific knowledge is formed, but beyond that, there is little agreement. Nature of science begins with an understanding of how scientific knowledge is formed, but it is much more inclusive.

For this study, I have chosen to define the central principles of NOS as an understanding that science is: (a) tentatively based, (b) empirically based, (c) subjectively interpreted, (d) creatively and imaginatively inferred because it involves humans, (e) distinctively a combination of observations and inferences, (f) socially and culturally embedded, (g) separately understood from technology (but each impacts the other), (h) related kinds of scientific knowledge, laws, and theories, and (i) an understanding of how scientific knowledge is formed.

According to Kelly and Duschl (2002), these central principles of NOS would translate into classroom practices by creating classrooms that demonstrate (a) investigative activities, (b) communicative environments, and (c) epistemic practices. For example, investigative activities using a communicative environment include students engaged in collaborative lab work or field work collecting data. A communicative environment would be further demonstrated by students discussing and sharing the meaning of their results. Finally, epistemic practices could be demonstrated in a science classroom when students gather multiple sources of data and begin to classify and organize the data into patterns. Because of their prior experiences and knowledge, second-career ACTs who have worked in scientific communities performing research may have a better understanding than traditionally-prepared teachers of the central principles of NOS , and of how scientific knowledge is produced. There is little literature available that examines how this previous scientific knowledge and experience that ACTs bring to the field of teaching is translated into classroom practices. This gap in the literature needs further exploration.

Implicit in *NSES* (NRC, 1996) and *Science for All Americans* (AAAS, 1990) science standards based on the central principles of NOS stated above is that science teachers must have an understanding of how science works, which includes the formation of scientific knowledge. Science teachers who have a thorough knowledge of the content, pedagogical content knowledge, and pedagogy incorporate the nature of science throughout their instruction in the classroom. *Science for All Americans (*AAAS, 1990) supports achieving science literacy through an understanding of NOS in the science classroom. All the standards were created to help guide science educators in the classroom. According to the NSTA (2000), the most important outcomes of science are the knowledge that is acquired and the process by which it is acquired; it is imperative that science teachers are able to teach their students how scientific knowledge is acquired, which is one of the most important tenets of NOS.

There is some evidence that teachers who have experience in scientific research have a deeper understanding of NOS than those who have never experienced scientific research (Cunningham, 1995; Veal, 2002). Science teachers' prior experiences and formal education impact their beliefs and how they portray science in the classroom. The NSES requires all science teachers to teach about how scientific knowledge is formed, yet most teachers do not understand NOS (AAAS, 1993; Abd-El-Khalick & Lederman, 2000), which is the foundation of understanding the formation of scientific knowledge. A paradox exists when *NSES* (NRC, 1996) requires science teachers to teach how scientific knowledge is formed, yet most traditionally-educated teachers have never achieved original scientific discoveries, a precursor to the formation of scientific knowledge (Avery & Trautman, 2006). Most traditionally-prepared science teachers have never conducted research, nor ever worked in the scientific community (Kelly, 2000); therefore, they do not know firsthand how scientific knowledge is formed. This is one area in which ACTs may have an advantage over traditionally-prepared teachers.

Many ACTS have conducted scientific research and worked in laboratories, and they directly understand how scientific knowledge is produced (Windschitl, 2004). We need to know more about if and how this knowledge and experience translates into effective classroom practices.

Purpose of this Study

While much is written about the induction programs of ACTs and their deficit preparation, knowledge and/or skills, (Abell et al., 2006; Darling-Hammond, 1989; Darling-Hammond et al., 1989; Greenwood, 2006; Wilson et al., 2002; Wong, 2003), we do not know enough about what second-career science teachers bring to the classroom. I argue that we should shift the study of ACTs from a deficit-based perspective to exploring the strengths they bring to the classroom. These teachers' rich scientific and real-world experiences and knowledge may translate into the kind of robust understanding of NOS called for by *Science for All Americans* (AAAS, 1990) and *NSES* (NRC, 1996). Further, a rich understanding of NOS may lead to standards-based classroom practices. Until now, with a few exceptions (Veal, 2002), researchers have virtually ignored the strengths-based perspective of ACTs. I propose to examine second-career alternatively certified science teachers' understanding of the NOS and how that understanding guides their classroom teaching practices.

Given our current reliance on ACTs to fill persistent science teacher shortages, this research is timely and necessary. Recently, science education scholars also argued for this kind of study. For example, Lederman et al., (2006) suggests that more research comparing the teaching skills, abilities, and attitudes of alternatively certified and traditionally certified teachers should be explored. Veal (2002) called for scientifically based research to study how ACTs learn to translate their content and experiential knowledge into classroom practices. Part of investigating classroom practices includes examining teachers' beliefs and knowledge, which will guide teachers' decisions and behaviors (Pajares, 1992). The fact remains that teachers and what they do in the classroom are the most influential factors in educational change (Duffee & Aikenhead, 1992).

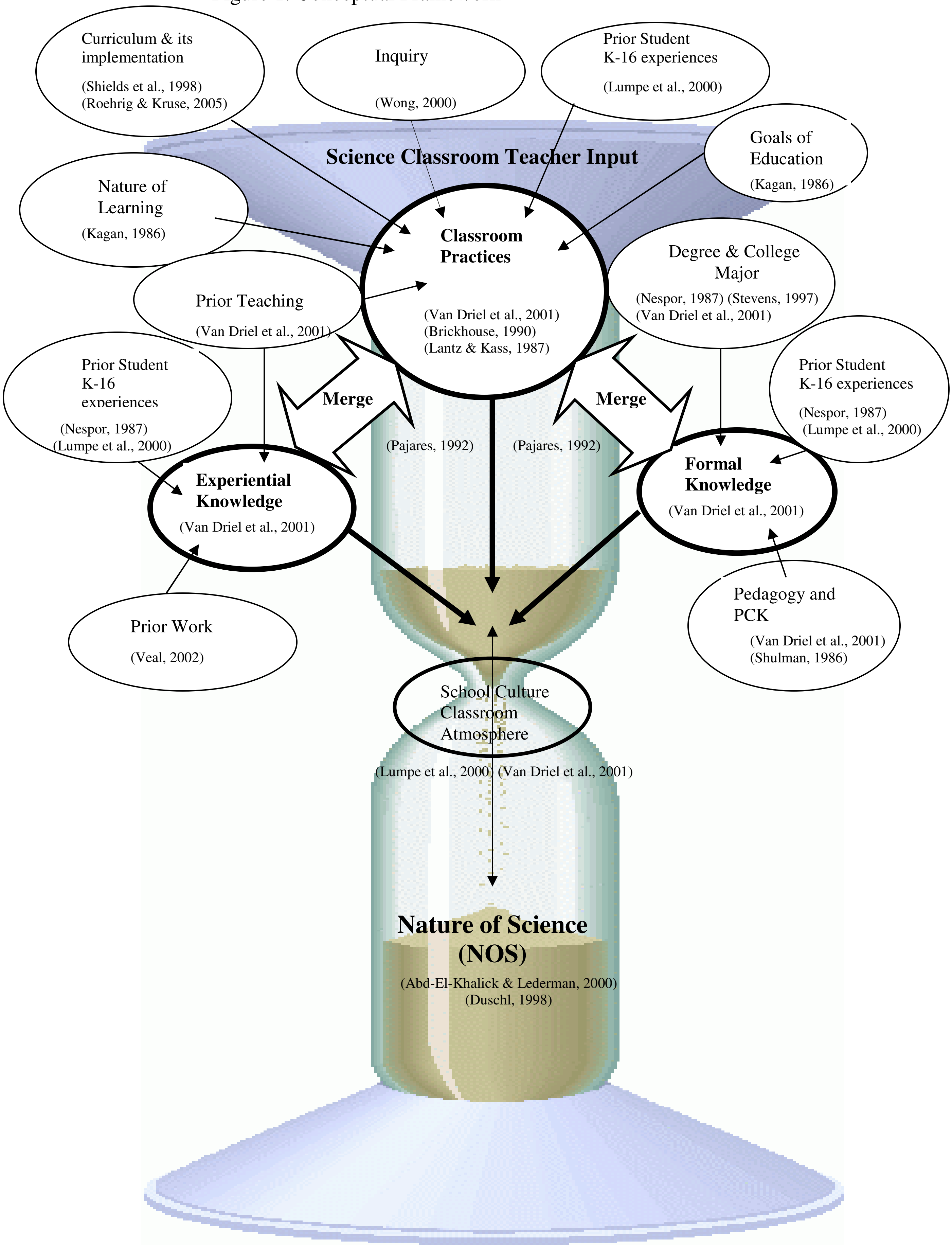
Research Questions

The specific research questions explored in this study are:

1. What are second-career alternatively certified science teachers' understandings of nature of science?
2. How did these second-career alternatively certified science teachers acquire their understanding of nature of science?
3. In what ways do second-career alternatively certified science teachers' classroom practices align with central principles of nature of science?
4. How does the physical environment reflect or contest the nature of science?
5. What do alternatively certified science teachers note as enabling and constraining factors in translating their knowledge into classroom practices?

Though this dissertation is an initial study of second-career, alternatively certified science teachers, their understanding of NOS, and how this understanding impacts their practices in the classroom, this study could also have an impact on how science teachers are

Figure 1. Conceptual Framework



prepared for the classroom based on descriptions of successful models of classroom practices portrayed in this dissertation.

Conceptual Framework

The conceptual framework that supports this dissertation emerged from my synthesis of existing research on this topic and my own professional experiences working with ACT science teachers. Figure 1, the conceptual framework, blends teachers' experiences with their formal knowledge and classroom practices, which are filtered through the context of the classroom to form their understanding of NOS.

Research Design

A qualitative research design, using a multiple case study approach that includes multiple sources of data, was the optimum fit to best investigate the research questions raised in this study. I explored the research questions using five instruments: (a) a background questionnaire, (b) Views of Nature of Science (VNOS) B Test (Abd-El-Khalick, 1997), (c) classroom observation checklist, (d) field notes from classroom observation, and (e) two interviews. I audio-taped the two semi-structured interviews. The two interviews were transcribed and coded. These case studies were constructed from observing the classroom practices of four second-career ACT science teachers as filtered through their understanding of NOS. Creswell (2005) explained that case studies are an in-depth exploration of a specific process, such as classroom practices, using multiple forms of data collection. Limiting the number of teachers and sites studied provided for a more detailed study which allowed for a richer data base from which conclusions could be drawn.

Organization of Dissertation

Chapter One described the purpose and rationale for studying second-career ACT science teachers and their classroom practices as guided by their understanding of NOS. Terms and concepts specific to this study are defined and explained in Chapter One.

Chapter Two contains a comprehensive literature review which examines current and past studies on NOS, including the best and most effective NOS classroom practices. Thorough explanations of the history of NOS, NOS classroom instructional practices, the methodology employed with the best NOS strategies, and alternatively certified science teachers will be detailed in Chapter Two as well.

Detailed study design and methodology will be described in Chapter Three. This chapter will elaborate on how the instruments were chosen or developed and provide descriptions of the selected participants. The validity, reliability and qualitative methods used to analyze the data will be thoroughly described and justified.

Chapter Four will present the findings of this study and analysis of the data. The importance of any study is presenting accurate and clear information derived from the research. The data will be offered in such a way that it can be clearly understood.

Chapter Five will analyze and relate the findings to current literature. I will conclude this study and introduce other studies that can be performed to further these findings. I will organize the data so that others can view it and comprehend it, while being aware of the potential it holds for further analysis.

Terms Defined

Alternative Certified Teachers (ACTs) - qualified individuals who have content-specific knowledge in a subject such as science, which allows individuals to enter the field of teaching, while concurrently obtaining a teaching license

Lateral Entry Teachers– terminology for alternative certification in the state of North Carolina

Nature of Science (NOS) – science is tentatively based, empirically based subjectively interpreted, creatively and imaginatively inferred because in involves humans, distinctively a combination of observations and inferences, socially and culturally embedded, separately understood from technology (but each impacts the other), and a body of laws and theories that provide a clear understanding of how scientific knowledge is formed.

Scientific community - the total body of scientists and their relationships and interactions

Second-career - any individual who worked in the scientific community, at the same profession for three or more years, and is now teaching

Sociological Understanding of Science (SUS) – the understanding that science is placed in a larger social context. Knowledge about science is necessary, but not sufficient, for sociologically informed curricula.

Traditionally-educated Teacher – a teacher who has completed a teacher education program at a college/university and is licensed to teach in that state after completion of the program

CHAPTER II

LITERATURE REVIEW

Chapter two is a review of the literature relevant to this study, which focuses on the five research questions that follow:

1. What are second-career alternatively certified science teachers' understanding of nature of science?
2. How did these second-career alternatively certified science teachers acquire their understanding of nature of science?
3. In what ways do second-career alternatively certified science teachers' classroom practices align with the central principles of nature of science?
4. How does the physical environment reflect or contest the nature of science?
5. What do alternatively certified science teachers note as enabling and constraining factors in translating their knowledge into classroom practices?

This literature review includes the history of the nature of science (NOS), a history of NOS and teaching, a history of classroom practices, a history of alternative certification or ACTs, a brief overview of student understanding of science, a brief overview of teacher learning, and a history of the methodology used in this study.

Nature of science has been a theme of science education since the early 1900s, when John Dewey stated that science-centered concepts seem to specifically underlie scientific inquiry (Dewey, 1910). Additionally, Dewey stated that science is an important area of study because it is more global and includes the whole concept of a democratic society. Dewey declared, "The experimental method is the only way compatible with the democratic way of life" (Dewey, 1910, p.15). He believed that science was much more than just a subject to be taken in school; it was an important part of a democratic lifestyle. Most science educators did not take notice of Dewey's concern about the importance of science education until the early 1960s, when Thomas Kuhn wrote a revolutionary book about science, *The Structure of Scientific Revolutions* (1962). Kuhn (1962), looked at the formation of scientific knowledge differently than it ever had been investigated before, exploring how it was formed and how it related to NOS. Additionally, Schwab (1964) stated that if teachers were made aware of how scientific knowledge is formed, they would understand that science is not just a group of lists and facts, and would perhaps teach differently. Currently, most educational scholars and researchers agree that a general definition of NOS typically refers to the epistemology of science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge. Yet most science courses, including science teacher education courses, usually demonstrate a static science with a great wealth of knowledge held only by scientists, rather than exploring science as a way of knowing (Davis, 2003).

History of the Nature of Science

With few exceptions, prior to Kuhn's revolutionary book, *The Structure of Scientific Revolutions* (1962), science education was mostly focused on developing a normative logical account to justify scientific claims rather than understanding how science works. Additionally, most of the science educators prior to 1962 were also concerned with developing a context of justification (a statement of the scientific claims) not a context of discoveries (an understanding of how and why) of science (Popper, 1959). However, there were others, such as Merton (1949), who were stepping out of the traditional philosophy of science education and pioneering a concept to provide an account of the social structure of science. Merton's new trends helped pave the way for the shift and introduction to the philosophy led by Kuhn, which introduced an interest in context of discovery of science and not the justification of science. Kuhn (1962) designed a revolutionary account of how scientific knowledge was formed and accepted within the scientific community and society. He looked at the history of science, not just the innovations or discoveries of science. Shortly thereafter, Collins and Pinch (1985) began to produce genuine sociological accounts of the production of scientific knowledge. At the same time, LaTour and Woolgar (1986) did extensive studies of science laboratories and examined the nature of collaboration and the formation of scientific knowledge within these scientific communities. They explored, in great detail, typical traditions and habits of scientific communities within research laboratories. All of this newly found knowledge about science education opened the door to questions about how and what science educators were teaching our nation's science students.

During the early 1960s, Pre-Kuhnian science education philosophy emphasized inquiry lessons and science process skills, such as observing, hypothesizing, inferring, interpreting data, and designing experiments. With the introduction of Kuhn's philosophy, a universal definition of NOS began to emerge, and the science education community began to take notice. Kimball (1968) defined eight guiding principals for

NOS. Science is a(n): (a) driving force of curiosity, (b) ongoing and dynamic study of specific content, (c) understanding and simplification of scientific knowledge, (d) endeavor that uses a variety of methods for discovery of scientific knowledge, (e) evolving combination of methods characterized by attributes described by values, not techniques (process over product), (f) understanding of human susceptibility and interpretation of the physical universe, (g) understanding that must have openness of mind, and (h) acceptance of tentativeness.

Researchers developed NOS inventories, many with quantitative components, to measure what teachers and students knew about NOS. The following NOS inventories were developed and administered during the 1960s:

(a) Cooley /Kloper 1961	*Test on Understanding Science (TUS)*
(b) Welch/Pella 1967-68	*Science Process Inventory (SPI)*
(c) Kimball 1967-68	*Nature of Science Scale (NSS)*

These tests were all forced choice tests that did not allow the participants to insert their own views. The participants were forced to choose an answer that was available, even if they did not totally agree with it.

During the 1970s, little research on NOS was done that expanded the understanding and/or definition of NOS, with the noted exception of Rubba and Andersen's work (1978). They took Kimball's eight principles of NOS and condensed them to six factors that defined NOS as: (a) amoral, (b) creative, (c) developmental, (d) simple, (e) testable, and (f) unified by laws, theories, and concepts. Increased research created more knowledge about NOS inventories that added to the understanding of NOS, which led to the development of more ways to measure student and teacher understanding of NOS. Billeh and Hasan (1975) created the *Nature of Science Test* (NOST) and Cotham and Smith (1981) created the *Conceptions of Scientific Theories Test* (COST), continuing the use of the forced choice NOS inventories.

The National Science Teachers Association (NSTA) (1982) acknowledged an inadequate understanding of NOS among our nation's science teachers and students. NSTA (2000) continued to detail and expand their statement of what NOS included: an understanding of the empirical and tentative nature of scientific knowledge, with an understanding that two of science's central tendencies are inquiry and the role theory plays in the formation of scientific knowledge.

In the 1990s, nearly a century after the first call for NOS reform, two major documents created a national plea for major reform in science education, *Science for All Americans* (AAAS, 1990) and *National Science Educational Standards* (NSES) (NRC, 1996). *Science for All Americans* (1990) outlined three major components for basic understanding of NOS:

(a) science is tentative and does not answer all questions

(b) science is creative and a human endeavor, and NOS is based on inquiry that relies on logic, empirically based observations, or data

(c) science is socially and politically embedded.

Science for All Americans (AAAS, 1990) further condensed the research on NOS to attempt to make it understandable and attainable for our nation's science classroom teachers. *National Science Educational Standards (NSES)* (NRC, 1996) were created to address the definitions of what science education should teach. The standards emphasized that NOS is based in a historical context, it is tentative, empirical, logical, laced with skepticism, full of open communication, and embedded with personal, societal, and cultural beliefs.

Today, science educators still struggle with the understanding of NOS and how to incorporate it into their daily activities in the classroom. Many researchers and science teacher educators provide guidance for science teachers and continue to explore NOS.

History of Nature of Science and Teaching

Early in the twentieth century, educational experts such as John Dewey suggested that science teaching had an epistemological dimension that was being ignored. An English inspector of schools and author of science education textbooks, Westaway (1929), defined a successful science teacher as one who understood the subject well, had knowledge in other branches of science, could speak well, understood how math and science work together, was something of a philosopher, and could place science in a historical context. Almost 80 years later, science educators today are still struggling to create a science classroom using Westaway's criteria. Teaching science so that a child loves science and wants to become a scientist involves much more than just classroom management, instructional strategies, and lesson planning. Current research indicates that teachers and students still do not have an adequate understanding of NOS (Aikenhead, 1973; Brickhouse, 1990; Bell, Lederman, & Khalick, 1997; Duschl, 1985). Having an understanding of NOS requires that NOS is embedded in instruction (Lederman & Lederman, 2004). McComas (2002) continues to try to reach science teachers and increase their understanding of NOS by offering teaching strategies and ideas by using NOS practices and publishing these ideas in teacher practitioner magazines, such as *The Science Teacher.* These short articles present key ideas based on scholarly literature of NOS to shape instruction; many of the articles give detailed lesson plans with references and background knowledge to help teachers with their classroom practices. An understanding of NOS creates a distinctive science classroom that encourages curiosity, inquiry, and investigations (McComas, 2004). Therefore, science teachers must develop an understanding of NOS in order to impact student learning and to be effective science teachers.

During the mid-1980s, the National Research Council (NRC, 1996) released the *National Science Education Standards* (*NSES),* which were written to address concerns calling for reform in science education. These standards represented a bold statement of what it would take to graduate scientifically literate citizens from our nation's school systems. Scientifically literate citizens are able to make personal decisions in the areas of science and technology, allowing them to participate fully in a democratic society (Dewey, 1910).

National Science Education Standards (*NSES)* (NRC,1996) specifically call for the inclusion of the teaching of NOS embedded throughout the entire curriculum as a strand in all science courses and at all grade levels. The *NSES* also require teachers to have a basic understanding of the history of science (HOS) and NOS at the elementary, middle, and high school levels. From elementary school to high school, one focus of *NSES* is that science is to be taught as a human endeavor, and is therefore tentative and creative at the same time. How are teachers to develop instructional strategies to teach this tenet of NOS when their knowledge of NOS is limited or nonexistent? By the summer of 2008, in compliance with *No Child Left Behind* (2002), quantitative data will be available showing elementary and middle school students' understanding of NOS, drawn from the recent federally mandated science test required of all fifth and eighth grade science students. Many intervention programs have been developed and implemented to increase the understanding of NOS in the science classroom.

Billeh and Hasan (1975) did a study using an intervention program on the understanding of science, which embodied many of today's principles of NOS, measuring the change in teachers' understanding of NOS. The summer intervention program addressed science content knowledge, introduced guided inquiry laboratory investigations, presented fifty minute lectures on the importance and use of NOS in the classroom, and explored enrichment activities for high school science classrooms. *Nature of Science Test* (*NOST*), a NOS inventory test, was given to the teachers before and after the intervention program to assess their understanding of NOS. Significant increases in the mean averages of the understanding of NOS among chemistry, physical science, and physics teachers occurred, but, surprisingly, not among biology teachers. During the four-week summer intervention program, the biology teachers did not get an opportunity to attend the fifty minute lecture on the importance and use of NOS in the science classroom. The researchers concluded that the formal and intentional lectures on NOS had a major impact on the results and increased understanding of NOS among teachers participating in the intervention program.

Lederman (1992) continued to develop evolving comprehensive research on NOS. His four lines of study about NOS include: (a) assessment of student conceptions of NOS, (b) development, use, and assessment of curricula designed to 'improve' student conceptions of NOS, (c) assessment of, and attempts to improve, teachers' conceptions of NOS, and (d) development of the relationship among teachers' conceptions of NOS, classroom practice, and students' conceptions of NOS. Lederman's line of research was logical because he first looked at the students' understanding of NOS and found that it was inadequate. He then looked at the curriculum to see if it was successful or needed improvement to increase the students' understanding of NOS. Lederman developed several units and topics placing science in its historical, sociological and societal context to improve students' understanding of NOS. All of this curriculum development neglected to account for the influence classroom teachers have on their students' understanding of NOS, which led to the third line of research.

Two major curricula were adopted in schools to help teach NOS views: *History of Science Cases for High Schools* (HOSC) (Kloper & Watson, 1957) and the *Harvard Project Physics* (HPP) course (Rutherford, Holton, & Watson, 1970). At first glance, researchers falsely concluded that student gains in understanding of NOS were independent of teacher input. Later, teacher input was re-examined after pre-testing the teachers, and accounting for and controlling for teacher experience and student prior knowledge in the study. Lederman and Zeidler, (1987) found that different teachers obtained different results when a similar NOS science unit was developed and taught.

As Lederman continued to teach NOS and examine teacher beliefs, he realized that an understanding of NOS did not always translate into classroom practice. This led to his fourth line of research. This complex line of research identified the relationships between teachers' understanding of NOS, classroom practices, and the students' understanding of NOS. Before this line of research, it was thought that an individual's understanding of NOS automatically translated into classroom practices using NOS philosophies. While Lederman explored the fourth line of research, he also discovered that observing classroom practices became very complex due to the following factors in a classroom: (a) teacher content knowledge, (b) teacher classroom management, (c) student motivational concerns, (d) school institutional constraints, (e) years of teaching experience, (f) teacher understanding of NOS, and (g) lack of resources in the science classroom. Lederman (1992) concluded, "Translations of teachers' conceptions into classroom practice indicates, and rightly so, that even though teachers' conceptions of NOS can be thought of as a necessary condition, these conceptions, nevertheless, should not be considered sufficient" (p. 342). However, he concluded the following factors are NOT related to a teacher's understanding of NOS: (a) thinking ability (logic), (b) calculating and quantitative aptitude, (c) speaking well, (d) managing a classroom, (e) teaching level (e.g., elementary versus secondary), (g) teaching different science subjects (e.g., biology versus physics), (h) training or professional development, (i) teaching through field-based experiences, and (j) years of teaching experience in years.

Cunningham (1995) found that most practicing teachers form their understanding of NOS through textbooks because they are not exposed to rich, real, laboratory experiences, other than those required in their college coursework. She believed that individuals who come into the classroom from the scientific community have the potential of having a better understanding of NOS due to their rich, real, laboratory experiences. Her research explored sociological understanding of science (SUS), a significant component of NOS, that encompasses the understanding of both subject-matter and pedagogical content knowledge (Cunningham, 1995). She claimed these seven assertions from her study: (a) stronger SUS teachers have classrooms that function more like scientific communities, (b) stronger SUS teachers situate their courses in a broader context such as other sciences, other courses, the community, and the world, (c) higher level SUS classrooms teachers have much more flexibility, (d) higher level SUS classroom teachers convey information about science in a more authentic manner, (e) higher level SUS classroom teachers have more contact with real research science, or some controversial topic or problem-based community research, such as citizen science, (f) stronger SUS teachers create original, complex, and innovative units, and (g) stronger SUS teachers' philosophy about the purpose of school science influences what is taught in a classroom. According to Cunningham (1998), science lessons need to accurately represent the practice of science and its interactions with society. Science teachers who demonstrate science as "messy", socially relevant, creative, open-ended, and socially responsible have a stronger sociological understanding of science.

Brickhouse and Bodner (1992) both believed that teachers need more than just book knowledge to fully understand and teach philosophy and history of science studies. Future teachers must be taught how to infuse or embed what they know about the philosophy and history of science into their classroom practices. McComas (2004) agreed with Brickhouse and Bodner (1992) that students will not understand NOS fully by doing only hands-on science activities or inquiry labs; teachers must directly instruct about NOS. Billeh and Hansan's (1975) intervention program on teachers' understanding also supported the positive effects of direct instruction on NOS. Additionally, McComas (2004) specifically believed that teachers must be taught how to embed NOS strategies directly within inquiry teaching strategies and activities. Furthermore, Southerland, Gess-Newsome, and Johnson, (2003) found that teachers who present from a scientists' point of view is not enough; they must have an understanding of NOS and present it to the students directly in order to complete a student's science education. In order for students to understand NOS, teachers must instruct directly about NOS, not just have an understanding of NOS.

Matthews (1998) firmly believed that distinguishing between science and pseudoscience and teaching good science in the classroom depends on a full and complete grasp of NOS. Matthews also believed that all students of science need to wrestle with the basic philosophical questions of science that begin with: What do you mean? and, How do you know?

Recently, Bartholomew, Osborne, & Ratcliff, (2004) did a study which confirmed that most teachers still do not have a clear understanding of NOS. Most teachers have no recognition about the tentative NOS, and still teach science from the positivist or empiricist view (one truth). Positivist science always has one correct answer to solve a problem, which is occasionally understood as the one truth. This study also concluded that teachers' conception of NOS does not always translate into practice and effective pedagogy. Teachers must allow and establish a context in which it is possible for students to engage and participate in reflective epistemic dialogue. Epistemic dialogue would engage students in a discussion about how scientific knowledge is formed. In this age of quantitative testing, teachers are in conflict over product versus process in the science classroom; therefore, they do not engage in enough reflective classroom practices. Bartholomew, et.al., (2004), proposed that teachers must allow reflection time in the classroom to promote student understanding of NOS.

Windschitl (2004) studied fourteen preservice teachers and found that teachers who had either significant research experience in the scientific community involving original research or had more extensive scientific content knowledge, such as holding advanced science degrees, did more inquiry-based activities in the classroom. Inquiry-based science classrooms tend to reflect a teachers' increased understanding of NOS (Wong, 2002).

In contrast to Cunningham's findings, other scholars have found that teachers' understandings of NOS does not correlate to their classroom practices (Abd-El-Khalick, 1998; Brickhouse, 1990). A closer look at this body of research reveals that it has generally been limited to traditionally-educated teachers (Abd-El-Khalick, 1998; Bartholomew et al., 2004; Brickhouse, 1990 & Lederman, 1999). Most traditionally-educated teachers do not have direct experience in the scientific community or direct exposure to an independent research component in their teacher education preparation, both which tends to promote a classroom with more inquiry-based learning (Windschitl, 2004).

History of Classroom Practices

Focusing on classroom practices is important to this study because of the influence it has on student learning. Research foci on variables that influenced student learning have changed over time from a focus on the effects of positive leadership at the school and district level (Daniel & Grobe, 1981) to the effects of content coverage (Stevens, 1997), then to the effects of teachers' exposure to professional development (Guskey & Sparks, 2002 & Stepanek, 2000), and currently to the effects of teachers' classroom practices on student learning (Bayazit & Gray's, 2004; Cochran-Smith, 2002; Lauer, Snow, Martin-Glenn, Stoutemeyer, & Snow-Renner, 2005; Darling-Hammond, 1998; National Education Goals Panel, 1998).

Quality of teachers remains the most important influential factor in predicting the achievement level of a student and in educational change; therefore, we must examine the teachers and their classroom practices (Darling-Hammond, 1999; Duffee & Aikenhead, 1992). Lederman (1992) identified a complex relationship between the science teachers' understanding of NOS, classroom practices, and the students' understanding of NOS. Classroom practices have evolved from the presentation of science as a rigid body of facts, theories, and rules to be memorized and practiced. Some teachers clung to these methods of teaching, whereas others embraced the change. In the early 1960's, pre-Kuhn, teachers were emphasizing scientific method through scientific inquiry and hands-on activities. Kuhn (1962) forced science educators to look at teaching science in a different way. This call for reform in science education created some new goals in teaching science (AAAS, 1993; NRC, 1996).

Instead of transmitting science as a rigid body of facts, the emphasis in science teaching would be on designing situations with a variety of activities. This classroom practice was derived from the reform goal that science is an active process and should be hands-on and minds-on in the science classroom (AAAS, 1993; NCR, 1996). Curriculum was designed to focus less on content and more on reflection, and engaging active thought among science students (Millar & Osborne, 1998). The change in emphasis also introduced the idea of identifying student misconceptions prior to teaching new ideas.

Teachers were also confronted with the challenge of creating a science classroom that was open and accepting of all students, not just the science elite. Again, there came a call for all teachers to embed NOS in all aspects of their science teaching with an intentional direct instruction of NOS (NSTA, 1982). While some science teachers embraced these reforms, others refrained from implementing them. Bricker (2005) advocated an inviting science classroom atmosphere with ample tools and space available for students to engage in hands-on science activities. She believed it is very important for the science teacher to develop into a classroom facilitator who allows ample time for reflection.

The preparation of teachers capable of the science reforms listed above necessitates a new brand of teacher preparation programs due to the many different individuals entering the teaching field today. The National Commission on Mathematics and Science Teaching (NCMST) for the 21st Century asserted, “the most direct route to improving science and mathematics achievement for all students is to better mathematics and science teaching." (NCMST 2000, p. 7).

History of Alternative Certification and ACTs

Alternative teacher certification is a broad term that has been used to refer to non-traditional routes of entry into the teaching profession. According to the National Center for Educational Information (2002), from 1999-2002, approximately 25,000 teachers nationally have been licensed through alternative routes. Alternative teacher certification has taken many avenues, from emergency licensure issues with as little as ten days' preparation, to well developed programs that require two years of preparation, including several field experiences. Darling-Hammond (1989) did an analysis of 89 alternative certification programs and concluded that the length of various programs ranged from 16 weeks to two or more years and the credits ranged from nine to 45. Schools of education are not producing enough teachers to fill the science classrooms; therefore, most states are allowing individuals to enter the teaching field via alternative certification. For example, according to the *Charlotte Observer* newspaper (Bethea, 2006), one North Carolina school district is recruiting science and mathematics school teachers from the Philippines, nearly 9,000 miles away.

It is crucial that school systems understand who they are hiring, so they can best educate and prepare them for the classroom. Significant evidence shows that student achievement is associated with teacher qualification, which includes professional development as well as preparing and educating well-qualified teachers (Darling-Hammond, 2000). Darling-Hammond (1999) found that well prepared teachers, with full certification and a major in their teaching field, are a more powerful predictor of student achievement than teachers' educational levels (master degrees).

Particularly, mathematics and science teachers are identified in school districts as individuals who lack state teaching certification in their fields. Nationally, 28-33% of all mathematics teachers and 18-20% of all science teachers lack teaching licenses when they enter the classroom to teach (Ingersoll, 1999; Olson, 2000). Yet, over the past decade, the demand for secondary teachers, especially in mathematics and science, has increased by 22% (Abell et al., 2006). Thirty-six percent of schools with vacancies in physical science found it difficult to fill 20% of those positions with fully licensed teachers. Equally as difficult, 32% of schools with vacancies in life science found it difficult to fill 16% of those positions with fully licensed teachers.

According to the United States Department of Education (2000), school districts across the nation will need two million more teachers in the next decade, creating a national shortage of fully licensed teachers in all content areas. Consequently, each state has developed and created an alternative certification program with the assistance and cooperation of local colleges and universities. These programs allow individuals with life experience, a desire to teach, and a minimum of a bachelor's degree in their chosen subject area an avenue to pursue a career in teaching. Kwiatkowski (1999) compiled data indicating that between 1983 and 1996, more than 50,000 individuals in the United States received alternative teaching certification. This trend of alternatively certifying teachers is expected to accelerate with the anticipated teacher shortage due to teacher retirement and growth in the number of school age children. The most critical needs for teachers are in the areas of mathematics, science, technology, and foreign language, requiring school districts to gather the next generation of teachers from pools other than schools of education exclusively.

According to the state of North Carolina (2005), by 2010 the total teacher need will be 5,236 teachers: 2,198 of these teachers will be ACTs, and the remaining 3,038 entering teaching through North Carolina public colleges and universities will fill our nation's classrooms.

In North Carolina, the term lateral entry is used to define an alternative route to teaching. In North Carolina, as in most states, there are eligibility requirements for entering the classroom, through an alternative certification route, including at least a bachelor's degree in the chosen content area, and the following:

- gainful employment in a North Carolina school district
- a minimum grade point average (GPA) of 2.5 on a 4.0 scale

  OR
- successful completion of the PRAXIS I test plus one of the following:
    - GPA of 3.0 in the major field of study
    - GPA of 3.0 in all senior year courses
    - GPA of 3.0 on a minimum of 15 semester hours of courses, (related to the chosen content area), completed over the last five years.

The federal legislation, *No Child Left Behind* (2002), further muddies the licensure waters by requiring that all teachers are highly qualified by the 2006 – 2007 school year.

According to the federal government, this means that they are experts in their content areas. In fact, most ACTs meet this requirement due to their extensive content area coursework in college.

School districts rely on many national programs that draw some of the nation's brightest young people into the field of education for a short period of time, such as *Teach for America* and *Troops to Teachers*. While these programs recruit emphatic, young, bright people into the field of education, many of them stay only the required amount of time, approximately two years. Another innovative program is International Business Machine's (IBM), *The Reinventing Education Grant Program,* which recruits scientists, researchers, technology experts and educational consultants from IBM to enter the field of teaching as they approach retirement age. IBM has created many incentives for these early retirees to consider a second career in education. The company pays for these individuals to complete their licensure and supports them financially for two years while they adjust to a teacher's salary. These individuals from the scientific community bring with them a unique quality in that they possess vast experience that most traditionally-educated science teachers do not have, including personal experience with the scientific process (Veal, 2002).

Veal's (2002) research on mid-career scientists entering the field of teaching found that teachers integrate their prior knowledge with curricular knowledge to form their PCK. Veal's study (2002) indicated that second-career ACT science teachers integrate and connect experiential knowledge with content area knowledge, which helps students merge the content knowledge from their science classes with everyday science.

Second-career ACT science teachers' experiences and prior knowledge may give them a better and more complete understanding of the NOS (McDonald, 2006). During my pilot study of second-career ACTs, I found that those teachers who possessed advanced science degrees, developed and experienced scientific research, and practiced some informal teaching had a more informed view of NOS. Through their classroom practices, they also demonstrated a more informed view of NOS, especially in elective science classes. Based upon my classroom observations and their administrators' formal observations, second-career ACT science teachers demonstrate thorough and advanced content knowledge: one of the components that affects classroom practices, according to Van Driel, Beijaard, & Verloop, (2001).

Alternatively certified teachers are a part of every school district's teaching population; therefore, studies must be done to investigate what knowledge these teachers bring into the classroom. Zeichner (2005) clarified that it is very important for researchers to understand how teachers use the knowledge they bring with them into the classroom. Lederman et al., (2006) believes that teachers who are completing alternative pathways are currently doing as well in the classroom as those completing traditional programs; however, the first few years of all teachers' careers are primarily occupied with classroom management and adjusting to all of the demands of first year teachers, including classroom organization and learning the curriculum.

Many second-career ACT science teachers have worked in the scientific community doing research, and have created scientific knowledge (Thrasher, 2006). Therefore, second-career ACTs' past experience within the scientific community may contribute to a better understanding of NOS and, consequently, a deeper understanding of how scientific knowledge is created.

Overview of the Performance of Science Students in the United States

Scores from an international test, *Trends In International Math and Science Study* (NCES, 2004), indicate that our nation's fourth graders rank sixth in science understanding out of 24 other industrialized nations, and our eighth grade students rank ninth in science understanding out of 44 countries. However, as our science scores begin to climb for our secondary science students internationally, our number of college science majors continues to decline (Seymour & Hewitt, 2000). Many colleges presently have a lower enrollment in science majors than they did a decade ago, leading to fewer scientists seeking education degrees in the United States (Seymour & Hewitt, 2000). In the United States in 2001, universities awarded 2,710 doctoral degrees in science and engineering, as compared to 2,880 doctoral degrees awarded in 1999. The United States now ranks 27th in producing undergraduates with science and engineering degrees, as opposed to third internationally in 1975 (Seymour & Hewitt, 2000). Increasingly, we are depending on international scientists to fill our science deficit, according to science and engineering indicators compiled by the National Science Foundation (NSF) in 2002. In 1999, over 50% of all our civil engineers with doctorates working in the United States were foreign born (National Science Board [NSB], 2003). Both our country's leaders and science educators have called for reform in science, requiring educators to teach rigorous science. President Bush, in his State of the Union address on January 31, 2006, proposed to bring 30,000 mathematics and science professionals to teach in our nation's classrooms. One must presume a large percentage of President Bush's professionals will be ACTs. As new teachers enter the classroom, those who prepare them must understand how teachers learn.

A Brief Overview of Teacher Learning

Shulman (1986) developed an understanding of the seven ways teacher knowledge is formed. It is an understanding of: (a) content knowledge, (b) pedagogy, (c) curriculum, (d) learners and learning, (e) contexts of schooling, (f) pedagogical content knowledge, and (g) educational philosophies, goals and objectives. Shulman (1986) also proposed that teachers' content knowledge is translated into classroom practices which blend an understanding of pedagogy with content knowledge, and is known as pedagogical content knowledge (PCK). PCK is composed of a teacher's understanding of four component areas: subject matter and content knowledge, student characteristics, pedagogy, and environmental context of learning. Grossman (1990) furthered Shulman's concept by defining four sources used to develop PCK: (a) observation, (b) disciplinary education, (c) specific courses taken during teacher education, and (d) classroom teaching experience.

My observations of ACTs have determined that all, or most, of the above are usually lacking in ACTs' experience before entering the classroom. Except for their understanding of content area, most ACTs lack PCK; they will learn it through professional development, classroom experience and/or the required coursework while they are obtaining their state licensure and/or an advanced degree.

History of the Methodology

This study of second-career lateral entry science teachers' classroom practices as directed by their understanding of NOS will require the use of qualitative methods because of the nature of the research questions asked. Originally developed in the late 1800s and early 1900s, qualitative research was created mostly for anthropological studies of cultures, social studies of immigrants in urban environments, and studies of poor urban communities in Europe (Bogdan & Biklen, 1998).

However, widespread use of qualitative design did not appear in educational research until about 30 years ago (Creswell, 2005). According to Creswell, the history of educational qualitative research has three themes: philosophical ideas, procedural developments, and participatory/advocacy practices. In the late 1960s, philosophers of education called for an alternative method to analyze and interpret educational research (Guba & Lincoln, 1988). They felt that the traditional approach took situations out of context, and placed it into an experimental situation which did not allow for the participant's view, rather relying only on the researcher's point of view. Introducing this new method of research emphasized the importance of the participant's view, allowed the setting or context to be introduced, and highlighted the personal meaning of education for the individuals involved in the study. This methodology allowed researchers to ask general, open questions and collect data within the classroom, where the greatest number of educational practices occur.

Tesch (1990) identified 26 different types of qualitative research used in educational and psychological studies; among them case studies. Case studies are a specific type of ethnographic research that involves in-depth and intensive study of an individual or a group as an entity, through direct observation, self-reports, interviews or any other means (Langenbach ,Vaughn, & Aagaard, 1994; Tesch, 1990). This study is a multiple case study of four second-career ACT science teachers. Observations, interviews, questionnaires, and surveys were utilized to collect data about this group of individuals.

Holstien and Gubrium (1994) sought to identify and clarify the key characteristics of phenomenology as the study of the way in which members of a group or community themselves interpret the world and life around them. Questions such as, "What is the participant's experience like?" are asked. The researcher's intent is to represent and understand from the participant's point of view. Observation occurs in the naturalistic setting in order to capture the participant's behaviors as they naturally occur (Adler & Adler, 1994). Observations during this study will be taken in the teacher's classroom during instruction to capture and represent a naturalistic setting. Spradley (1980) identifies five types of participation during the observation: nonparticipation, passive participation, moderate participation, active participation, and complete participation. Researchers are emphasizing more participation in the observation to gain more complete insight in the study. This study will engage the observation as passive participation so that the observation depicted will be a true reflection of the teachers' classroom practices.

Limited observation allows collection of information through direct contact; however, it does not always permit intimate, repeated, and prolonged involvement in the life of the community (McCracken, 1988). Therefore, another frequently used qualitative method is participant interviews. Generally, interviews are done in a minimally structured format to grasp the participant's full understanding or meaning (Mertens, 1998). This study will employ two semi-structured interviews to allow the teachers to clarify and detail their answers, views, and choices on all of the instruments used during this study.

While qualitative methods for research are relatively recent, they are gaining importance and acceptance. It is extremely difficult to grasp an individual's perspective using quantitative data that focuses on collecting and analyzing information in numerical form or comparison data of student achievement tests.

Summary

This study utilizes and draws upon the past literature concerning the history of NOS, the history of NOS and teaching, the history of classroom practices, the history of alternative certification in teaching, an overview of the performance of science, a brief overview of teacher learning, and the history of the methods used in this study. Using past research and studies will help direct this study.

CHAPTER III

METHODOLOGY

Introduction

Exploring science ACTs' prior knowledge and experience as demonstrated through their classroom practices, as guided by their understanding of nature of science (NOS), resulted in a complex and detailed case study using a qualitative research design. This chapter begins by describing the research questions as they evolved from the conceptual framework (see Figure 1), and a brief overview of the results from a pilot study that was comparable in design to this study.

This chapter also provides a detailed description of the qualitative methodology, including: selection of the participants, instruments, design of the study, time-line, and procedures for data collection and analysis. Data collected from the semi-structured interviews and the *VNOS B Test* were analyzed using qualitative methods of coding, searching for patterns, and then identifying categories through hand-scoring. Methods of data analysis included a thoroughly detailed description of the triangulation of the data. The chapter concludes with a summary.

Second-career ACT science teachers are entering the classroom with a set of skills and prior knowledge from their previous job experiences. Some of these teachers bring with them scientific research experience. According to the *NSES* (NRC, 1996), teachers must have an understanding of NOS in order to teach NOS, and teaching NOS is a standard for all science teachers. Teachers who fulfill all of the *NSES* standards will be the best science teachers for the classroom (NRC, 1996). Veal (2002) claims these individuals with experience in scientific research often bring real world science experience with them that may include a better understanding of NOS. Does this previous experience translate into their classroom practices? According to many educational researchers, teachers' classroom practices have a dominant influence on student achievement; therefore, their classroom practices are the focus of this study (Bayazit & Gray's, 2004; Cochran-Smith, 2002; Lauer et al., 2005; Darling-Hammond, 1998; National Education Goals Panel, 1998).

Teachers' classroom practices constitute a complex, integrated matrix consisting of teachers' knowledge and experience developed in the context of a teaching situation, and then merged by incorporating their formal knowledge and experiential knowledge (Van Driel et al., (2001). Nature of science (NOS) is a unique component demonstrated in the science classroom. Teachers' understanding of NOS must be measured, observed, interpreted, and understood if we are concerned about or interested in studying ACTs in science.

Classroom practices are demonstrated during instruction through actions which provide evidence of a teacher's knowledge and experiences (Van Driel et al., 1998). However, Pajares (1992) stated that practices and experiences can become intertwined as teachers gain experience in the classroom. Ideas about teaching begin to take shape early as a student and then continue to develop as one enters the teaching field (Lumpe et al., 2000). All teachers enter the classroom having at least sixteen years of experience as students, and having already established well developed beliefs about education from an "apprenticeship of observation," according to Lortie (1975). These beliefs are representations or personally held theories that are often difficult for less informed teachers to articulate (Nespor, 1987). Beliefs can include teachers' ideas about the influence that administrators have on the school culture, or the effect state assessments have on curriculum development. Many educational researchers agree that teachers' beliefs guide the actions of their classroom practices (Lantz & Kass, 1987; Brickhouse, 1990; Verloop, 1992). Important to this dissertation is the assumption that teachers' classroom practices play an active and direct role in student learning.

Research Questions and Conceptual Framework

This case study examines second-career alternatively certified science teachers and their classroom practices as filtered through their context to reveal the teachers' understanding of NOS. The research questions addressed in this study include:

1. What are second-career alternatively certified science teachers' understandings of nature of science?
2. How did these second-career alternatively certified science teachers acquire their understanding of nature of science?
3. In what ways do second-career alternatively certified science teachers' classroom practices align with the central principles of nature of science?
4. How does the physical environment reflect or contest the nature of science?
5. What do alternatively certified science teachers note as enabling and constraining factors in translating their knowledge into classroom practices?

Conceptual Framework (see Figure 1)

While Van Driel's et al., (2001) research supported this dissertation, the conceptual framework explains the main components or key factors to be studied (see Figure 1) (Miles & Huberman, 1994). This conceptual framework is symbolized by an hourglass filled with sand to represent the main factors that stream together to form the teachers' understanding of NOS. Many times, experiential knowledge, classroom practices, and formal knowledge merge, making it difficult to distinguish the source of the behavior exhibited in the classroom (Pajares, 1992). All classroom practices are understood within the context of the school culture and classroom atmosphere. Understanding how second-career science teachers' experiences influence their classroom practices and reveal their understanding of NOS is worthy of investigation because, presumably, these experiences determine many of their classroom practices and classroom practices impact student achievement.

As can be seen in Figure 1, the four major influences on NOS are represented by the bold ovals: (a) classroom practices, (b) experiential knowledge, (c) formal knowledge, and (d) classroom atmosphere. These four influences will be examined in this study (Kagan, 1992; Van Driel et al., 2001). As teachers gain experience in teaching, the three influences of

classroom practices, formal knowledge, and experiential knowledge begin to merge, and the ovals begin to overlap (Pajares, 1992). For example, when a pedagogical strategy, such as inquiry, is part of a teacher's knowledge and she gains teaching experience with this strategy, she then implements it in her classroom. Therefore, formal knowledge and classroom practices begin to overlap.

Science teachers' classroom practices are a unique and individual blend of instruction that combine understanding of the nature of learning, prior teaching experiences, prior school experiences, prior job experiences, understanding of the goals of education, college majors, general pedagogy and pedagogical content knowledge (PCK), classroom management skills, and the understanding of a teachers' role in the classroom (Brickhouse, 1990; Kagan, 1986; Lantz & Kass, 1987; Lumpe, Haney, & Czerniak, 2000; Nespor, 1987; Van Driel, et al., 2001; Veal, 2002). Choosing the appropriate classroom practices may increase a student's understanding of NOS; therefore, examining classroom practices is very important (McComas, 2004).

Many times there is a compartmentalization of one or all of the three major components of this conceptual framework (classroom practices, beliefs, experiential knowledge, and formal knowledge) when a teacher does not have a clear understanding of NOS (Roehrig & Luft, 2004). Experienced teachers often blend these three main influences as represented by the narrowing of the hourglass in Figure 1, where they become streamed together and filtered through the context of the individual classroom. For example, some teachers may have a thorough understanding of NOS which touches every aspect of their teaching (equivalent to every grain of sand in the hourglass) and is reflected in their classroom practices. While Cunningham (1995) found when teachers demonstrate a clear understanding of NOS, that understanding is sometimes reflected in their classrooms practices. Abd-El-Khalick (1998) and Brickhouse (1990) did not find a relationship between an understanding of NOS and classroom practices.

Pilot Study

The pilot study that laid the foundation for the current research included a study of four different second-career eighth grade science ACTs with six months to two years of teaching experience. The purpose of the pilot study was to investigate these teachers' understanding of NOS and how it related to their classroom practices. The four individuals involved in the pilot study completed a background questionnaire, *VNOS B Test*, and had two formal classroom observations by the author. These observations included submission of lesson plans for the week of the observation, and one semi-structured, audio-taped interview lasting approximately one hour. The data from this case study of eighth grade science teachers indicated that their understanding of NOS varied greatly depending on their individual experiences. Those teachers who had an advanced degree, some scientific research experience, and informal teaching experience prior to entering the classroom seemed to have a much better understanding of NOS. There were conflicting results pertaining to the teachers' classroom practices due to their inadequate skills in classroom management, a typical concern among the new ACTs.

As the pilot study progressed, I found that these teachers were still burdened with a lack of classroom management skills. They were teaching with few science supplies and a lack of administrative support. This issue complicated my interpretation of the data with respect to how NOS was demonstrated through classroom practices. In this current study I selected only ACTs with at least two years teaching experience (Lederman, 1999). The main purpose of the pilot study and the research questions essentially remained the same, but I felt that teachers with fewer classroom management issues would yield richer, clearer data.

Research Design

Case studies are most often used to describe, interpret and/or evaluate some phenomenon or to build theory. Creswell (2005) explained that case studies are an in-depth exploration of a specific process, such as classroom practices, using multiple forms of data collection. This multiple case study described and interpreted a specific phenomenon, the classroom practices of second-career ACTs.

Stake (1995) claimed that an important qualitative research assumption is that reality is subjective and this is reflected in the analysis. Stake (1995) further explained that qualitative research is multifaceted and open to the researcher's interpretation while occurring in a bounded context.

Merriam (1998) explained that qualitative research is characterized by thick, rich descriptive narrative explanations of a phenomenon. Merriam (1998) believed that the outcome of qualitative research focuses on process meaning and understanding which clarifies the study. Merriam (1998) stated that all descriptive and interpretative case studies must focus on the process of accurately and thoroughly representing the participants in the context of their study. The context and the participants in this study are interrelated and therefore can not be separated, much like a character from a specific novel.

Yin (1994) examined qualitative research as a method to uncover patterns and seek similar patterns. Additionally, Yin (1994) explained that qualitative research reveals discrepant evidence and reports it. Yin (1994) also claimed that qualitative research investigates how and why questions to examine specific context. According to Yin (1994), qualitative research is used when the investigator has little to no control over the events that may or may not occur. Yin allows research questions to emerge from the setting but I did not use this idea of Yins in this study.

This multiple case study used pieces of Stake's, Meriam's and Yin's methodology of qualitative research. Conforming to Stake's (1995) assumptions, the participants and the researcher's voices were heard in the interpretation of data. I used more of Stake's (1995) understanding of case studies by using a multifaceted approach to qualitative research investigating an observable behavior in a bounded context. I followed Yin's (1994) criteria for analyzing the qualitative data by (a) uncovering patterns, (b) seeking patterns, and (c) revealing discrepant evidence. This study also conformed to Yin's (1994) use of how and why research questions to aid in gathering rich, thick descriptive narratives (Merriam, 1998).

In addition to describing and interpreting a phenomenon, case studies must occur in a bounded context (Merriam, 1998; Miles and Huberman 1994; Stake, 1995). This study included second-career lateral entry science teachers who had at least two years or more teaching experience in the classroom. This study was also limited to teachers in a school where 55% or more of the student population was receiving free and reduced-price lunches. The teachers' practices (activities, tools, and talk) and their physical classroom environments were examined. This study excluded a focus on students' achievement or students' understanding of NOS.

The purpose of this study was to investigate second-career science ACTs teachers' understanding of NOS and the ways their classroom practices align with the central principles of NOS.

Case Study Design

This case study developed over a two year period of time when I worked for a large southeastern school district as a mentor for new middle school science teachers. During my employment, I visited several schools regularly, observing many middle school science teachers. Through my experiences with middle school science lateral entry teachers this multiple case study was spawned.

After visiting several ACTs' classrooms and assisting teacher with classroom management, instructional strategies, and identifying curriculum goals, I began to notice something different about those teachers who were second-career teachers. Many of these teachers were among the most competent science teachers in the schools.

Most of the ACTs in this school district where I worked were placed at high needs schools (55% or more students qualifying for free and reduced-price lunches). All of the ACTs, prior to entering the classroom, participated in a ten-day induction program with no content area instruction other than an introduction to the standard course of study they needed to understand to address the state curriculum goals for middle school science instruction.

Prior to mentoring and training that these teachers, I thought these teachers would mostly be a liability in the classroom. However, after many encounters with them professionally, I thought perhaps these teachers had something positive to offer in the classroom. For example, one eighth grade science teacher who was trained as an engineer entered the classroom and quickly became the content knowledge leader at his school.

Table 1. School Demographics

	Huntington	Branch	Burrows	Murphy
Number of Students	600	1200	500	800
Teacher	Marcus	Sam	Shanice	Michelle
Grade	7	8	8	8
Ethnicity	58% African-American 29% Hispanic 7% Caucasian 3% Asian 2% Multi-racial	34% African-American 34% Caucasian 24% Hispanic 5% Asian 2% Multi-racial 1% Native American	75% African-American 15% Hispanic 4% Caucasian 4% Asian 2% Multi-racial	58% African-American 24% Caucasian 10% Hispanic 5% Asian 2% Multi-racial 1% Native American
Test Scores*	M – 30 R – 66	M – 57 R – 84	M – 32 R – 77.5	M – 79 R – 90
LEP Population**	21%	16%	15%	4%
Disability Population	17%	11%	25%	13%
Free and reduced-price lunches	83%	58%	86%	55%

* Test Scores – (M) – Mathematics, (R) – Reading. The number represented is the percentage of the grade level passing ** LEP – Limited English Proficiency

Many other teachers came to him when the science curriculum changed and they needed some explanations and review of the chemistry goals they would be responsible for teaching. I became interested in ACTs and wanted to know more about what they brought to the classroom from their prior experiences.

The teachers selected for this study teach in four schools: Huntington Middle School, Branch Middle School, Burrows Middle School, and Murphy Middle School which are pseudonyms for the actual schools.

Schools (see Table 1: School Demographics)

Huntington Middle School (7th grade)

Huntington Middle School is an International Baccalaureate (IB) magnet urban school with approximately 600 students (58% African American, 29% Hispanic, 7% Caucasian, 3% Asian, and 2% Multiracial). International Baccalaureate schools encourage students to be active learners and well-rounded individuals, and to engage as world citizens in global projects. Approximately 83% of the student population received free/reduced-price lunches. Approximately 33% of the teachers had master's degrees in educatin, and 74% of the teachers had four or more years teaching experience. Seventh grade students at Huntington Middle School performed well below the district average (59%) in mathematics, with only 30% passing. The students performed better in reading and writing, yet still did not reach the district average in either. Sixty-six percent of the students passed the state reading test, while only 30% of the students passed the writing test. District-wide, 84% of the students passed the seventh grade reading test, and 47% passed the state writing test.

Branch Middle School (8^{th} grade)

Branch Middle School is a rapidly changing, large, suburban school with approximately 1,200 students (34% African American, 34% Caucasian, 24% Hispanic, 5% Asian, 2% Multiracial, and 1% Native American). Approximately 58% of the student population received free and reduced-price lunches. Approximately 31% of the teachers had master's degrees in education, and 50% of the teachers had four or more years of teaching experience. Among eighth grade students at Branch Middle School, 57% passed the state mathematics test and 85% passed the state reading test. District test score passing averages were 59% for math, and 84% for reading. Students in the eighth grade remained about average, according to the state test scores, in their understanding of reading and mathematics.

Burrows Middle School (8^{th} grade)

Burrows Middle School is an urban math, science, and environmental studies magnet middle school with approximately 500 students (75% African American, 15% Hispanic, 4% Caucasian, 4% Asian, and 2% Multiracial). Approximately 86% of the student population received free and reduced-price lunches. Approximately 28% of the teachers had master's degrees in education, and 59% of the teachers had four or more years of teaching experience. The eighth grade students struggled with the state mathematics test, with only 32% passing (district average 62%). However, the eighth grade students at Burrows Middle School had a 78% passing rate on the state reading test (district average 85%).

Murphy Middle School (8th grade)

Murphy Middle School is a well-established IB magnet and Paideia magnet school located in an urban setting, with approximately 800 students (58% African American, 24% Caucasian, 10% Hispanic, 5% Asian, 2% Multiracial, and 1% Native American). Paideia schools focus on three main instructional strategies: (a) didactic instruction, (b) intellectual coaching, and (c) seminar dialogue. Approximately 56% of the student population received free and reduced-price lunches. Approximately 26% of the teachers had master's degrees in education and 69% of the teachers had four or more years teaching experience. Murphy Middle School's eighth grade students were the only participants in this study who achieved higher than the school district's average on the state mathematics and reading tests. Ninety percent of the eighth grade students passed the state reading test (district average 85%), and 79% of the students passed the mathematics test (district average 62%).

Teacher Participants (see Table 2: Teacher Information)

Table 2. Teacher Information

Teacher	**Marcus**	**Sam**	**Shanice**	**Michelle**
Middle School	Huntington	Branch	Burrows	Murphy
Number of Students	600	1200	500	800
Grade	7	8	8	8
Direct Instruction on NOS	Yes – one semester course	None	Yes – one hour workshop	Yes – one semester course
Prior Job(s) to Teaching	Computer specialist Salesman Non-profit 5 years	Marine technologist, trainer, and specialist 3 years	Medical technologist 16 years	Park ranger 5 years
Research Experience	Yes Marketing research	Yes Oceanographic studies for 12 days for 2 semesters	Yes Pharmaceutical company internship	Yes Designed experiments at the coastal park
Undergraduate Major	Biology minor in chemistry	Parks and recreation Environmental studies Marine technology	Biology	Parks and recreation ** Master (MAT)
Years Teaching	3	3	6	5
Age **Ethnicity**	39 Caucasian	29 Caucasian	41 African American	32 Caucasian

** Graduate degree

Four teachers were selected for this study. One of the original five participants had to withdraw from the study prior to the administration of the *VNOS B Test*. The teachers were selected from a pool of approximately ten seventh and eighth grade middle school second-career science ACT volunteers in a large southeastern public school district. All participants have taught for two years or more at high-needs middle schools. High-needs schools are defined as schools where at least 55% of the student population receives free and reduced-price lunches. Seventh and eighth grade teachers were chosen because sixth grade teachers in North Carolina may hold an elementary teaching license, which usually means fewer science courses completed at the undergraduate level. I selected second-career ACTs from high-needs schools because that was where this district places most ACTs. In my professional practice, teachers with two or more years of teaching experience are better classroom managers than teachers with less experience. Consequently, classroom observations focused more on the teacher's instructional practices than on practices associated with classroom management. Lederman (1999) lists several factors that can interfere with the interpretation of a teacher's understanding of NOS, and classroom management is one of the factors. By bounding my study to those teachers with two or more years teaching experience, I hoped to limit that factor.

All of the teachers selected for this study were lateral entry science teachers who had been in the middle school science classroom for a minimum of two years and were fully licensed middle school science teachers at the beginning of this study. These teachers taught at schools with a minimum 55% of the student population receiving free or reduced-price lunches. The names of the teachers and the schools are pseudonyms, as outlined in the consent forms.

Marcus Wilson

Marcus taught seventh grade science for three years at Huntington Middle School, where 83% of the student population received free and reduced-price lunches. Huntington Middle School's LEP population is approximately 21% of the student population, the highest in the school district. Marcus was the department chair and represented Huntington Middle School at many of the school district's science meetings. Marcus is a 39-year-old Caucasian with a bachelor's degree in biology, who currently is licensed to teach in this state. Marcus's degree in biology has a primary focus on microbiology and chemistry. Prior to teaching, Marcus had several jobs in the following order: (a) software specialist in an Internet business, (b) sales person for the same Internet business, (c) marketing researcher, and (d) advertising agent for the Boy Scouts of America. He did some limited research as a marketing specialist. As a marketing specialist, Marcus test marketed various products and analyzed them individually. After that he met with other test marketers to discuss their findings and reach consensus about different products.

Sam Howard

Sam taught eighth grade science for three years at Branch Middle School, where he is the athletic director and manages all of the science equipment for the science department. Branch Middle School has rapidly changing demographics and a large LEP population, with 16% of the students receiving support for English language. Fifty-eight percent of the student population received free and reduced-price lunches.

Sam is a 29-year-old Caucasian teacher who originally received a bachelor's degree in environmental science with a minor in parks and recreation. After he received his four-year, degree he continued on with his formal education at a community college and received a two-year degree in marine technology. After college, he worked for a marine company as a trainer, manager, and troubleshooter. He performed some original oceanographic research during college, where he collected data aboard a ship for 12 days. Sam's research experience included determining water quality, measuring currents, and monitoring temperature along with other weather conditions. He and a team designed, collected, and analyzed data for a study that was conducted aboard a research vessel.

Shanice Baker

Shanice is a 41-year-old African American who has taught at Burrows Middle School for six years. Burrows Middle School is one of the lowest performing schools in the district. Burrows has 16% of the student population LEP and 97% of their student population comprised of ethnic minorities.

Shanice has a bachelor's degree in biology and worked as a medical technologist for sixteen years prior to teaching. She worked in a laboratory, testing blood, and reporting test results to doctors and hospitals. She had a unique scientific research experience as an intern with a large pharmaceutical company in the research and design department. Her research experience involved designing investigations of new products. These products were tested on animal and human subjects. The results were analyzed and given to anther division at the pharmaceutical company.

Shanice was the department chair and the lead teacher at Burrows Middle School for two years. She also attended many of the professional development opportunities that the school district offered.

Michelle Little

Michelle is a 32-year-old Caucasian teacher with a master's degree in teaching (MAT) and five years teaching experience. She taught eighth grade science at Murphy Middle School all five years. Her school had state testing scores above the district average. Murphy Middle School's eighth grade reading score passing rate was 90% (district average 85%) and the mathematics scores were 79% (district average 62%). Murphy Middle School had the highest scores of all the schools in this study. This school offers many different programs such as IB, Paiedia, and Advancement Via Individual Determination (AVID). Michelle was trained in all of these programs, and is a certified trainer for the AVID program within the region. Michelle is also Global Learning and Observations to Benefit the Environment (GLOBE) certified which is a citizen science project that reports atmospheric weather conditions to scientists on the Internet. Michelle also chaired the large science department at Murphy Middle School, and was the student government faculty sponsor. Prior to teaching, Michelle earned her bachelor's degree in parks and recreation with a minor in environmental studies, which she enjoys and shares with her students. Michelle worked as a coastal park ranger prior to teaching and conducted many scientific research studies with the plants and animals at the park. One of the studies Michelle conducted was determining a way to increase the park's crab population in a four-wheeling area of the park. The team of park ranger's made a decision to not allow the four-wheeling to occur in certain areas where the crab's live. Within days the fiddler crab's population increased significantly, allowing the birds to return as well.

Instruments, Data Collection, and Data Analysis

Table 3. Crosswalk of Data

Research Questions	Background Questionnaire	VNOS B Test	Classroom Observation Checklist	Semi-structured interview	Field Notes
How are second-career alternatively certified science teachers' understandings of nature of science?	YES	YES	YES	YES	NO
How did these second-career alternatively certified science teachers acquire their understanding of NOS?	YES	NO	NO	YES	NO
In what ways do second-career alternatively certified science teachers' classroom practices align with central principles of NOS?	NO	YES	YES	YES	YES
How does the physical environment reflect or contest the nature of science?	NO	NO	YES	YES	YES
What do alternatively certified science teachers note as enabling and constraining factors in translating their knowledge into classroom practices?	NO	NO	NO	YES	NO

This case study used a multiple-instrument approach, triangulating data for validating the findings (Creswell, 2005). The multiple-instrument approach refers to the five instruments used in this study: (a) the background questionnaire, (b) *VNOS B Test*, (c) classroom observation checklist, (d) field notes, and (e) two semi-structured interviews. Table 3 describes how each instrument was used to answer the research questions posed by this study. Below I describe each instrument and its connection to the research questions, the procedures for administration of the instrument, and the techniques for analyzing data gathered with each instrument.

Instrument Description : Background Questionnaire (Appendix A)

This questionnaire, designed by the researcher, was used to gather information about the participants' formal education, prior work experience(s), science experience(s) as a student, and teaching experience(s). The specific information requested about their formal education includes: college majors in undergraduate and graduate school, any formal courses relating to NOS, and all informal education focusing on science (workshops, seminars, and non-degree programs). Questions that focused on their college majors relate to the teachers' content area of expertise and any research classes or internships that they may have participated in during their college careers. This background information was important because research indicates that individuals with formal or informal instruction in NOS will have a better understanding of NOS (McComas, 2004). Research also indicates that those individuals who have participated in research will have a better understanding of NOS compared to those who have not had a research experience (Windschitl, 2004).

The next section of the questionnaire established the teachers' understanding of science in the work place. Questions that refer to prior job experience(s) asked the participants to describe their work duties, how it related to science, and if they conducted or participated in any scientific research. A small, open-ended section asked the teachers to reflect on their own experiences with science as students. The last section asked the participants to describe all teaching experience(s), including those outside of school, for example teaching in your community, working with the scouts, and in churches. Additionally, the participants were asked to describe any professional development, workshops, and in-service activities they participated in that related to NOS. Collection of this information was necessary because individuals who participate in research or direct instruction of NOS have a better understanding of NOS compared to those who do not (Lederman, 1992). This instrument addressed research question two that asks how the teachers acquired their understandings of NOS.

Data Collection Procedure

Participants were given a copy of the background questionnaire (Appendix A) and allowed to look at it and ask any clarifying questions. I did not give any verbal instructions; I only answered questions. I allowed the participants to complete this questionnaire independently and return it to me in a pre-addressed envelope.

Data Analysis

This instrument was used to collect demographic information from the participants. I looked at each teacher's background to understand what they had learned or experienced about NOS, what research experience they had acquired, and what teaching experiences they had participated in. Understanding this information was important, because my pilot study showed that individuals with advanced degrees and more scientific research experience had an increased understanding of NOS and demonstrated more sophisticated classroom practices (McDonald, 2006). This information may provide clues to gather a greater comprehension of ACTs' understanding of NOS. Analysis of this instrument will provide a better understanding of how the teachers acquired their understanding of NOS (research question two).

Instrument Description: VNOS B Test (Appendix B)

The *VNOS Test* was originally developed by Lederman (1990), and was used to assess secondary science students' (7-12th graders) understanding of NOS. The *VNOS Test w*as then altered by Abd-El-Khalick (1997) to assess teachers' understandings of NOS, and was labeled the *VNOS B Test*. The *VNOS B Test* consists of six, open-ended questions that inquired about the participants' understanding of NOS, including the eight major tenets listed earlier in chapter two. This instrument was important in that it provided a better interpretation of teachers' understanding of NOS (research question one).

Data Collection Procedures

After I received the participants' background questionnaires, a time was arranged to administer the *VNOS B Test.* The *VNOS B Test* was administered in a room free of distractions. To reduce the possibility of bias, the completed *VNOS B Test* was placed in a sealed envelope in a secure location, and was not read until after the classroom observations occurred.

Data Analysis

Each of the six open-ended questions addressed one or more of the tenets of NOS. Question one looked for the participants' understanding of the tentativeness of science and the role of technology as a tool of science, understanding that technology is not responsible for paradigm shifts in science. According to the central principles of NOS, scientific theories do not change due to the accumulation of new facts discovered with more well developed technology (Lederman & O'Malley, 1990). Scientific theories change due to paradigm shifts in science (Kuhn, 1962). Question two assessed the participants' understanding of the role of human subjectivity and creativity in science. Question three addressed the misconception of the hierarchical nature of laws and theories. McComas (2004) stated that laws describe the generalizations or patterns of nature, while theories attempt to explain why the laws are true. Question four explored the role of creativity and imagination in science. Additionally, this question addressed the social, cultural, and political embeddedness of science in our society. Question five examined the creative nature of the entire scientific method, not just the experimental design, but the data analysis as well. Question six posed a scientific controversy and asked the participants to provide explanations for the conflicting perspectives. This question looked at the factors that affect a scientist's work, including bias and personal preferences.

The authors of the test have provided some guidance in understanding and analyzing the participants' answers (Appendix D). Each of the six questions was analyzed using a research-based rubric (Appendix E) I created following the guidance of the Abd-El-Khalick (1997) analysis of the *VNOS B Test*. Each response was examined for understanding of NOS and rated on a scale ranging from a less informed view of NOS on one end of the scale, to a more informed view of NOS at the other end of the scale. A Likert scale was used for each question on the *VNOS B Test*. An additional science educator and I independently read and analyzed each participant's *VNOS B Test* and scored their understanding of NOS using the rubric. This science educator who assisted me was a professor from a large southeastern university who understands NOS and teaches a graduate course on NOS. We convened and discussed our answers and came up with a mutual agreement for each participant's understanding of NOS for each of the six questions. This instrument was necessary to address research question one: What is the teachers' understanding of NOS? The information gained from this instrument was used to create the semi-structured interviews.

Instrument Description: Classroom Observation Checklist (Appendix C)

The classroom observation checklist was designed by the researcher to examine the practices of the teachers in their classrooms. The checklist was created to examine classroom practices of science teachers based on Van Driel's et al., (2001) research and I used Carlone's (2000) explanation of science practices in the classroom. The checklist (Appendix C) has three major components: (a) instructional strategies, (b) physical environment, and (c) and social community within the classroom.

Each major component on the classroom observation checklist was based on Carlone's (2000) concept of prototypical science practices and alternative science practices. Prototypical science practices are defined as "the combined, traditional science practices and beliefs about science and science education" (Carlone, 2000, p. 27), reflecting low central principles of NOS. These science practices would include activities such as worksheets and isolated laboratory investigations that have one correct finding. Alternative science practices are those science classroom practices that reflect high central principles of NOS, such as inquiry based investigations or student-led debates. This instrument was designed to capture the central principles of NOS of each teacher's instructional strategies, physical environment, and social community within their classroom.

Additionally, field notes were taken to fill any gaps the checklist may have omitted. This instrument was designed to assist in the understanding of research questions three and four: In what ways do the teachers' classroom practices align with the central principles of NOS, and how do the physical environment and science practices reflect or contest NOS?

Data Collection Procedures

Each participant and I mutually agreed on four consecutive classes that I came to observe. The school district is on a block schedule with A and B days. This means that students go to science class either on an A day or a B day for one, approximately 70 minute block of instructional time. Prior to my classroom visits, the teachers submitted electronically six lesson plans. These lesson plans helped me understand what occurred in the classroom prior to my arrival. I observed the same class every other day for four full blocks which allowed the teacher to focus on teaching and the students on learning without my presence causing a distraction.

Data were collected during the classroom observations using field notes and the classroom observation checklist (Appendix C) that I developed supported by NOS literature. This instrument was used to report which central principles of NOS were used in the classroom and whether they were high or low on the central principles of NOS. Additionally, field notes were taken during the observations to monitor classroom movement, the physical environment, and science practices.

Data Analysis

This instrument was a checklist of classroom practices, physical movement, and social community for the observed teachers and their classrooms that were tallied after the observations. One checklist was used daily for each of the four observation days. Using the checklist and field notes I tallied and noted the amount of time on the classroom observation data analysis tool (Appendix F) when a specific central principle of NOS was demonstrated in the classroom. The more time accrued on the high central principles of NOS indicated a more informed understanding of NOS. Likewise, more time demonstrating the low central principles of NOS indicated a less informed understanding of NOS. Field notes were used during classroom observations to record any events that are not captured with the checklist, or were missed during the classroom observation. The field notes were reviewed and transcribed immediately after the observation to capture and expand on the teachers' classroom practices. Descriptions of the physical environment and classroom movement were analyzed soon after the observation using the classroom observation data analysis tool (Appendix F).

The observational checklist has a variety of practices listed which demonstrate a more informed understanding of NOS, while fewer practices demonstrate a less informed understanding of NOS (Cunningham, 1995; Wong, 2003). The field notes were analyzed using coding of data to generate two categories, type of practices and time involved in that practice. I checked the practice on the checklist and noted the time the activity began and when it ended.

The development of this instrument to accurately encapsulate the teachers' classroom practices as they are guided by NOS was thoroughly and deliberately planned, with each component chosen and supported by literature (Carlone, 2000). The field notes were reviewed immediately after the observation to ensure that all instructional strategies, the physical environment, and classroom movements were noted.

Instrument Description: Semi-structured Interviews

Two separate, semi-structured interviews were conducted after all classroom observations were completed. Each semi-structured interview took approximately 60 minutes and was audio-taped and transcribed. Each individual participant was allowed the opportunity to verbally clarify written statements, thoughts, and classroom practices through the semi-structured interviews.

The first interview was conducted to verify and confirm the results of the *VNOS B Test*. Lederman and Abd-El-Khalick (1998) suggest asking the *VNOS B Test* participants to clarify and explain their choices on each of the six questions. Each question from the *VNOS B Test* was asked, and the participants were allowed to clarify and explain their answers. The interview was used to assess the scope of each teacher's understanding of

NOS along with the analysis of the *VNOS B Test* and helped interpret research question one: What is the teachers' understanding of NOS?

The second semi-structured interview was individually prepared after reading the background questionnaire, reading the lesson plans, and referring to the classroom observational checklist and field notes. I began all the interviews by asking each teacher to explain in detail their research experience, specifically describing what they did in their research experience. I then asked each teacher to explain why they choose the specific instructional strategy for each activity during the four days that I observed. The participants were allowed to clarify past experiences (work and teaching), and classroom observations that I collected using the checklist. This interview assisted in clarifying and better understanding research questions two through five.

Data Collection Procedures

Both semi-structured interviews were audio-taped in a quiet environment to avoid distractions. Each interview was conducted separately and each lasted approximately 60 minutes.

The second semi-structured interview was conducted to clarify all of the other instruments: lesson plans, the classroom observation checklist, and the background questionnaire. I standardized each interview asking each individual to expand on and describe further any coursework taken that involved NOS. I explored the duties and any research the participant performed in their prior work. Additionally, the participants were given an opportunity to describe their lesson plans.

Finally, I further explored the participants' classroom observations and asked them to explain why they chose a specific instructional strategy. In conclusion, I asked if the participants noted any enabling or constraining factors in translating their understanding of NOS in the classroom.

Data Analysis

Upon completion of the interviews, I transcribed the audiotapes and read the transcripts, writing notes which helped develop tentative ideas about categories and patterns (Maxwell, 2005). Miles and Huberman (1994) believed that memos serve a reflective purpose in analyzing qualitative data, and can facilitate thinking and stimulate analytic insights. Analysis of the data was done by hand-scoring of the transcripts to see what themes or patterns emerged within cases and across cases. According to Creswell (2005), qualitative research design requires that many of the protocols be self-designed to help organize and record information required by the research questions. To increase the validity of the findings from the *VNOS B Tests*, I asked another science educator to read the tests and interview transcripts to help determine the participants' understanding of NOS. After individually reading and scoring each participant's *VNOS B Test* the other science educator and I met to consult and agreed on each teacher's understanding of NOS on their *VNOS B Test*. The science educator and I both used the data analysis instrument (Appendix E) to assess each individual's VNOS B Test.

Analysis of the interviews followed Maxwell's (2005) and Creswell's (2005) approach to the analysis of qualitative data, which was established using Miles and Huberman's (1983) philosophy of data analysis, data reduction, data display, and drawing conclusions. Data were coded by narrowing to a few useful themes and disregarding the others. The themes were identified and placed into similar categories. Patterns were identified within and across the cases to increase the internal validity. The noncoded sections of the transcribed interviews were read again to double check for any missed patterns.

The data collected and analyzed from this instrument helped answer all the research questions asked by this study. Along with the other instruments, data summaries and conclusions were drawn about classroom practices of second-career science ACTs.

Data Analysis – Conclusions and Summaries

The most important elements of any study are how the data are interpreted and understood, and then the findings shared with others. The data from this study were analyzed in three major sections: (a) the data from each individual instrument, (b) the compiled data from each of the four teachers on all five instruments, and (c) the group as a whole. Sections two and three required analyzing the data using categorizing strategies of coding, breaking down, and rearranging the information into thematic groupings. This helped facilitate comparisons between ideas in the same categories (Maxwell, 2005).

Traditionally, terms such as internal validity, external validity, reliability, and objectivity are used to determine the quality of the study (Creswell, 2005; Yin, 1994). These terms are used in a positivist paradigm that adopts a philosophical perspective that qualitative research of the social sciences should emulate the natural sciences. This paradigm is not an accurate evaluation framework for my research, because the tenets of this philosophy are: (a) research mimics that of the natural sciences, (b) research uses observable data only, (c) research data are arrived at through an accumulation of verified facts, (d) research should be formed from deductive means, and (e) research should be purged of all personal values.

Nonpositivist qualitative research philosophy is very dependent on the context, the role of the investigator, and the ability to gain access to develop an understanding of the phenomenon being studied. This research will portray the individuals' voices, and because it is socially constructed, it can not be replicated or reproduced. The voice of the researcher is heard in the study because of the impact it has on the study.

The overall trustworthiness of the study was evaluated using the following terms from Lincoln and Guba's framework (1985):

> *Credibility* - allowing the phenomenon to unfold – researcher being the instrument – reporting the entire story – including the non-supportive evidence – allowing the voice of the participant to emerge and the context in which it is being presented (Patton, 2002)
>
> *Dependability* – will be demonstrated through the consistency of data and when steps of research are verified through examination of raw data, data reduction and process notes (Campbell, 1995)
>
> *Confirmability* – triangulation of data (Mathison, 1988 and Creswell, 2005 and Patton, 2001)

Trustworthiness of this study was established by allowing member checks of the transcripts to document the voices of the participants. I also was seeking discrepant evidence, searching for negative and non-supportive evidence and permitting the readers to draw their own conclusions from data that have been accurately presented.

Triangulation of the findings from this study was important in order to validate the accuracy of the study. According to Lincoln and Guba (1985), qualitative research must have some method of validating the findings. This study answered the research questions using written, verbal, and observational instruments that were documented. (see Table 3).

First, I outlined the specific validity threats to this study, then I explained how the design of the study minimized these threats.

Minimize Validity Threats

Specific validity threats to this study include background assumptions, which were subject to my personal interpretations of the participants and my personal relationship with them. I personally knew all of the participants, and wanted them to be portrayed as successful science teachers. While I have known all of the participants for three years and wanted to represent them positively, this could have threatened the validity of the study.

Another threat was that the eighth grade teachers may have felt pressured to include as much information as possible with the upcoming state test mandated by *No Child Left Behind*. My study was conducted near the end of the year and the eighth grade teachers may have felt pressured to include all the remaining content for the test. Other threats could include a lack of rich data collection due to conducting only four classroom observations, of each teacher and finally, that I have unknowingly influenced the teachers' responses through biased questioning during the interviews.

My professional experiences as a classroom teacher may be another limiting factor of this study. While I have supervised over 400 middle school science teachers during the school year, and I bring professional supervision experience to this study, I also taught in the classroom for 16 years. There is a possibility that my opinions and educational experience created a bias toward the teachers in this study.

Means to Minimize Validity Threats

This study's design minimized the threats as indicated by Table 3 (crosswalk of data) which shows a crosswalk of the instruments and how each instrument addresses each research question. Conducting four classroom observations where I have known the participants for three years could perhaps lead to observation of authentic teaching rather than classroom "performances" for someone the teachers do not know and trust.

I have known all four participants in this study for at least three years which could have biased my findings. I had to intentionally separate my classroom observations from my personal relationship with them. I have observed hundreds of teachers in my prior position with the school district and many times I had to separate a teacher's personality from their teaching. I carried that skill with me to this study.

A major concern, or limitation of this study, was that I might have influenced the teachers' responses through biased questioning during the interviews. I had the opportunity to perform the pilot study and used semi-structured interviewing techniques. Throughout the four pilot study interviews, my interviewing technique improved, and I provided fewer "cues," or leading statements which allowed the participants' views to emerge, rather than mine.

Despite the limitations of this study, and in view of the severe shortage of science teachers across the nation, this study may be useful to those who license, employ, and provide professional development for entry level science teachers in their states and school districts.

Summary

Collecting and analyzing the data necessary to answer all of the research questions is essential to any study. This chapter explained the qualitative methods used to answer the questions, the conceptual framework that supports this study, the participants and how they were chosen, the instruments, and how the data were analyzed. The next chapter presents the findings of this study.

CHAPTER IV

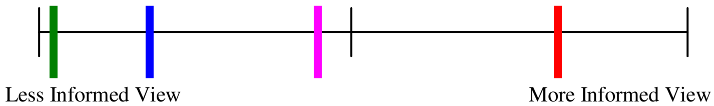
FINDINGS

Introduction

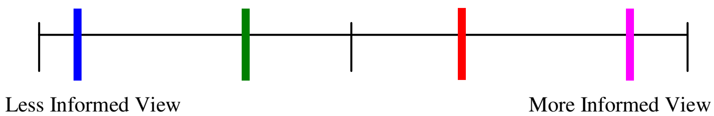
This chapter presents data collected on four middle school science teachers who were initially alternatively certified (lateral entry teachers) with prior job experience in science. Prior to teaching, each teacher in this study had a science related career, and some scientific research experience. Each taught for a minimum of two years at a high needs middle school (55% or more of the student population receiving free and reduced-priced lunches). This study examines the strengths of these four second-career, alternatively certified science teachers, and elaborates on the strengths they bring to the classroom. This study took approximately ten weeks, from initial contact with the participants to the final interview. In this chapter, I describe the teachers' knowledge of nature of science (NOS) (Figure 2) and how they acquired this knowledge in the course of their educational and occupational experiences. I then describe the classroom practices of each of the four teachers. My insights on classroom practices came from observations and individual personal interviews. Finally, I provide a cross-case comparison of the data.

Figure 2. VNOS B Test Answers: A Comparison of the Participants

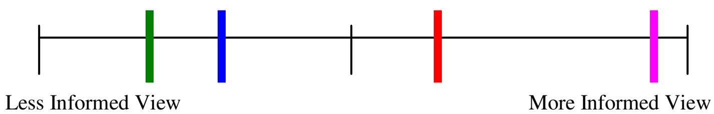
Question 1 – Do Theories Change?



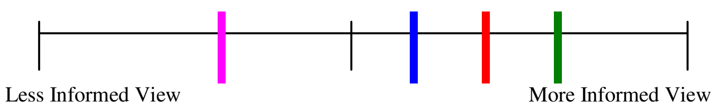
Question 2 – How Certain are Scientists about the Structure of an Atom?



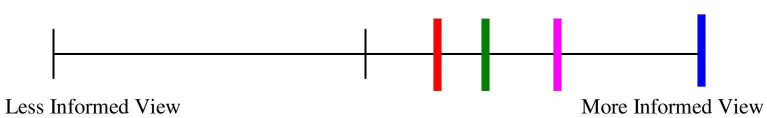
Question 3 – What is the Difference, if any, Between Theories and Laws?



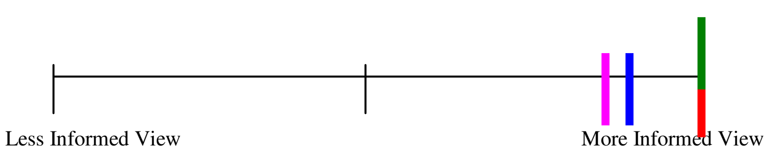
Question 4 – How are Art and Science Similar/Different?



Question 5 – Do Scientists use Creativity/Imagination?



Question 6 – How Can Scientists Have Different Conclusions Looking at the Same Data?



Key:

All of the teachers participating in this study were employed by the same large, southeastern public school system. All of the schools are at least 40 years old, and have been, or are in the process of being, renovated. Additionally, at least 55% of the student population at these schools qualify for free or reduced-price lunches. The participating teachers came from Huntington Middle School, Branch Middle School, Burrows Middle School, and Murphy Middle School (pseudonyms). Student populations vary in size from 500 to 1,200. Collectively, the schools' student population is comprised of 58% to 90% minority students, and, with the exception of Murphy Middle School, has a high Limited English Proficiency (LEP) population (15% to 21%).

Every middle school in this district is on an alternate day block schedule (A and B days) comprised of approximately 70 minutes. Science classes meet every other day. Many middle schools in this school district allow mathematics and language arts classes to meet every day (double block), creating some tension among the teachers, because science and social studies teachers have half of the instructional time that language arts and mathematics teachers have with the same groups of students. Two of the four schools (Burrows and Huntington) struggled with low state mathematics and reading scores while the other two schools (Murphy and Branch) either met or exceeded the district averages for math and reading scores during the 2006 – 2007 school year.

The science teachers who agreed to participate in this study are Marcus Wilson, a seventh grade teacher from Huntington Middle School; Sam Howard, an eighth grade teacher from Branch Middle School; Shanice Baker, an eighth grade teacher from Burrows Middle School; and Michelle Little, an eighth grade teacher from Murphy

Middle School. All of these teachers are presently certified in the state of North Carolina as middle school science teachers. Approximately 22% of the teachers at all of these schools have less than one year of teaching experience.

Each teacher's responses to each of the research questions are presented below. The research questions for this study are the following:

1. What are second-career, alternatively certified science teachers' understandings of nature of science (obtained through the *VNOS B Tests* and interviews)?
2. How did these second-career, alternatively certified science teachers acquire their understanding of NOS (obtained through questionnaires and interviews)?
3. In what ways do second-career, alternatively certified science teachers' classroom practices align with central principles of NOS (obtained through classroom observations, interviews, and lesson plans)?
4. How does the physical environment reflect or contest the nature of science (obtained through classroom observations and interviews)?
5. What do alternatively certified science teachers note as enabling and constraining factors in translating their knowledge into classroom practices (obtained from interviews)?

Information about each teacher is presented (see Table 2) and then, I present the data collectively for each research question, introducing a cross-case comparison. Figure 2 was determined using the information obtained from Appendix E, which was designed and created by the researcher. Emergent patterns are presented. After examining the data collectively, I share a summative statement of the information, presented at the end of the chapter.

Marcus Wilson

Marcus is an innovative and inspired 39-year-old Caucasian teacher whose unique experience and educational background merge to form his understanding of nature of science. As the most senior science teacher at Huntington Middle School, Marcus is the chair of the four-person science department. Marcus has been teaching integrated seventh grade science for three years at Huntington, where 83% of the student population qualifies for free or reduced-price lunches. Huntington Middle School is comprised of 58% African American, 29% Hispanic, 7% Caucasian, 3% Asian, and 2% Multiracial students. Marcus teaches struggling seventh grade mathematics students. Only 30% of the seventh grade students passed the state math test (the district passing average for seventh grade is 59%). More of his students, 66%, passed the state reading test (the district passing average is 84% for seventh grade). Approximately 21% of the school population struggles with the English language; Marcus had several LEP students in his classes. At Huntington Middle School 17% of the student population has disabilities; most of them are learning disabilities. Most of Marcus's classes have 24 to 27 students. However, on any given day, another classroom of students could be moved into his room, creating a class size of 40, due to the lack of substitutes willing to come to his school.

Marcus's bachelor's degree is in biology, with heavy emphasis on microbiology and chemistry. His personal science interests include endangered species and environmental studies. While studying for his bachelor's degree, Marcus took an informative class on bioethics presented by an instructor who held biology and theology degrees. During his professional career, and prior to teaching, Marcus participated in research marketing, where he discovered, "Research is loaded with emotions and always influenced by finances."

Prior to teaching, Marcus worked as a computer specialist for an independent Internet business. After the Internet business crashed, he worked for the Boy Scouts of America. When he realized that the Boy Scouts was not a good fit for him, his father, who is a teacher, suggested teaching. That is how he came to be a classroom teacher.

When he first began teaching, he simply presented information to his students, sometimes using hands-on activities. Marcus thought presenting concepts and ideas was the sole purpose of a science teacher. After a couple of years in the classroom and exposure to some innovative ideas from a professor at a local university, his ideas about teaching science began to change. He discovered the true nature of inquiry through activities presented in one of his university classes. He successfully implemented some of the same methods in his own classroom.

Marcus has a reasonably sophisticated understanding of NOS, as demonstrated by the classroom practices he acquired through his formal education, prior work experience, and years of teaching in the classroom.

What is Marcus's Understanding of the Nature of Science? (VNOS B Test/Interview)

According to Marcus's written expression and verbal clarification of the *VNOS B Test*, he has a more informed understanding of the nature of science (NOS) (see Figure 2). His written answers were often incomplete and difficult to understand until we spoke about them during the interview. For example, he acknowledged that theories change, yet he continued to struggle with the concept of theories and laws being related in a non-hierarchical sense. His verbal responses in the interview contradicted his written test answers on the idea that laws and theories are hierarchical; however, Marcus's last comment was, "I used to believe you come up with a hypothesis and then eventually the hypothesis from the theory becomes a law." He continued, "In high school, some of my teachers taught that a theory will become a law once it is repeated many times and then is proven."

Question One (Do Theories Change?)

In examining Marcus's written and verbal answers from question one on the *VNOS B Test*, I concluded that he has a more informed understanding of NOS. He stated, "Theories are tentative, and change" (see Figure 2). He also claimed that we teach theories because they are reliable and use observable evidence to explain the natural world around us. He continued to state that a theory is the best explanation of a scientific phenomenon. It only becomes a theory when society accepts it as true. Marcus said, "Everybody pretty much agrees that this is the accepted [theory], so now we move on and we do our research based on this assumption." Most of his explanations regarding this question leaned toward the more informed side of the NOS rating scale, except for one written answer: "Some theories can be proven wrong." This terminology demonstrates a less informed understanding of the concept of theories, according to the author of the *VNOS B Test* (Abd-El-Khalick, 1997).

Marcus continually came back to the idea that "…science *never* proves anything correct; instead, you can only prove things incorrect." This statement conforms to Popper's idea of falsification from the philosophy of science (Popper, 1959). Again, Marcus struggled with how this statement fit into his idea of the relationship between laws and theories, supporting his belief with the fact that Newton's Laws do not exist in outer space. According to Dr. Carlone, this specific example represents a fairly sophisticated understanding of NOS, even though many contemporary philosophers of science may not agree with this view (Carlone, 2007).

Question Two (How Certain are Scientists about the Structure of an Atom?)

Question two on the *VNOS B Test* asks how certain scientists are about the structure of an atom, and what evidence they used to determine the structure of an atom. Marcus struggled with this question; however, he did provide other, useful information that revealed his understanding of the nature of science. On the scale of understanding NOS, he had the least informed answers of all four of the participants for this question, as depicted on the graphic representation in Figure 2. He never expressed the idea that models are the primary mode of representation of unseen structures. He wanted to tell me about Rutherford's experiments in determining the structure of an atom, which addressed only part of the question. During the interview, Marcus admitted to telling his students on occasion to just accept what he was saying, sort of a blind-faith statement. Marcus said, "I can explain to the students about [the structure of an atom] or they can just believe that this is our best guess of what an atom looks like." Marcus maintained that the students would not understand his explanation, and given the time constraints of testing at the end of the semester and keeping up with the pacing guide, he just could not take the time to explain.

During the interview, Marcus confidently stated that society influences science, although he thinks it should not. He demonstrated this concept by describing an exercise he and a colleague did during the last presidential election. Marcus and the social studies teacher held a mock presidential campaign, where each of them debated current issues such as stem-cell research, environmental issues, funding space exploration, and alternative fuel technology. Marcus said, "I did research on the current policies under George Bush, and I looked at some organizations that were very moderate in their opinions, like the Juvenile Diabetes organization. I examined their position statements and I had the kids look at their positions statements. A lot of [the students] think George Bush is anti-stem cell research, and they discovered that he is not really anti-stem cell research, he just does not want any *new* stem cell research." The students got an opportunity to see that science and politics are very closely related and often fiercely debated.

As I stated earlier, Marcus did not completely answer this question. He did not indicate that models or representations are used to illustrate science concepts. However, he does show a more informed understanding of the idea that science is influenced by politics, religion, culture, money, and society.

Question Three (What is the Difference, if any, Between a Theory and a Law?)

Question three asks for a distinction between a law and a theory, and an explanation of their relationship, if one exists. According to the data, Marcus had a more informed understanding of NOS, as shown in Figure 2. He explained that theories change due to paradigm shifts created by the scientific community, and then they must be accepted by society. Marcus asked his students, "If everybody in the world believes that something is correct, well, is it? Remember Galileo; he challenged the idea that the world was flat with shadows." This is a very sophisticated understanding of NOS; however, Marcus remained conflicted about the relationship between laws and theories, finally stating they are related by context but are not hierarchical in nature. While Marcus has a more informed understanding of theories and how they change, he refused to fully embrace the nonhierarchical relationship between laws and theories as illustrated by his written answers on the *VNOS B Test* stating that they are related and occasionally change into one another.

Question Four (How are Art and Science Similar/Different?)

Question four asked the respondents to compare and contrast art and science. Marcus clearly saw that science must be creative and imaginative during the design and interpretation of an investigation, but he believed that data collection should follow a standard of pre-set rules. Marcus's written answers, paired with his interview responses, indicate a more informed understanding of this question, as shown by the graphic in Figure 2. He does not describe how art and science are different, rather, he focused on how science must be creative. He clarified this point during the interview by stating, "You do not really want people to really be creative or imaginative when they get to the point of collecting data. I think it is great to be creative and imaginative before, when you are coming up with different ways to look at things." According to the central principles of NOS, science is creative throughout he entire scientific process. Marcus did not completely agree with this understanding of NOS.

Marcus spoke frequently about the rules that scientists must obey when creating scientific knowledge. These rules are determined and agreed upon by the scientific community. He also indicated that science is continually looking for one neat answer, but this does not happen because people have differing opinions and perspectives. These opinions and prior experiences are important, because they allow the scientific community to debate and look at the same problem from different points of view. Marcus believed this is a very good attribute for science. He also felt that scientists inhibit and limit their thinking by looking for cold, hard facts. While Marcus clearly indicated the need for creativity and imagination in science and art, he never addressed the differences between art and science, other than to say that science is more strictly governed by rules than art.

Question Five (Do Scientists Use Creativity/Imagination?)

This question examines the idea of scientists using creativity and imagination during the entire scientific process. Marcus believes that scientists should be creative during the design and interpretation of data, but not during collection of data, which limited his understanding of this question. According to the authors of the test, scientists should use creativity and imagination during the entire scientific process. Marcus forgot to answer the written question on the *VNOS B Test*; therefore, the answers to this question come only from the interview about the *VNOS B Test*. Later, Marcus told me he was going to answer the question after he gave it more thought, but he closed the test and gave it to me without looking back over the answers. According to the interview, Marcus had a more informed view of the understanding of this question (somewhere near the middle of the scale), as indicated by the graphic in Figure 2.

Marcus clings to the notion that the collection of data must follow a preset list of rules. He also believed that science is influenced by everyone involved in an experiment, although it would be best for the experiment if that were not the case. This last statement conflicted with many other statements he made. For example, Marcus stated, “Science benefits from many possible solutions and not just one answer.” He indicated that science is a continual process, where many thoughts and different ideas are accumulated from which science gains knowledge. Including Marcus’s conflicting statements, he had mostly a more informed understanding of the role that creativity and imagination play in the scientific process due to his limited belief that scientists should only be creative during the design and interpretation of a scientific investigation.

Question Six (How Can Scientists Have Different Conclusions?)

Question six examined how scientists can draw different conclusions from examining the same data. Marcus appeared to fully understand this question as the author intended it. He believed it would be easy to come up with different conclusions because they are based on assumptions of the presented facts. These assumptions are informed by the scientists’ prior knowledge and experiences. Scientists can draw different conclusions using the same data because they are influenced by their own context, experiences, and expectations. Marcus felt that the conclusions depend on one’s paradigm. He used the example of a glass of water being half full or half empty. It all depends on the point of view of the observers, and how they are biased from their past experiences.

Marcus believed that society influences scientific thought. He indicated that society is not always correct in its assumption about some scientific ideas and that society occasionally needs a paradigm shift. He used this example: "At one point in time, the earth-centered universe was accepted mostly due to the church's influence on this decision at the time." Marcus continued to explain that change causes turmoil because it takes a while to happen and for society to accept it. Marcus concluded that, "The scientific community must agree on the paradigm shift first." Examining Figure 2, it appears that Marcus fully understood this question as the author intended, and had a more informed understanding of this facet of NOS.

How did Marcus Acquire his Knowledge of NOS? (Questionnaire/Interview)

Although he answered the background questionnaire with few words, and needed some clarification of this question during the second interview, Marcus acquired some knowledge of NOS in his undergraduate studies. He took a class in biology ethics at a large mid-western university, where he majored in biology. The biology ethics course taught him that many emotions can be "stirred up" during science discussions and often politics and religion influence science. He also discovered that the emotions evoked by science may be rooted in politics and can cause contentious debate, as with issues such as stem-cell research. Marcus said, "Sometimes my students get into arguments over issues such as stem-cell research or even abortion rights and attempt to support their ideas with scientific knowledge."

Marcus participated in several focus groups for a marketing research company, where he was asked to evaluate several products by using them for an extended period of time. After using a product and assessing its effectiveness, a group of users convened to discuss the product. During this process, Marcus learned that research is rife with feelings, opinions, and financial issues. He was surprised to learn that scientific research often involved decisions based on money. For example, Marcus was asked to wear some white gym socks for several months to see how well they absorbed sweat. He wore them in various situations and in different weather conditions. When the test group met to discuss the socks and how well they prevented sweat, the discussion turned to the cost of the socks, rather than their effectiveness. This group's purpose was to test the effectiveness of the socks, not assess their price. Marcus concluded, "People do not like controversy, so they will not say anything controversial about the product, just comment on the cost."

Marcus revealed in the interview that he frequently reads science journals and science news magazines, a distinctive method of gaining some understanding of NOS. Several times during the interview, he referred to a science study or an article from a scholarly journal. For example, he mentioned a study that explored the unique understanding of culture and science among native Alaskan people.

During his own K-12 science experiences, Marcus observed the teacher's role of "fact-giver" and the students' role of "fact retriever," spitting back facts with very little hands-on experience. His science classes were mostly for gifted students who wanted to be doctors or engineers. However, he did have one experience in an advanced placement

(AP) biology class with a teacher who engaged him and his classmates in thoughtful debates. On one occasion, he and a few of his classmates went on a Saturday field trip to visit the natural prairie grasslands of the Midwest. While it was a wonderful experience, the vehicle that took them through the grasslands was a large-wheeled, pontoon, gas guzzling truck that matted down and occasionally ripped up the grassland. The class discussed the contradictory nature of the message gleaned from this trip.

Marcus had some unusual jobs prior to teaching. He worked as a computer software specialist and was later a sales person for the same company. When the company went out of business he went to work for the non-profit Boy Scouts of America as an advertising representative and a trainer. Neither job suited him, so at his father's suggestion, he left the non-profit world and found himself teaching middle school science.

While his prior experiences were important and laid a partial foundation for his understanding of NOS, the pivotal point with respect to his understanding of NOS occurred when he participated in a licensure program through a large university in the southeastern United States. Here he learned about scientific inquiry and how to use it effectively in the classroom. One day in his classroom, he decided to try an inquiry lesson about cloud formation, as posed by his instructor. He asked his students a series of questions about cloud formation, then gave them some equipment to test their personal theories. He said "the light went on" about how science should be taught, and his teaching methods changed.

Marcus's educational background and experiences have helped form his understanding of NOS. He believes that everyone, including teachers who have been teaching for "100 years," should take the course he took on inquiry. Marcus feels that this course and instructor completely changed his perspective on what it means to be a science teacher. Marcus said, "All alternatively certified teachers should have [this professor] come in and teach them about inquiry in the science classroom. It will change the way they teach forever."

In What Ways Do Marcus's Classroom Practices Align with the Central Principles of NOS? (Observation Checklist/Field Notes/Lesson Plans/Interview)

I observed Marcus over four consecutive days with the same students during the same class time. I began my observations in Marcus's room on a Monday morning during the first block. His friendly, engaging conversation greeted each student as s/he entered the classroom. He stood between the door and the hallway to monitor both, and greet students. It was quickly apparent that he had a routine to begin each class. The class began promptly when the bell rang and all students were seated, silently beginning the warm-up. The warm-up was a five-to-eight minute independent activity in the form of a textbook created worksheet or overhead projection. Once I heard a student helping another student; but this was acceptable because the student was new to the class and did not know the classroom routine.

Day One

The first eight minutes of class was independent work, the warm-up, where the students were graphing information and interpreting the data. The warm-up activity was to be completely independent, with no collaboration. This activity indicates that the social community is low on the scale of NOS central principles; however, the activity involved interpretation of data, which is higher on the scale of NOS central principles. This activity took the initial 10% of the class time. Next, the teacher engaged the students in interpreting graphs and answering questions on the worksheet, which took about four minutes. Marcus allowed the students to ask questions and examine other student's answers, activities that are highly rated on the central principles of NOS.

After the warm-up Marcus reviewed for a quick, multiple choice, written assessment. This activity was teacher led, allowing for few student questions. The teacher recited some facts and formulas about force and motion. This activity continued for eight minutes and was very low on the central principles of NOS. After the quiz, the teacher handed out some papers and reviewed procedures for an outside activity about speed. This activity, too, was teacher-led in a lecture format, and took about seven minutes. Our walk to and from the track took about eight minutes and was necessary, but neither low nor high in central principles of NOS, in my opinion. School policy prohibits talking in the halls.

For the last 42 minutes of class, students learned how to calculate speed by running various distances on the school track. They ran timed distances of 100 and 400 meters, graphed their speeds, and compared their speeds at the two distances. During the investigation, the students used several high NOS central principles, i.e., (a) sharing information, (b) discussing and interpreting findings, (c) taking on leadership roles, (d) conducting an activity outdoors, (e) using high cognitive ability, (f) being creative, (g) making decisions, (h) connecting science to the world we live in, (i) demonstrating science as tentative through the teacher talk, and (j) showing science as creative and imaginative.

These principles are taken from the classroom observation data interpretation checklist in Appendix C. After the data were collected, the students sat on the bleachers reflecting on the information they had collected, trying to interpret the data. One student suggested that the data were not valid because a few students had walked or intentionally slowed down during the races. The teacher allowed the debate to continue and then asked, "Now that you have identified this as a problem with the data, what are you going to do?" Discussion continued as they wrote down their thoughts about this problem. During the last half of the class, students modeled high NOS central principles; however, at the beginning of the class they modeled both high and low NOS central principles.

The data indicate that Marcus's classroom instruction demonstrated an understanding of NOS for 59% of the class period. Interestingly, Marcus's choices of classroom instruction for this day emphasized his greatest understanding of NOS as evidenced by the interview and the *VNOS B Test*. He demonstrated the following principles through his teaching: (a) science allows questions and conversation about conclusions, (b) science is creative and imaginative, (c) science uses evidence and data to form conclusions, (d) science is tentative and changing, (e) science is connected to the world, and (f) science is collaborative.

Day Two

Marcus showed consistency by beginning his class the same way he did on day one of my observation. He stood in the doorway greeting students while monitoring the hallway. The students entered the classroom, picked up the warm-up activity and settled into their seats. When the bell rang, the room was completely silent as the students worked on the warm-up worksheet. This day's worksheet investigated the concept of acceleration. It was reading intensive, and included difficult science terminology. Many of the students struggled with it. This activity lasted about 11 minutes, and was very low on the central principles of NOS.

After the warm-up, Marcus spent about ten minutes engaging the students in correcting the worksheet by asking them about roller coasters and the local amusement park. Most students were engaged in the conversation and asked numerous questions about velocity and how it is related to acceleration. This was a very rich discussion and rated high on the central principles of NOS.

For the remaining 56 minutes of the class, the students were engaged in an activity using a marble, and a ramp created out of two meter sticks, to investigate how the slope of the ramp affected the acceleration of the marble. This day, Marcus allowed the students to form their own work groups. Marcus quickly handed out the equipment and allowed time for each group of four to play and get comfortable with the tools. After about 10 minutes, he told them to begin the investigation, with the ramp at an angle of their choosing. Marcus walked around the classroom, leaving the students free to make mistakes and discover why the experiment did not work. He had a rule, "Ask three before you ask me," meaning that the students were to refer their questions to three other students before asking the teacher. This class rule allowed the teacher more freedom to facilitate, and encouraged collaboration among the students. Upon completion of the experiment, Marcus had each group post another group's findings on a chart. Near the end of the class period, Marcus tried to have a discussion about the group data, but ran out of time. This acceleration activity demonstrated that Marcus's classroom practices show high central principles of NOS. He allowed equipment practice, choice of groups, and sharing of information. Each group discovered different parts to the problem, and attempted reflection on the data findings.

Day two engaged the students in activities with high central principles of NOS for 79% of the class period, with only 12% of class time spent in low central principles of NOS. The remaining 9% of class time was spent on office disruptions and transition time.

Day Three

This was a Friday, and the students were much louder, and probably more comfortable being observed. Marcus stood at the door again; the students got bunched up in the hall and there was a commotion in the hallway. As the students entered, they were talking, perhaps about the hallway incident. They got their warm-up worksheets with word problems on force and motion, took a few minutes to settle down, and then got to work.

After 12 minutes, Marcus stopped the students and began correcting the worksheets. Most of the students did not finish the word problems. The teacher tried to engage them with questions, but most of the students would not respond. Ten minutes later, he finally engaged them by asking questions about driving automobiles. For the next 12 minutes the students asked several questions, and some students answered them. This was student led time, where the activity was very high on the central principles of NOS. Marcus collected the worksheets and asked the students to get out their journals; there was a collective moan.

Evidently the journals meant it was time for note-taking or working problems. Marcus handed out a worksheet of 15 problems and asked the class not to write on it. He instructed them to work individually on the problems, saying that sometimes they just needed to practice problems in order to understand the concept. The students struggled to stay quiet and engaged. A few just rested their heads on their desks, in defeat. Marcus made an unsuccessful attempt at asking questions to get the students involved, and after about 25 minutes he told them to stop working on the problems and put their journals away. One student collected the journals and put them on the shelf in the back of the room. This activity ranked very low on the central principles of NOS.

For the next experiment, Marcus selected two female volunteers, and asked them to come to the front of the room. Everybody was wondering what was happening. He had their attention as he asked some students to move their tables to the side. He then struggled to push two large tubs up to the front of the room. He told the two girls that they were going to race to see who could get a tub to the back of the room first. What the students did not know was that one tub was filled with books, and the other was empty. The teacher said, “GO.” The student with the empty tub got to the back of the room in no time, while the girl pushing the tub with the books struggled to get it to the back of the room. Marcus engaged the class in a discussion of what happened, and why. Several students shouted out their ideas; Marcus asked them to discuss the experiment with a neighbor. Discussion was lively. After about three minutes, Marcus asked for an explanation. Several students tried to explain; some of the explanations were correct. On the board, Marcus wrote F=MA, (force equals mass times acceleration) with an upward arrow next to the A (acceleration) and a downward arrow next to the M (mass). He asked for an explanation of the formula and the arrows. One of the girls who moved a tub replied that when the mass of the tub is less, the acceleration increases, and her tub had less mass. Most of the students shook their heads in agreement. This activity lasted only 10 minutes, yet it was very high on the central principles of NOS.

Next, the students took a six minute multiple choice quiz. This was a fact recall quiz with a few definitions and a simple "fill in the formula" problem, placing it very low on the central principles of NOS.

Day three had students engaged in high principles of NOS for only 26% of the class time. Marcus told me later during one of the interviews that he was disappointed in this day because he had spent more time addressing on-task behavior than any other day, and perhaps it was due to the activities he had chosen.

Day Four

At the beginning of class, Marcus was again at his post between his classroom door and the hallway. Students filed in and grabbed a warm-up worksheet on acceleration. There were two lengthy paragraphs to read that some students clearly struggled with. Marcus allowed about 11 minutes for this worksheet and then corrected it by announcing the answers. He did not allow questions. This activity is low on the central principles of NOS.

Next, Marcus engaged the students in a quick review for a vocabulary quiz by asking them to demonstrate inertia. The students pushed their desks forward and Marcus asked, “At what time was it hardest to move the desk?” The students replied in unison, “The beginning.” This activity lasted for about three minutes, and then Marcus handed out a fill-in-the-blank quiz with a word bank. The review was very high on the central principles of NOS, while the quiz was not.

For the remaining 55 minutes, the class investigated Newton’s laws of motion by building a straw bottle rocket and experimenting with how each group could make it fly further each time. Marcus distributed the equipment for the lab and told the students how to make the rockets with two straws, a water bottle, and clay. The students created the rockets by placing the narrow straw in the empty water bottle and placing clay evenly around it to seal it. Next, they built the structure that would fly off the rocket by placing rings of paper onto a larger straw that fit over the smaller straw sealed off by clay. The students then placed the larger straw into the smaller straw and squeezed the water bottle to launch the larger straw off the rocket. Marcus took the students outside and explained that they must alter the rocket so that it traveled farther each time they launched it. He reminded them to use the same amount of force on each launch. The students were highly engaged, collaborating, exploring new information, discussing, and interpreting what they discovered. This rich inquiry activity reflects high central principles of NOS.

Does Marcus's Physical Environment Reflect or Contest the NOS? (Classroom Observation)

Marcus had some innovative and creative lessons, yet he clings to a few traditional thoughts about science education. For example, he believed that his classroom is best arranged in traditional rows, but at the same time, he allowed the middle school students to investigate how certain areas of science are researched based on the political climate at the time. He felt that the traditional rows and having the black top lab tables face the front of the room is the best physical layout for teaching science, an indication of low understanding of the central principles of NOS. The demonstration table with a sink at the front of the room overpowers this small classroom that was built in the 1960s. The only other sink in the room is located at the side of the classroom.

The room was very friendly, with posters on the wall depicting diversity in science including women, individuals with disabilities, and minorities engaged in science. Two walls display student work, and several student-created models of cells are displayed on the back bookshelf. Students in this classroom have access to a variety of research tools: a computer, several books, rocks, models, globes, and science related fiction and non-fiction DVDs and video tapes. There are other tools of science present in Marcus's room such as microscopes, beakers, limited chemicals (mostly household items), and test tubes. The supply room located here houses other science tools and equipment.

Marcus's physical environment reflects high central principles of NOS, with the notable exception of the table arrangement. Even though the lab tables are arranged traditionally in rows, Marcus encourages collaboration by having the students turn their chairs around and work in groups of four at one table.

What are the Enabling or Constricting Factors That Translate into Marcus's Classroom Practice? (Interview)

Marcus indicated that the administration and central office of the school district can be both enabling and constricting factors with respect to classroom practices. For example, administrators who trust a teacher's instruction will allow outdoor investigations, while others will not permit a teacher to try different classroom practices. At Marcus's present school, students are not allowed to talk in the halls, thereby limiting time that could be used in reflection about an activity. Another constricting factor was the district mandate of twice as much instructional time for mathematics and language arts as for science and social studies.

Marcus admits that there will always be constricting or limiting factors in teaching, but he interpreted them as excuses. He feels that if students are engaged, they will remain involved in class and out of trouble and therefore, a teacher can fly "below the radar" of administrators and central office personnel. Marcus says, "When you stay out of the way, you can use the classroom practices that work best for your students!"

Summary

Marcus had a good understanding of NOS as it translated into his classroom practices (see Table 4). Interestingly, Marcus seemed to emphasize in his classroom practices the areas of NOS that he understood most thoroughly on the *VNOS B Test* and during the interview. Over the four observation days, Marcus demonstrated that more than 50% of his classroom practices are high central principles of NOS.

Marcus had a partially more informed understanding of NOS and demonstrates it more than 50% of the time in his class. He tended to focus on those questions he understood best on the *VNOS B Test*. During my four days of observation, he did not talk about theories and laws as they relate to each other, even though the lessons were on Newton's laws. Perhaps there is a relationship between the *VNOS B Test* and the classroom practices.

Table 4. Marcus Classroom Practices as Aligned with the Central Principles of NOS

Central Principle of NOS Science is:	Example of Classroom Practices Through Classroom Observations	Literature Cited
1. Tentatively based.	Observed poster in room depicting science now with diversity of individuals and science then. The poster included contradictory discoveries of then and now.	Science is tentative and does not answer all questions (AAAS, 1990; NCR, 1996).
2. Empirically based.	Collected data for student speed, bottle rockets, and time on the track using marbles.	Science is based upon empirical observations (NSTA, 1982).
3. Subjectively interpreted.	Discussion about how to interpret students racing. Some students walked or slowed down intentionally.	Science is embedded with personal beliefs (NCR, 1996).
4. Creatively and imaginatively inferred because it involves humans.	Creating bottle rockets and discovering methods to increase distance in flight.	Science is creative and uses imagination (AAAS, 1990).
5. Distinctively a combination of observations and inferences.	Understanding laws of motion and applying them to bottle rockets and marbles on a track.	Science is a blend of observations and scientific predictions (AAAS, 1990).
6. Socially and culturally embedded.	** Role of science among Presidential candidates (i.e. stem-cell research)	Science is socially, culturally, and politically embedded (AAAS, 1990; NCR, 1996).
7. Separately understood from technology (but impacts each other).	NOT OBSERVED	Science and technology impact each other in order to gather an understanding of the natural world for its own sake (NSTA, 2000)
8. Related kinds of scientific knowledge, laws, and theories.	NOT OBSERVED	Science is unified by theories, laws, and concepts understood by scientific knowledge (Kimball, 1968).
9. An understanding of how scientific knowledge is formed.	Gathering new information and discovering how to increase the distance a bottle rocket goes without increasing the force.	Science must demonstrate how scientific is practiced by showing how scientific knowledge is formed (Cuningham, 1995).

*Not direct observation of classroom practices but a poster in the room demonstrating this central principle of NOS
**Not direct observation of classroom practices but teacher discussed during interview.

Sam Howard

Sam stands six feet five inches tall and commands his classroom by walking around and keeping the students on task. Sam has a very quiet, relaxed manner about him and enjoys interacting and joking with the students; however, when it is time to learn he gets intense and expects the same of his students. He is a 29-year-old Caucasian who plans to enroll in a master's program next year and to get Nationally Board Certified as well. His students enjoy his class and like talking sports with him. He is presently the boy's basketball coach and athletic director at Branch Middle School.

Branch Middle School's student population is quickly changing due to new schools being built, and the recent influx of Latino immigrants. Just five years ago, only 30% of the students qualified for free or reduced-priced lunches. Last year, the free or reduced-priced lunch percentage was 58%, and this year the anticipated count is up 3%, which is a large jump for one year.

The school has a student population comprised of 34% African American, 34% Caucasian, 24% Hispanic, 5% Asian, 2% Multiracial, and 1% Native American, where about 21% of that population has limited use of the English language. Approximately 11% have disabilities. Branch Middle School's eighth grade students were on par academically with the school district as a whole, according to passing rates on the state math and reading tests. Fifty-seven percent of the eighth grade students at Branch Middle School passed the state math test (district passing average for eighth grade math test is 59%) and 85% of the students passed the state reading test (district passing average for eighth grade reading test is 84%). Most of Sam's classes have 27 to 32 students.

Sam has taught eighth grade science for three years at Branch Middle School, where he has recently taken on additional jobs as team leader and science equipment leader. He declined an offer to be department chair, as he felt pressed for time. Sam's unique educational background includes intensive scientific research experience. He first attended a large, southeastern university and obtained a bachelor's degree in environmental science, with a minor in parks and recreation. He then attended a coastal community college on a basketball scholarship and majored in marine technology. There, he had the opportunity to design and perform original oceanic scientific research while taking a research ship to the Bahamas. One semester, Sam's oceanic scientific research team designed an investigation to collect and compare yearly climatic and oceanic data from the Atlantic Ocean.

Prior to teaching, Sam worked at a marina as a technology specialist, and led community workshops open to the public. He designed and held trainings on requested topics, such as preparing a vessel for the winter months, or increasing fuel mileage on the open water. He felt this career path was not challenging enough, so he looked into teaching science because he really enjoyed the workshops he designed and presented. He also wanted to coach basketball. He packed his bags and moved to this large southeastern city to find a teaching job. He acquired the job four days prior to the first day of school, and ended up in the classroom with very little training and no mentoring.

Sam had a limited understanding of NOS, which he acquired through experience, formal education, and three years in the classroom.

What is Sam's Understanding of the Nature of Science? (VNOS B Test/Interview)

Sam's overall understanding of NOS was very polarized according to his *VNOS B Test* and interview. He tends to either fully understand a concept or possess a less informed view of the topic. For example, question five asks about when scientists use creativity and imagination in performing investigations. Sam fully understood this topic according to the central principles of NOS, but lacked understanding of other topics such as the relationship between theories and laws, and he was less informed on the scale of understanding NOS (see Figure 2).

According to the test and the interview, Sam's understanding of NOS is in the middle, between more informed and less informed. His written answers and interview answers were very short and incomplete. It was difficult to get him to talk about many of the topics. In the latter part of the interview, Sam confided that the questions were difficult and he had not thought about them in a long time, and really did not know how to answer some of them.

Question One (Do Theories Change?)

Sam's understanding of this question was less informed, because he believed that theories change once they are proven by testing them many times so they become facts. He also believed that there was a hierarchal relationship between theories and laws. As indicated by the two statements above, Sam was not very confident with any of the information about theories. Later during the interview he admitted that he was not very comfortable talking about some of the questions because he just did not understand them very well. While Sam was consistent in his written and verbal ideas that changing theories are proven and become laws, he clarified some other points during the interview. Sam stated that theories can be explained, but we do not always know why. For example, he said, "The world's an ever-changing place, and there is new stuff coming up all the time with the new factual information, so the scientists have to keep trying to prove facts as best they can." He also stated during the interview that theories are always being investigated and explored by several scientists. He inferred that many scientists investigating one problem is good for science, because it can bring many different views to an issue.

While Sam had a few more informed ideas about theories, he continually insisted that theories change so they can be proven and become facts and then laws. This view of theories ranked Sam toward the less informed side of the scale on central principles of NOS (see Figure 2).

Question Two (How Certain are Scientists about the Structure of an Atom?)

Sam had a less informed understanding of how models are used to represent structures of "unseen science." Sam's less informed view of how scientists determined the structure of an atom was clearly stated when he said, "Really, I do not have a clue how!" It was very hard to get him to comment on this question; I really believe he did not understand how to answer it, so he said very little. Therefore, Sam ranked on the less informed side of the scale of understanding the central principles of NOS (see Figure 2).

Question Three (What is the Difference, if any, Between a Theory and a Law?)

Sam had a lot more to say about this topic of NOS; however, most of it was from the less informed point of view (Figure 2). Sam clings to the notion that a theory was a sort of opinion formed by scientists, and finally, after some period of testing time, it can become a law. According to Sam, a theory can only become a law after it has been "proven" many times with experiments. Sam believed that the relationship between laws and theories is hierarchical, and that theories are below laws in the truth of science. He stated, "I believe that some theories can almost be proven with laws, and laws are factual. I think theories are always being worked on to be proven as a law."

Sam had a few sophisticated ideas associated with understanding this question. He stated that theories are an accumulation of many scientists' ideas: "I think they [theories] are built up from not only one scientist but other people's ideas as well." He also indicated that theories change sometimes due to the individual perspective on science as a whole. After speaking with him again about this, I learned that he believed that society influences scientists to change their thoughts sometimes. Even though Sam has a few sophisticated ideas, he continually comes back to the idea that theories and laws have a hierarchical relationship, which keeps his understanding of this question on the less informed side of the scale.

Question Four (How are Art and Science Similar/Different?)

Sam's written and verbal answers were very different, which leads me to think he misunderstood this question on the *VNOS B Test*. His answers on the written portion of the test were less informed. He wrote that art and science are similar because they both have been around since the dawn of human existence. He also wrote that they are both seeking a desired outcome by testing different hypotheses.

Conversely, during the interview Sam stated that both artists and scientists use creativity and imagination to work. He also felt that they are very similar because they use the same thought processes to create an end product. During the written test, he did not write about any differences, while during the interview he claimed that science was different from art because science reveals patterns. Sam also claimed, "Art is more creative, more spur-of-the-moment thing; you just sit down and put something on paper, where science you might have to work it out a little bit longer, you might have to come back to it." He also shared with me that he classified himself both as an artist and a scientist. Sam said that he draws a lot, but would never consider being an art teacher. He was much more confident in answering this question verbally, and has a more informed view according to the central principles of NOS (see Figure 2).

Question Five (Do Scientists Use Creativity/Imagination?)

Clearly, Sam had a more informed understanding of this question (see Figure 2). He consistently stated, in both the written and verbal forms of this question, that scientists use creativity and imagination during all phases of problem solving. He even stated, "[Scientists] use their creativity and imagination during and after the data collection. They should also explore and test a variety of methods prior to making any conclusions."

Question Six (How Can Scientist Have Different Conclusions?)

Sam seemed to have a mostly more informed understanding of this question (see Figure 2). He believes that scientists interpret data based on their opinions, influences, and past experiences. Sam feels that science is messy, and can have more than one correct answer or explanation. He said, "You have one person saying this, another person saying something else, and both of their conclusions are correct, looking at the data." Science is full of opinions that are formed from an individual's past experiences, including their education and societal experiences. On the written portion of the *VNOS B Test*, Sam seemed to misunderstand the question, and thought the scientists obtained different data; therefore, I am basing most of my ranking from his interview answers.

How did Sam Acquire his Knowledge of NOS? (Questionnaire/Interview)

It is no surprise that Sam became interested in science due to his own K -12 science experiences. His teachers demonstrated science through hands-on activities and thoughtful reflection. He recalled one biology class where the teacher set up the room like the zones of the ocean, and he had to become like one of the organisms in the zone where his desk was located. He was in the inter-tidal zone and had to become a crab. He really enjoyed and learned a lot from this teacher, so he was determined to conduct his classes in a similar manner, as best he could.

Sam has a bachelor's degree from a large southeastern university. He majored in environmental science, with a minor in parks and recreation management. His answers on the questionnaire were very short and incomplete; however, he did attach a very comprehensive list of the courses he took. The university course descriptions included several courses in biology and environmental sciences. The environmental courses emphasized a combination of the social sciences, humanities, and the natural sciences. Some of the courses Sam took included a public interest lobbying course, energy policy, and social science law.

After obtaining a bachelor's degree, Sam studied marine technology at a coastal community college. The courses at the community college were hands-on and required original scientific research. These courses taught him how to design, implement, and interpret research by requiring him to board a vessel for several days and sail the Atlantic to the Bahamas every semester. The students were responsible for designing their own research.

Sam talked a lot about his coursework at the community college and the scientific research he conducted there. For example, on the 12 day cruise to the Bahamas, the students measured the Atlantic Ocean's temperature, turbidity, salinity, and barometric pressure, and they collected and identified bioindicators in the ocean. While in the Bahamas, Sam toured a naval base that conducted research and experimentation with diving and simulations. Here Sam indicated that he learned more about the physics of water pressure and the impact it has on living organisms. Sam's science experiences at the community college provided him with ample opportunities to design, implement, and interpret scientific research. This had a profound influence on his understanding of how scientific knowledge is formed. He indicated that sometimes the research on the cruise was exciting, yet at times it got very complicated and messy during the interpretive part of the investigation.

Once Sam became a teacher, he was fortunate to attend several workshops for English as Second Language Learners. He was trained in Sheltered Instruction Observational Protocol (SIOP), where he learned how to teach students with limited or no English language skills. In this training, Sam learned to make science inclusive for all.

He had not really thought about this prior to the training. Sometimes he was trying to teach science as a challenging, difficult subject for only the smart kids to master. After the training he had a different view of science and how it should be inclusive of all learners. He also learned through the SIOP class that students can be assessed in different ways. He began assessing some students orally. This was the beginning of his work on alternative assessments. He now uses checklists during labs and allows assessments to be oral presentations.

Sam's rich background and scientific experiences have helped form his knowledge of NOS. His experience on the research vessel helps to explain his more informed knowledge of question five (creativity and imagination during experiments) and question six (variety of conclusions from the same data).

How do Sam's Classroom Practices Align with the Central Principles of NOS?

(Observation Checklist/Field Notes/Lesson Plans/Interview)

On three of the four days I observed Sam's class, the students were seated, watching morning announcements on television when I entered his classroom. I observed his first block, eighth grade science class for four consecutive days in late spring. Because the school was being renovated, teachers were required to have breakfast in their classrooms before class; therefore, their days began 20 minutes earlier this year. After the morning announcements, Sam frequently had to use 10 minutes of his class time to address additional eighth grade announcements. Sam's class was very well structured, with a daily agenda listed on the board, including the amount of time allotted for each activity. Not once did I hear, "What are we doing today?"

Day One

The warm-up lasted 10 minutes and was low on the central principles of NOS because the students were completing a true/false statement sheet. All of the statements were very low cognitive tasks that required only recall, and they all had only one correct answer. The warm-up had four short statements about cells that the students copied into their science notebooks, and answered independently and quietly. Sam led a discussion of the warm-up by asking the students to correct their own papers while he read the statements, with no explanation as to why they were true or false.

Next, the teacher gave a short lecture on the differences between a light microscope and an electron microscope. Only one question was asked during the 10 minute lecture, and the teacher never really answered it. A student asked if an electron microscope would be used to view atoms. Sam said, "Good question, but that is not what we are discussing now, so we need to move on so we can get to the activity." This 10 minute activity was also low on the central principles of NOS.

For the next 15 minutes, Sam placed a textbook prepared drawing of the light microscope on the overhead. He asked the students to sketch it and label all of the parts. I wandered around the room as the students were attempting to do this; most of the class was struggling tremendously in their attempts to draw the microscope. Finally, Sam got up holding a real microscope, and quickly listed the parts, without referring to the drawing on the overhead. Many of the students stopped working and did not attempt to finish the activity. This activity was low on the central principles of NOS because it was copying, teacher-led, independent work that students found too difficult.

This day, the students were exploring the differences between animal and plant cells by preparing two different slides. The teacher told them where to gather the equipment and how to avoid breaking the slides by moving the stage up and down on the microscope with the coarse focus. He did not read the directions for the lab to the students; he said they must read the directions themselves to figure out what to do. Later, Sam said, "This is a way to assess who had read and really comprehended the activity as I walk around the room." This 10 minute activity was necessary and somewhat higher on the central principles of NOS, because he allowed the students' time to explore what they were going to learn and use the tools of science.

They performed the classic lab activity of scraping cheek cells from the inside of their mouths with toothpicks and placing the cells on a slide. The cells were then stained with methyl blue so the nuclei were visible. Students compared these cells to plant cells, in this case, onion cells. Sam prepared the thin slice of onion for the students due to the short class time remaining. All of the students were highly engaged in this activity. Sam never helps anyone for the first few minutes of a lab, especially when it involves new equipment that the students need to explore. Today was the first time this class had used microscopes. Sam believes that students need to "play" with new equipment. The students are allowed to help each other, so a lot of collaboration was occurring. After about five minutes, Sam went around the room and assisted students who were frustrated with the equipment. This activity took 35 minutes of the class time, and for about 75% of the time, students were highly involved in the central principles of NOS.

Sam's cell viewing activity demonstrated a high understanding of NOS as shown by his classroom practices. About one half of the class time (45%) was spent in demonstrating classroom practices that were high on the central principles of NOS, while the remaining portion of the class time (55%) was not reflective of a high understanding of NOS.

Day Two

On the second day, the announcements for eighth grade students continued for an additional 10 minutes of class instruction time, which irritated Sam. The interruption was extended when a counselor came in and gave Sam three more informational papers to be sent home with the students. He handed them out after he placed the warm-up on the overhead. The warm-up activity was high on the central principles of NOS. The students were to explore the relationship between animal and plant cells using a graphic organizer and their books. Even though this was an independent activity, the students were cognitively challenged. The teacher did not provide the correct answers; instead, he asked the students to share their answers with a neighbor and discuss the possibilities. After a few minutes, he asked them to use a different color pen or pencil and make corrections on their own. This activity lasted 10 minutes and demonstrated many high central principles of NOS. This activity demonstrated collaborative work that involved students discussing and questioning each other graphic organizers.

Next, the teacher described where he got the water sample for the day's lab experiment. Students were to observe and identify microscopic organisms from two pond water samples. The teacher explained, "There are two samples of water: sample one was from a large pond near my home with many geese, and sample two was from a different section of the pond and had very muddy water due to the recent rain." The students asked a few questions about the samples, and then began the lab. The teacher allowed them to choose their own lab groups. This activity took 10 minutes, about half of which involved interactive questions from a variety of students – a demonstration of high central principles of NOS.

The activity began again with the "no involvement rule" from Sam. Students worked collaboratively. Some students were frustrated, because the organisms on the slide moved, and the students had not figured out how to follow them with the microscope. After about five minutes, Sam got involved and helped a few of the students locate and identify organisms. The other students were engaged and working well with each other, sharing the different organisms they found.

One group had a defining moment when they realized how much the microscope magnifies an object. A girl in the group identified a small, moving structure in the sample, and then screamed frantically when she realized it was snake-like. The teacher calmly asked what the problem was. In a loud, panicked voice, the girl explained that there was a snake under her microscope. Asked by the teacher why she was so worried, the student said, "I am really afraid of snakes and this one might get me." The teacher removed the slide from the microscope, and asked her to show him where the snake was. She examined the slide from a distance, and then came closer. "Where did it go Mr. H.?" she asked quietly. "Well, let's look at the slide again." he suggested. They finally found the snake-like organism, and the student said she understood how small it really was and that the microscope was a powerful tool to make it seem that big. Sam helped the student learn about the power of the microscope by allowing her discover it rather than just telling her about it, which is high on the central principles of NOS.

To conclude this activity, Sam asked the students to use a Venn diagram to compare and contrast the organisms they found in the two samples. This activity demonstrated many high central principles of NOS that involved students identifying different organisms and sharing their data with the class. The students had to speculate why the different organisms were in the different water samples. I heard one idea from a group of students stating the differences in organisms could have been due to different water temperatures of the samples.

The last 15 minutes of class time was spent copying information word for word from an overhead. Sam read the notes as the students madly copied every word. There was not a sound in the room except the teacher talking and pencils on paper. Sam reminded them that this information would be on the next test, and given the way everyone was writing, I believed him. This activity was very low on the central principles of NOS.

This day's classroom practices demonstrated high central principles of NOS 72% of the class time, omitting the extra 10 minutes of announcements. The demonstrated classroom practices were: generating questions, cooperative learning, positive communication between students, science as a human endeavor, and interpretation of data.

Day Three

This class began in the same manner as the last, with announcements cutting into class time. Yesterday's announcements were repeated, taking an extra five minutes of class time. Sam stood by the television waiting for the end of the announcements, so he could begin class as soon as possible.

The warm-up was similar to most of the other warm-ups: a textbook prepared sheet was placed on the overhead, and students were required to match cellular biology terms with their definitions. This activity took 10 minutes, including the time it took the teacher to read the answers, and it ranked low according to the central principles of NOS.

Next, the teacher reviewed information that would be included on the chapter test during the next class meeting. He read what was written on the board, and the students copied it into their agendas. As students finished copying they raised their hands, and the teacher came by and initialed their agendas. Again, this activity was teacher led with no student interaction, and was therefore very low on the central principles of NOS.

The majority of the class time, 55 minutes, was spent in a small group activity that demonstrated several high central principles of NOS. Students selected important information from the textbook and taught it to the class. Each small group was given a different section of the chapter to teach; however, the scientific knowledge that was presented and just transferred from the textbook to the students in the classroom which is low on the central principles of NOS. The students were allowed to choose their own groups. Within the groups, each student had a specific role: reader, writer, presenter, or graphic designer. Many groups debated about which topics from the assigned reading were most important. Some groups had to re-read the pages and really discuss the information. This activity generated a lot of discussion among the students. Once the important topics were agreed upon, the group had to decide how to present them. After 55 minutes, some of the groups had not completed the task. Sam understood the value of the activity, but he had underestimated the time required. Day three activities demonstrated an understanding of NOS through classroom practices 69% of the class time. While Sam originally planned for the small groups to take only 25 to 30 minutes, and for presentations to begin the same day, he seemed to understand the importance of the small group activity and changed his daily schedule.

Day Four

Day four was chapter test day, so the routine was a bit different at the beginning of class. There was no warm-up, and the students were allowed to quietly review during the overflow of announcements into class time. For the third class block in a row, the same three announcements were repeated. I thought Sam was going to explode when he heard them again. He turned down the television volume to allow the students to review; most students chose not to. This activity was low on the central principles of NOS.

The test was a written assessment, mostly on the recall level, therefore using only low central principles of NOS. There were 29 questions in all; the first 13 were fill-in-the-blank with a word bank. The next group of question, 14 to 20, required the students to label a drawing of a microscope. The last nine questions were short answer; however, all were definitions or knowledge-level questions, with one exception. That question asked the students to explain, using specific terminology, how and why cells specialize.

Students who finished the test quickly had an additional reading assignment about local issues in North Carolina that was very thoughtful, and required interpretation of new information. Most of the students were eager to do the reading. The issue was the water shortage in the Piedmont region, and how this affected everything from boating to watering lawns. After the reading, the students wrote a personal statement about the water shortage, including whether the reading made them think about changing any personal habits pertaining to water use. This activity was high on the central principles of NOS for those students who had the opportunity to participate. Many students were still working on their test.

After 45 minutes, the teacher called time, and asked those individuals who still had a test to bring it up to the front. There were about eight students with tests (approximately ¼ of the class). After all the tests were collected, the students began their presentations from the small group work from yesterday. While this was a student led activity, it was presented in lecture format, with students copying what other students wrote. There was no interaction at all, and on occasion, too many notes for the students to copy. I ranked this activity low on the central principles because of the lack of interaction, and because the students were just copying information into their notebooks that was scientific information transferred from one source to another.

The slower test takers were involved in classroom practices that show a high understanding of NOS about 6% of the class time, compared to 25% for the fast test takers. During day four, Sam's classroom practices for the most part did not demonstrate high central principles of NOS.

Does Sam's Physical Environment Reflect or Contest the NOS? (Classroom Observation/Interview)

Branch Middle School was 40 years old and was undergoing a renovation. This is a suburban school that is rapidly changing to an overcrowded urban school due to the recent wave of immigrants and the expansion of the city. Entry to Sam's room was accessible only from an old, covered loading dock outside. The low ceiling and absence of windows gave the room a closed-in feeling. Access to all the of other 7th and 8th grade science teachers was available through a science equipment and storage room. The walls were a dingy, dirty yellow, but Sam claimed that will change next year due to the renovation.

The lab tables and chairs were very old, many with holes and rips in them. The room was crowded, with lab tables arranged in three rows, all facing the front of the room. Sam told me that he tried other configurations, but because of the shape of the room, this was the only one that worked. Sam also stated that this set-up of the tables was the best arrangement for encouraging student movement. The lab tables were black acid-topped, and were replaced with another covering about ten years ago. The back of the room has a sofa for student use; the front of the room has a permanent demonstration table with a sink. To the left of the demonstration table sat a small desk for Sam's computer and personal papers. The students were not allowed to use this space without the teacher's permission.

Sam had plenty of classroom storage, with glass cabinets above the lab counters along both the left and right walls. The lab counters had three sinks per side and all are functional except one sink on the right wall. All of the cabinets contained tools of science and were accessible to the students. There were also a large bookshelf at the back of the room containing resource books and magazines such as *National Geographic* and an ecology magazine that the students were allowed to use. A smaller bookshelf held a class set of the science textbook.

There was not a lot of wall space, due to the cabinets and the low ceilings, but the two bulletin boards displayed student-created work. One wall had lab safety rules posted; the other had posters about mutual respect. The small bulletin board at the front of the room displayed school information, e.g., the school calendar, notices of upcoming events, and the bell schedule. Next to it, the large white board displayed the daily schedule, upcoming tests or projects, classroom goals and objectives, and a teacher created calendar with the state test dates circled in red. The test dates were also in a larger font than the other calendar dates.

On one of the counters was an aquarium containing local species of plants and animals. It was well kept, and of great interest to the students. On top of the cabinets were several models, some student created and others company manufactured.

Sam told me that he tried to create a room where students move around and "do" science. He wanted his room to be student friendly, a place where students can conduct investigations. He seemed to have accomplished this in spite of restrictions he cannot change. Sam's room was easily identified as a science room. Sam had created a room that highly reflects the central principles of NOS.

What are the Enabling or Constricting Factors That Translate Into Sam's Classroom Practice? (Interview)

Sam was clearly irritated by the interruptions for announcements. This was evident during most of the classes I observed. Routinely, the morning announcements took 5 to 10 minutes of the first block. Sam felt that science classes were shortchanged anyway, and taking instructional time from him was unfair. He did not understand why mathematics and language arts teachers were given twice as much time as science teachers. He was hopeful that eighth grade science will be double-blocked, due to the state testing. He has voiced his opinion about the interruptions, but due to school administration turnover in the last two out of three years, nothing had been done to curb this practice.

Sam was also hopeful that the renovation will bring him a door that opens into the hallway rather than outside, because the door to the hallway is currently locked and he had to unlock it regularly for students, another task that takes up his instructional time.

His administration did allow him to go outside for activities with the students. When he asks for lab equipment, somehow the administration finds the money and within weeks the equipment is there. His administration also encourages professional development and allowed the teachers to take time off to attend workshops and conferences. Sam was very excited about being able to leave school early next year to attend classes at the local university so that he can begin work on his master's degree.

Constricting factors include the building structure and the interruptions during class. Sam remained hopeful that the renovations will help with the building structure, and that the new superintendent will not move the principals around the district so much. The enabling factors were exceptional in helping teachers translate their knowledge into classroom practices, because the teachers at this school felt that the principal values teacher education by allowing them the freedom to attend professional development.

Summary

Sam had a very polarized, either more informed or less informed, understanding of NOS as it is translated into his classroom practices (see Table 5). His understanding of NOS, as seen through his *VNOS B Test* and interview, mirrors classroom practices that demonstrate high central principles of NOS. His classroom practices and understanding of NOS primarily reflected his experiences with scientific research while aboard the educational cruise ship. Sam allowed his students to investigate science in his classroom, yet he clings to the traditional notions of written recall tests and copying of lecture notes. Sam’s classroom did reflect some high central principles of NOS, especially with the hands-on opportunities he provided.

Table 5. Sam Classroom Practices as Aligned with the Central Principles of NOS

Central Principle of NOS Science is:	Example From Classroom Observation	Literature Cited
1. Tentatively based.	* Reading about how to deal with water shortage problem in NC.	Science is tentative and does not answer all questions (AAAS, 1990; NCR, 1996).
2. Empirically based.	Observing and comparing and contrasting cheek and onion cells	Science is based upon empirical observations (NSTA, 1982).
3. Subjectively interpreted.	Students decided what information should be taught from textbook.	Science is embedded with personal beliefs (NCR, 1996).
4. Creatively and imaginatively inferred because it involves humans.	NOT OBSERVED	Science is creative and uses imagination (AAAS, 1990).
5. Distinctively a combination of observations and inferences.	NOT OBSERVED	Science is a blend of observations and scientific predictions (AAAS, 1990).
6. Socially and culturally embedded.	NOT OBSERVED	Science is socially, culturally, and politically embedded (AAAS, 1990; NCR, 1996).
7. Separately understood from technology (but impacts each other).	Microscope use in observations.	Science and technology impact each other in order to gather an understanding of the natural world for its own sake (NSTA, 2000).
8. Related kinds of scientific knowledge, laws, and theories.	NOT OBSERVED	Science is unified by theories, laws, and concepts understood by scientific knowledge (Kimball, 1968).
9. An understanding of how scientific knowledge is formed.	NOT OBSERVED	Science must demonstrate how scientific is practiced by showing how scientific knowledge is formed (Cuningham, 1995).

* Not all students participated (approximately 10% of the classroom participated) in this activity.

Shanice Baker

Shanice is a very involved, nurturing, eighth grade science teacher at Burrows Middle School. She is a 41-year-old African American who has been teaching at Burrows for six years. Seventy-five percent of the student population was comprised of African Americans. Other demographics among Burrows students include 15% Hispanic, 4% Caucasian, 4% Asian, and 2% Multiracial students. Eighty six percent of the students qualify for free or reduced-price lunches. The school building is over 60 years old and has many structural problems, such as heating, plumbing, and electrical wiring. I have visited the school when parts of the building were flooded with several inches of water. These were just a few of the school's physical challenges. The students come to school with many academic challenges as well. Fifteen percent of the students struggle with the English language. A number of parents have problems communicating with the teachers and staff because they do not speak English. Approximately one quarter of the student population has a diagnosed disability: most of these are learning disabilities. Only 32% of the entire eighth grade student population at Burrows passed the state math test, compared to a 67% passing rate district-wide. Unlike the low math scores, the reading scores for Burrows' eighth graders were at 77.5% passing, compared to an 85% passing rate for the district. Fortunately, this school restricts class size to 20 students. Most of Shanice's classes had fewer than 16 students.

Shanice greeted each student individually, and often had a personal comment, concern, or question for each one. One morning, she greeted a student and asked how her grandma was, knowing the girl's grandmother had been hospitalized recently. She truly listened to all of the students, and she took every opportunity to teach them positive alternative choices while encouraging them. For example, one girl was not sure she could become a doctor and go to medical school. Shanice encouraged her and told her that she was very gifted academically and just needed to remain focused for the rest of her years in school. Last year she taught seventh grade, and this year she teaches many of the same students in eighth grade, and she knows them well. Although she and her students were well acquainted, Shanice never allowed disrespect in her classroom. She made it very clear that her classroom was a place where mutual respect is expected. For example, Shanice does not allow any student to talk badly about other students in her classroom. One boy began a discussion about another boy and said, "He is so weird and I am sure his mother dresses him." Shanice overheard this discussion and would not allow it to continue and told the boy who started the conversation not to speak about others like that in her classroom. The boy apologized and told Ms. Baker that he would not talk that like that anymore.

Shanice enjoyed teaching at Burrows, but was frequently tired due to the many demands: parent conferences, social worker meetings, and grade level meetings. She was working on her master's degree in technology education from a university in Massachusetts when I visited her. Classes are held on-line, and meet locally one weekend a month. Shanice is very involved at the school and district levels. She is the department chair and a former lead teacher for Burrows Middle School. Burrows is in close proximity to the local university, where Shanice got assistance from the math and science center.

Shanice brought 16 years of experience as a medical technologist to her classroom. She was in charge of the blood lab, where she conducted various blood tests, recommended other courses of medical tests, and reported the results to the doctors. During her undergraduate studies, she had a wonderful internship in Michigan helping design and implement scientific research for a pharmaceutical company that I will discuss in detail later.

Shanice had a polarized, more informed or less informed, understanding of NOS, depending on the question, as demonstrated through the classroom practices she acquired through her experiences, education, and six years in the classroom.

What is Shanice's Understanding of the Nature of Science? (VNOS B Test/Interview)

Prior to discussing Shanice's data, I must mention that her answers were very different from those of any other participant. Because Shanice was called to an emergency meeting, I was not present for the administration of the VNOS B Test; Shanice completed it without me present and therefore could not ask me any questions that she may have had. The interview helped me understand her short and often incomplete answers. The entire written test was only about one third of a typed page and she omitted one test question. She reported that she had used her computer to research some of the questions, because she was unsure of the answers and did not want to leave them blank.

Shanice's answers to many of the interview questions contradicted her answers on the written *VNOS B Test*. Half of her verbal answers indicated a less informed view of the understanding of NOS, while the other half suggested she possessed a more informed view of NOS. She struggled with the understanding of the nature of a theory, and clung to the notion that theories never change.

Question One (Do Theories Change?)

Shanice had a less informed understanding of this question (see Figure 2). She stated consistently in her written answers and verbal explanations on the *VNOS B Test* that theories never change. Later, during the interview, she said, “Theories are expanded by different scientists when more evidence is provided.” She tried to explain that even these theories did not change; they just acquired more detail because evidence and new facts were present. She also indicated that students should learn theories, because they are important to the understanding of science.

Question Two (How Certain are Scientists about the Structure of an Atom?)

Shanice attached three pages of information from the Internet on the evolution of the structure of the atom from Democritus, 5 BCE, to Rutherford’s experiments in the 1940s, where he determined the positive-charged nucleus of an atom. Shanice searched the internet for information to help her answer this question because she did not know how to answer this question given her present knowledge. Shanice stated, “Each theory was built upon previous scientists’ work to end up with the present day atomic theory.”

During the interview, she told me that models were used to represent the atom, but she was not certain how scientists developed the models. She described the scientists who discovered the structure of the atom as pioneers. When asked to elaborate, she said, “It was because they often went against society to come up with these radical ideas.”

Shanice had a few sophisticated ideas in combination with some less informed views (e.g., theories never change), indicating a predominantly less informed understanding of this question (see Figure 2).

Question Three (What is the Difference, if any, Between a Theory and a Law?)

Shanice again struggled with the idea that theories never change, yet she defined theories as facts and explained that laws could be tested. She defined scientific laws as phenomena that are in place when certain conditions are present. Her less informed view of this question represented theories as phenomena that can be tested and proven. According to Shanice, laws and theories should be taught to students because they are important. She cited cell theory and atomic theory as examples. Although the definitions can be interpreted as true, when combined with her less informed understanding of the differences between a law and a theory, they indicate a less informed understanding of this question (see Figure 2). She concluded her thoughts on this question by stating, "Theories and laws are not related at all."

Question Four (How are Art and Science Similar/Different?)

Shanice had a more sophisticated grasp of this question, giving her a more informed view of this facet of NOS (see Figure 2). This was her most comprehensive, original answer. During the written test and the interview, Shanice acknowledged that both art and science are full of creativity and imagination. Her description of artists and scientists as individuals who represent ideas and express themselves through the lens of society indicated a complex understanding of NOS. She gave an answer in her interview that intrigued me. She said, "Both artists and scientists are intense and single visioned (sic) with their work." Perhaps she formed this idea based on her exposure to scientists and advertising artists during her internship with the pharmaceutical company.

Her answers to the question of how art and science differ were predominantly less informed views. She clung to the notion that science can use many methods to solve a problem, but they always yield the same answer to the tested question. On the written portion of the *VNOS B Test*, she indicated that science is loaded with opinions but art is not; conversely, during the interview, she told me that art involves an emotional side that science does not have. Her inconsistent responses indicated a lack of understanding of the similarities and differences between art and science.

Question Five (Do Scientists Use Creativity/Imagination?)

Shanice's written answer to this question was a very short sentence fragment with no example; however, during her interview she expressed herself more fully by explaining how science is packed with emotions. Earlier during the interview, she stated that science was not emotional when compared to art. She explained that during her research experience as an intern, she saw how messy science was, how politically charged it could be, and how it was greatly influenced by money. Her pharmaceutical internship in the design and research division exposed her to marketing strategies for new medicines, and she had an opportunity to observe the entire process of the creation of a new drug, from design and research to its placement on the pharmacy shelf. Her understanding of this question revealed a more informed view of NOS (see Figure 2).

Question Six (How Can Scientists Have Different Conclusions?)

Shanice's answer to this interview question surprised me. She did not answer the written question, yet she provided more informed answers during the interview (see Figure 2). She explained, "Scientists are often opinionated and outspoken individuals when it comes to their research. They see things differently from other people. Their opinions are influenced by their experiences, which impact the way they view everything, including their research." She further defined experiences as one's upbringing, education, and the people with whom one comes into contact over the course of a lifetime.

The sophisticated answer she gave at the end of the interview was very thoughtful, and I can only attribute this to her experiences at the pharmaceutical lab. She claimed that scientists learn a lot when they argue, and that there is value in educational debate.

Shanice seemed to have a polarized understanding of NOS. She had a less informed view of scientific theories, embracing the notion that theories never change, and she did not see a relationship between a laws and a theories. However, she appeared to understand the role of creativity and imagination in science, and to hold a more informed understanding of this facet of NOS. Shanice's understanding of NOS was in the middle of the scale. However, it would be incorrect to conclude that Shanice has an understanding of NOS that is the middle of the scale. It is polarized, either less informed or more informed, depending on the facet of NOS under discussion.

How did Shanice Acquire her Knowledge of NOS? (Questionnaire/Interview)

Shanice had multiple experiences that helped her understand NOS, but perhaps the most defining experience was her participation in original research during a summer internship at a large pharmaceutical company. Her work in the research and design division helped Shanice understand how new scientific knowledge is formed. She helped with the creation of new products during the testing phase of the product on human subjects. Shanice explained, "It got very messy when the marketing people tried to get certain information for the advertising of the product." The marketing people would "put words in their mouths of the scientists" about the data they had found during the research. She also saw how the advertising division worked, and inferred that the artists and the scientists were similar in many ways.

Animal testing at the pharmaceutical company bothered her, especially the removal of dogs' vocal chords for medical research. When she questioned the procedure, she was told that they did not want to hear the animals barking all day. She thought this practice was a serious breach of research ethics. At the time of this research, restrictions on animal testing were not as stringent as they are today.

Prior to teaching, Shanice also worked as a medical technologist for 16 years, where her primary responsibilities were testing blood and communicating the results to doctors and hospitals. Most of the blood analyses were for routine work such as cholesterol, protein level, and diabetes testing. Occasionally, Shanice would recommend further medical tests due to her observation. She also had to maintain and upgrade her equipment.

Shanice participated in a school district workshop on NOS. One of the requirements was to use some NOS strategies in her classroom, and report the results to her supervisor. The inquiry activities she tried took longer than she anticipated, but they were effective. For example, she had the students' project tree growth at Burrows Middle School, and the students needed to explain the economic and ecological benefits of keeping the trees versus cutting them down.

Shanice participated in an interactive physics workshop at a local university one summer. The participants conducted physics activities and had to explain their results phenomena. Shanice admitted, "This was quite difficult for me and often caused a lot of frustration, but really taught me how to explain science." She also learned physics content. When she gave a wrong answer, the professor would continue to ask questions to lead her to the correct answer. I asked Shanice if she used this strategy in her science classes and she said, "Yes!"

Shanice's rich experiences have helped form her understanding of NOS. An experience she mentioned frequently was her summer at the pharmaceutical company in the research and design division. She learned a lot about how scientific ideas originate, are tested, and are marketed to society. These experiences relate closely to the last three questions on the *VNOS B Test*, on which she showed a greater understanding of NOS than she showed on the first three questions on the *VNOS B Test*.

In What ways do Shanice's Classroom Practices Align with the Central Principles of NOS? (Observation Checklist/Field Notes/Lesson Plans/Interview)

Shanice allowed time for her students to understand, read, comprehend, and reflect on required class work. At first glance, this time appeared to be wasted time, but a look at her practices suggested it is a good teaching strategy for her students. Shanice was the oldest teacher in this study, with children of her own who have already gone through middle school. Her patience and caring nature help give the students confidence in her classroom.

Many of her activities demonstrated high central principles of NOS. Her method of getting students to explain and demonstrate knowledge through questioning was very sophisticated, and perhaps related to the methods she learned in her active physics course. During a discussion of the characteristics of living things, she kept prodding one student to explain what he meant by organization of living things. The student replied that it keeps stuff in order. Shanice was not satisfied with that answer, so she asked, "Why and how do things keep organized in living organisms?" The student explained that it was like a desk with drawers to keep it organized, but within the drawers were little containers to further organize it. Shanice finally got the student to use the terms cell, tissue, organ, and organ system. This technique took more time, but the student probably remembered these terms longer because Shanice encouraged him to discover the answer.

Day One

This was the first day back from spring break, and the students were tired and sleepy. Shanice handed them a quiz first thing in the morning, reminding them that they would take the quiz after break. Most students struggled with the quiz, which was an assessment containing recall questions. After about five minutes, during which most students were not able to recall any information, the teacher allowed them to use their books. It took 20 minutes for them to complete a short, 10 question, fill-in-the-blank quiz, even though they were given a word bank. It took an additional five minutes for the teacher to read the correct answers. This activity was very low on the central principles of NOS.

Next, the students engaged in a 10 minute discussion about the four characteristics of living organisms. Shanice involved most of the students, and she seemed like a different teacher with completely different teaching strategies compared to the first activity. She asked probing questions and demanded explanations and examples of the answers. Interestingly, no one in the class raised their hands when they spoke, yet nobody interrupted. The teacher frequently asked the students what they thought of another student's answer. This social interaction was demonstrated throughout the time I observed in the classroom, and demonstrated high central principles of NOS.

Expanding on the characteristics of living organisms and the discussion of organization within the organisms, Shanice asked the students to label the organelles within a cell on a drawing. She distributed papers with pictures of an animal cell on one side and a plant cell on the other. She asked them to open their books and look at the animal cell first. Although this appeared to be another copying activity, I quickly realized that the drawing was correct, but different from the textbook drawing, requiring the students to interpret the information. Students were allowed to work in groups or on their own. Most students chose to work in groups. After a few minutes, Shanice walked around the room and looked at their work. Students with incorrect answers were asked questions about the shapes to help them change their answers. They were not given the answers; instead, they had to discover them from her clues. This activity took about 20 minutes, and was higher on the central principles of NOS than a copying of knowledge level material.

On my first day of observing Shanice's classroom practices, she demonstrated high central principles about 55% of the time, with the plant/animal cell activity and her method of questioning students.

Day Two

The day began with a textbook prepared warm-up, matching definitions to functions of eight cell organelles. Students worked independently, using the books on their tables. This activity took 10 minutes and reflected low central principles of NOS. When Shanice provided the answers, she just read them and did not involve the students at all.

The next activity involved the creation of a picture glossary of animal or plant cell organelles. Each student had a laptop computer and logged onto the Internet to find pictures of the organelles. They had to describe, in their own words, the function of each organelle. Each picture glossary was to be placed online by creating a link to the school's website, so they could access it from home or the library. A large debate ensued about a cell's nucleus. One student found a representation of an atom's nucleus and another student said, "Hey, that is the wrong type of nucleus." He showed her the right one, and she agreed that it was from the chemistry unit. Quite a bit of sharing was going on, and one artistic student used the LCD projector to demonstrate how to create colorful backgrounds and word textboxes. Shanice celebrated when a student was knowledgeable about a topic, and allowed the student to become the classroom facilitator. Two students who were sitting close to each other had a debate about a website's authenticity. Both students were working on the mitochondria, and one website had some misinformation. This spawned a great conversation about how to determine if a website was providing accurate information. The group came to the conclusion that they would use only websites ending in edu, gov, or org.

The computer activity was extended for 20 minutes due to the National Junior Honor Society meeting. Everyone was excited to continue working at their computers. Several students included me in the activity, wanting to show me their work. The teacher never had to speak with them about how to use the computers, or caution them about using the computers inappropriately. The computer activity was high on the central principles of NOS due to the collaboration, the positive communication involved, and the interpretation of science.

Eighty-six percent of the extended class time activity demonstrated high central principles of NOS. This class time encouraged learning rather than creating anxiety, and the discussions among the students were rich in science content.

Day Three

As I arrived in the classroom, I was greeted by Shanice, who said that the day had "gotten messed up again," and I would not see the regular students. I had intentionally arrived later in the day because of a class schedule change due to computer testing. Just as I arrived, the schedule was changed again. Shanice and I agreed that I would stay in the class and watch the lesson. I did not see the same students that I had observed during the first two classroom observation days.

First, the students completed a 15 minute survey from the National Science Teachers Association (NSTA) asking for their ideas about science and science careers. I had not planned to include this in the classroom observation, but after reading the survey and listening to Shanice talk about it, I realized it would be a significant demonstration of high central principles of NOS. The survey asked the students to think about science and their futures, as well as how science has impacted their school experience. Shanice asked the students about jobs they had dreamed of doing. One girl said quietly, "I thought about being an X-ray technician because my uncle had to have a lot of X-rays recently for his cancer and those folks have been so helpful and understanding with my uncle." Another girl said, "I want to study waves at the ocean for sources of energy, perhaps." Shanice encouraged them. "You need to pursue those dreams, and don't let anyone discourage you from doing that." This activity was mostly high on the central principles of NOS; for about five of the 10 minutes, students were engaged in nonreflective, demographic survey information.

For about 10 minutes prior to the next activity, the students and teacher got into a discussion about many nonscience topics, ranging from high school choice to how rental furniture companies steal money from customers, and how it is better to save money and purchase the piece of furniture. This topic, although it was not science related, was a lesson in analyzing data. Shanice asked the students to calculate the cost of television rental versus purchase. The students were stunned at how much money was spent on rentals: thousands of dollars more than the item is worth. This activity was high on the central principles of NOS because of the interpretation of empirical data.

Next, the students wrote about theories for 20 minutes. The overhead displayed instructions to write a theory about the difference between a living and a nonliving thing, and to describe how this theory could be tested. This question required advanced cognitive thought, and is high on the central principles, even though it was an independent activity.

Finally, the students were asked to classify 10 items as nonliving or living. Most of the selected items were not in the book, and the students had to research the items and draw conclusions on what they read. It was a collaborative activity where they had to provide evidence that the items were living or nonliving. A small group of students got into a debate about whether or not the sun was alive. One student argued, "The sun is alive because it was growing." Other students found some information in a resource book that the sun was not growing, which is one of the requirements for something to be considered alive. This activity took about 30 minutes and was high on the central principles of NOS.

This class was extended to 75 minutes due to the computer testing, and 87% of Shanice's classroom practices demonstrated high central principles of NOS.

Day Four

Computer testing altered the day again. After I entered Shanice's classroom, the principal asked everybody to change classes. Confusion reigned for about 15 minutes, with students moving from classroom to classroom; at one point Shanice had 40 students in her room. She put me in charge and left the room to settle the confusion. The grade level administrator came in with her, and finally the classes were settled and the lesson began, 15 minutes late into first block.

This class was taught the same lesson as the last class I observed; however, it was the original class of students I had observed on the first and second observation days. Class began with the NSTA survey, but this class spent only 10 minutes on it. There was no class discussion about the survey. Approximately one half of the survey is high on the central principles of NOS.

One student asked Shanice about the Virginia Tech shootings. She stopped the rushed pace of the lesson, pulled up a chair, sat down, and asked the students what they thought. The conversation was important, but had nothing to do with the central principles of NOS, so I ranked these five minutes of class time as low on the central principles of NOS.

Students worked independently for 15 minutes on the next activity: writing a theory on the difference between a living and a nonliving thing, and describing how the theory would be tested. Shanice then asked them to share their theories with two other people in the room. Afterward, the teacher asked two people to share their answers with the class, because there were too many correct answers and they did not have time to share them all. This activity was high on the central principles of NOS.

Shanice gave the students about 15 minutes to classify 10 items as living or nonliving, and provide evidence of their choices using resource books. The students worked mostly in pairs and finished this assignment quickly. Due to the interpretation of science and collaboration, this activity demonstrated high central principles of NOS.

Because of another extended class block, the students had about 10 minutes left to look at some mosquito larvae a fellow science teacher had brought in from his pond. The students viewed the larvae under the microscope, and were amazed that mosquitoes look like worms prior to becoming flying insects. The teacher facilitated a class discussion about the larvae, and the water where the mosquitoes laid their eggs. She helped students understand that the eggs are laid in the water, and cautioned them to be careful around stagnant water near their homes and apartments. This investigative activity and open discussion demonstrated high central principles of NOS.

Seventy-five percent of these classroom practices demonstrated high central principles of NOS. This does not include the first 15 minutes of confusion, where nobody seemed to know where the students belonged.

Does Shanice's Physical Environment Reflect or Contest the NOS? (Classroom Observations)

Burrows Middle School was built in the early 1960s, and the architecture reflects its 60 year old history with small hallways. Shanice teaches in the new wing of the school, which was built in 1991, with larger hallways and a larger science room than the older rooms. Her room had two doors. One led to the hallway, the other directly outdoors. She also had a large storage room which holds most of the eighth grade science equipment.

Like most science rooms, hers had a large, acid-top demonstration table that runs across the front of the room. The demonstration table had two sinks, one at each end. Her room had new, adjustable, black-top science tables where the students sit. The student tables were arranged in two giant Us, one inside the other, opening toward the demonstration table. This allowed freedom of movement around the room. The arrangement Shanice chose for the student tables and the space it creates for movement are high on the central principles of NOS. The teacher's desk was located at the back of the room, diagonal to the hallway door. Her desk held a computer and printer, and the book shelves behind her desk store books and other resources. This space was reserved for the teacher; students may use it only with her permission.

Student created posters adorn the front wall above and below the full width white board. The posters show some common elements from the periodic table with all of the important information (atomic mass, atomic number, and electron configuration), the common uses of the element, and whether the element is found naturally in North Carolina. A large student created word wall created at the beginning of the school year is on the side wall, along with the door that opens to the outside. The back of the room had professionally created posters of earthquakes and volcanoes from the United States Geological Survey (USGS). There was also a large NASA poster displaying the night lights of Africa in comparison to the night lights of the United States. In the corner near

Shanice's desk was a large banner of Nelson Mandela. She often referred to this banner, because she did a teacher exchange program in South Africa one summer.

All of the walls except the front wall have lab counters on them for student activities. Each counter had two working sinks with electrical outlets, and each wall has soap and a paper towel dispenser. This allowed plenty of space for students to conduct science investigations, which is high on the central principles of NOS.

Above the counters were glass fronted cabinets that provide easy student access to equipment and resources. There was a large bookshelf near the front door with *National Geographic* magazines and other resource books for student use. In front of the demonstration table was a large, plastic cabinet on wheels that holds arts and crafts supplies.

In the hallway outside the classroom was a large fish tank with many different species of fish. As they come to class, the students enjoy observing the fish. Each week, one student was in charge of maintaining the tank, including feeding the fish and monitoring the water quality.

Shanice's room reflects high central principles of NOS, with all the student accessible equipment, student-created work, and space to participate in science investigations. The fish tank and the student responsibility for it demonstrated practices that are high on the central principles of NOS.

What are the Enabling or Constricting Factors That Translate Into Shanice's Classroom Practice? (Interview)

Shanice got very frustrated with the last minute changes in the schedule. I saw the schedule change quickly twice in the four observations I completed. She felt these schedule changes misuse her class time, and frustrated staff members as they try to determine where everyone was supposed to be. Directions for these daily changes arrive in the morning, via email, at a time when Shanice is preparing for class. She seldom had an opportunity to read email prior to the beginning of class. She found out about schedule changes from her students.

Shanice spent a lot of time in meetings and completing paperwork for her students with special needs. Approximately one quarter of her students had disabilities of some sort; therefore a great deal of her time was spent completing observations and grades, and fulfilling individualized accommodations.

The district-created pacing guide covers approximately one chapter of the textbook each week. According to Shanice, the district did not consider those students who need extended time to read and reflect. She accommodated her students by teaching only part of the material, which she felt must be all right, because they all passed the last quarterly test. Quarterly tests are standardized tests created by the school district to assess student understanding of the material presented during the nine week quarter.

Although Shanice felt that there were many constricting factors at Burrows Middle School, she acknowledges some enabling factors that help her teach. She had tremendous support from the local university, which provides programs for her students.

The school had a strong volunteer contingent, and the administration supports teacher participation in the many free professional development opportunities available for science teachers. Shanice also enjoyed her room and the outdoor green space available to her and her students, even though she teaches in an urban school. Shanice enjoys her colleagues as well. They support each other academically, emotionally, and spiritually. They have even gone on vacation with each other during the summers and holidays.

Summary

Shanice's classroom practices demonstrate many high central principles of NOS (see Table 6). She encouraged vigorous scientific discussions that were often student generated. She allowed time for reflection, and most of her classes are not rushed to get more content crammed into the class period. She demanded thoughtful answers and explanations from her students.

Although her weakest area of understanding on the *VNOS B Test* had to do with theories, she does not shy away from using this concept in her classroom practices. One activity involved the students in creating a theory to explain the difference between a living and a nonliving thing. She asked the students how they would test this theory. The central principles of NOS are those which demonstrate that science: (a) uses creativity and imagination, (b) is biased, (c) is influenced by society and politics, and (d) is allowed to reach different conclusions from the same investigation. Shanice's experiences prior to teaching are also reflected in her classroom practices, i.e., allowing students choices, scientific debate, and discovery learning. Her active physics experience taught her a questioning technique that she used often and effectively in her classroom.

Shanice's understanding of NOS as demonstrated through her classroom practices is mixed, more informed on some facets of NOS and less informed on other facets of NOS.

Table 6. Shanice Classroom Practices as Aligned with the Central Principles of NOS

Central Principle of NOS Science is:	Example From Classroom Observation	Literature Cited
1. Tentatively based.	NOT OBSERVED	Science is tentative and does not answer all questions (AAAS, 1990; NCR, 1996).
2. Empirically based.	Observations of mosquito larvae.	Science is based upon empirical observations (NSTA, 1982).
3. Subjectively interpreted.	A warm-up that had many answers.	Science is embedded with personal beliefs (NCR, 1996).
4. Creatively and imaginatively inferred because it involves humans.	NOT OBSERVED	Science is creative and uses imagination (AAAS, 1990).
5. Distinctively a combination of observations and inferences.	Classification activity on living and nonliving.	Science is a blend of observations and scientific predictions (AAAS, 1990).
6. Socially and culturally embedded.	Discussion during the NSTA survey.	Science is socially, culturally, and politically embedded (AAAS, 1990; NCR, 1996).
7. Separately understood from technology (but impacts each other).	Computer use in picture glossary.	Science and technology impact each other in order to gather an understanding of the natural world for its own sake (NSTA, 2000).
8. Related kinds of scientific knowledge, laws, and theories.	NOT OBSERVED	Science is unified by theories, laws, and concepts understood by scientific knowledge (Kimball, 1968).
9. An understanding of how scientific knowledge is formed.	NOT OBSERVED	Science must demonstrate how scientific is practiced by showing how scientific knowledge is formed (Cuningham, 1995).

Michelle Little

Michelle is an enthusiastic, loud, fast-paced, 32-year-old Caucasian eighth grade science teacher who is very involved at Murphy Middle School. The majority of the student population (76%) at the time of my visit was comprised of ethnic minorities, 58% African American, 24% Caucasian, 10% Hispanic, 5% Asian, 2% Multiracial, and 1% Native American. Fifty-six percent of the students qualify for free or reduced-price lunches. Murphy Middle School is an International Baccalaureate magnet school with an emphasis on academic rigor that was represented by its above average state test scores. Ninety percent of the eighth graders passed the state reading test, compared to the district average of 85%, while 79% of the same students passed the math test, 17 percentage points over the district average. There were not many LEP students at Murphy (4%); however, the school has an average percentage of students with disabilities (13%). Along with an academically strong student population, the school had several unique programs such as Advancement Via Individual Determination (AVID), and Paideia. AVID is an academically rigorous program for middle school students in academically challenging classes which prepared them for advanced placement classes and college courses. Paideia creates critical thinkers and problem solvers through open student led discussions in the classroom.

During Michelle's five years of teaching, she became department chair, a mentor for two new science teachers, Global Learning and Observations to Benefit the Environment (GLOBE) certified, and AVID trained. She also developed the most popular elective at Murphy Middle School, Forensics, modeled after the CSI (Crime Scene

Investigation) television program. In this class, students designed investigations and used evidence to solve murder mysteries. Additionally, Michelle received certification as an environmental educator. Environmental studies is one of her favorite topics to teach. While teaching at Murphy Middle School, Michelle also earned her master's degree in science education.

Michelle's no nonsense approach to teaching and her commitment to learning was very apparent in her classroom. Her students understood that they were in her classroom to learn, yet it was all right to make mistakes. Her classroom was different from many other classrooms at Murphy Middle because of the high noise level, and the fact that students were allowed to move around during class. Michelle encouraged collaboration and sharing of information during group work in her classroom. One of her primary rules was "Ask three before you ask me," to encourage shared knowledge.

Prior to teaching, Michelle worked as a park ranger at a North Carolina beach state park. Teaching came naturally to her; she frequently instructed school children at the park and really enjoyed it. As a park ranger, she implemented informal research and had to determine allocation of the park's money, sometimes based on her research.

Michelle's undergraduate degree in natural resource management was earned at a large southeastern university. After changing careers, she earned her Master of Arts in Teaching (MAT) from a local university while working full time. Science was a natural choice for Michelle due to her robust K – 12 science experiences and positive teachers. She particularly recalled some wonderful high school ecology and biology teachers, and the outdoor activities they conducted outdoors. These teachers allowed a lot of science talk and movement in their classroom, which Michelle feels strongly influenced the way she designs her classrooms.

Michelle had a good understanding of the nature of science as shown through her classroom practices. She demonstrated this understanding more through her teaching than her *VNOS B Test* or interview revealed. Her education, prior work experiences, and teacher workshops all contribute to her understanding of NOS.

What is Michelle's Understanding of the Nature of Science? (VNOS B Test/Interview)

Michelle's understanding of NOS was on the more informed side of the scale according to her written test and interview (see Figure 2). Her written, and occasionally her verbal explanations on the *VNOS B Test* were often incomplete or underdeveloped thoughts. Many times, her actions in the classroom did not match what she had told me during the interview or had written on the *VNOS B Test*. Occasionally, it seemed that she innately knew how to conduct her class without the theoretical or philosophical knowledge of NOS. She could not articulate, verbally or in writing, that science is creative and requires imagination throughout the scientific process, yet she demonstrated the concept regularly through her classroom practices. Throughout her interview and written *VNOS B Test*, Michelle strongly insisted that new scientific information is only acquired by evidence, and that this evidence is usually obtained by using sophisticated technology. She never indicated that scientific knowledge could be acquired theoretically, e.g., explanations that cannot be obtained by direct observation, such as the creation of black holes.

Question One (Do Theories Change?)

Michelle's understanding of the tentativeness of theories was slightly more informed on this tenet of NOS (see Figure 2). Michelle understood that theories change, yet she clings to the notion that they change only after new observational evidence has emerged. Michelle felt that the new evidence was most often found through advancing technologies. Michelle explained that criminal evidence changed when police could use DNA evidence to prove criminal presence at the crime scene. The use of DNA in solving crimes was advanced by new technology. These statements about using new technology only to advance theories indicate a less informed understanding of NOS. This belief was continually expressed throughout the interview and the written portion of the *VNOS B Test*.

Michelle strongly felt that theories should *not* be expressed as a guess or even a scientific guess. She said, "I really go off on those students who say this, because theories must have evidence to support them." Again, she referred back to the notion of evidence to support theories. Michelle believed teaching theories was important because students need to understand what they are and how they explain a phenomenon. She further explained, "Theories are sometimes a way of seeing a concept which teaches students how to think. Teaching students to think and analyze data are the main purposes of a science teacher." I am not really sure what Michelle meant when she indicated that theories are a way to see a concept. It could be interpreted that theories change because Michelle indicated that it was one way of looking at a concept.

Question Two (How Certain are Scientists about the Structure of an Atom?)

Michelle understood the concept of representation of unseen science through models. She had a more informed understanding of this facet of NOS, but continually interjected the idea that new scientific concepts are developed through new evidence (see Figure 2). Even though Michelle thinks that all new scientific concepts and theories are developed with the help of evidence, she demonstrated a more informed understanding of NOS by stating that models are used by scientists to create theoretical inferences, which contradicts the idea of always needing new evidence to form scientific knowledge.

Michelle said, "Scientists are as certain as they can be about the structure of an atom without seeing it." In her class, she demonstrated the use of models by using a sealed box with two or three objects in it. She asked the students to figure out what is in the box. They would shake the box and listen to the noise created as the objects bang together. She then gave them limited, new information about the objects, and the students modified their guesses. She contradicted herself at this point and said that some scientists use theoretical knowledge, not just observable data. She continued to explain to her students that this is very similar to the process scientists go through when they try to describe what is happening with a phenomenon such as the structure of an atom. Michelle claimed this helps a lot when students ask "how do you know" questions. This example demonstrates a sophisticated understanding of NOS through classroom practices.

Question Three (What Difference, if any, is There Between a Theory and a Law?)

Michelle had a more informed understanding of the difference between a theory and a law, as shown in Figure 2. Her written answer to this question was very short, but clearly stated: "A theory is how and why something happens while a law explains what has happened." She understands that they are related, because a theory can explain a law but can never become one. Expanding on her understanding of theories, she said that theories are one way individuals organize and understand science because they explain how something works. This question matches very closely the author's more informed understanding of theories and laws.

Question Four (How are Art and Science Similar/Different?)

Michelle never really answered this question as the author intended. She stated that art and science are similar because anybody can do them, inferring that art and science are for everyone. She never explained how they are different, but she did state, "Science is formed by individual experiences and perspectives." I ranked her toward the less informed understanding of this tenet of NOS.

Michelle's answers to this question perplexed me the most of all her *VNOS* data because of the differences between the written test and the interview. I am not sure why this happened. On the written portion of the test, Michelle claimed that anybody can do science and art; however, some individuals are given a talent in art or science. During the interview, she focused more on how science is accepted by society based on scientific research and studies. She believed that "Science is influenced by many outside perspectives that the individual scientists bring with them." However, she never associated art and science with creativity and imagination, so I ranked her less informed on this NOS item.

Question Five (Do Scientists Use Creativity/Imagination?)

Michelle clearly stated, "Scientists must use creativity and imagination and think outside of the box when researching." She believed that the best scientists adjust their thinking when unexpected data appear, a very informed view of NOS. However, her suggestion that science is innate in some gifted individuals, tipped her more informed views back a bit (see Figure 2).

Michelle demonstrated an understanding of theory-laden NOS during the interview by saying that science is generally predictable and scientists usually expect a certain outcome. However, she added, "Often you have to reevaluate and adjust your thinking when the unexpected outcome does happen." She confirmed that scientists need creativity in their explanations of why things happen. Overall, Michelle had a more informed understanding of this question.

Question Six (How Can Scientists Have Different Conclusions?)

Michelle clearly understood that scientists bring with them their own perspectives and experiences that influence their decisions and conclusions. She firmly and consistently clung to the concept that science changes due to new observable evidence. Michelle's understanding of this question was more informed, based on her insistence that science changes only when presented with new evidence.

Michelle believed that "Students may have lasting positive or negative science experiences during middle and high school and these experiences last a long time and then become influences." According to Michelle, other influences are also molded by the way an individual is raised. These influences form the way we interpret data; therefore, different scientists see things differently. This answer conforms closely to the way the author intended it to be understood. Michelle has a more informed understanding of this question (see Figure 2).

How did Michelle Acquire her Knowledge of NOS? (Questionnaire/Interview)

Michelle was a North Carolina Park Ranger for about two and a half years. She was responsible for prescribed burns within the park, and she designed plans to protect endangered and threatened species, including sea turtles, piping plovers, and carnivorous plants. She and other rangers conducted scientific studies at the state park; however, none of them were formally published. Even though the data were never published, they were used to determine allocation of park funding. This experience taught Michelle that science is often influenced by finances.

Michelle participated in a course where the class discussed the philosophy of science through evolution. She said, "It quickly became a hot topic in class, where I learned that science is full of emotion."

Michelle took several courses that helped form her understanding of NOS. She did not list these courses on her questionnaire, but after we talked about them, she told me that perhaps they were significant. Her advanced natural resource management class explored how park rangers have to use the resources on their property, and sometimes that involves choices of time and financial resources. She also indicated that this course included some law. Another course that influenced Michelle's understanding of NOS was a parks and recreation class that examined societal issues, such as who has the right to use the water. Conflicting groups of people who use the water (people who fish, boaters, and the government) were introduced and debated their points. Michelle learned that science is messy and never has just one clean answer.

Michelle also monitored sea turtle reproductive rates in her prior job. She had to count the number of turtle eggs, hatched and unhatched, and then try to figure out why the rate had changed from previous years. She told me, "I had to keep excellent records on egg hatchings and monitor them in a scientific manner so the data were usable." She also had to solve problems, e.g., finding a way to increase the number of shore birds in a certain region along the beach to control the increasing crab population. This problem was solved by simply roping off an area of the beach to limit four-wheeler access. This helped the shore bird population increase two-fold almost overnight, even though it frustrated and angered some of the four-wheeling community.

Michelle's own K-12 science experience was good. She indicated that her teachers allowed science to be messy, and that sometimes the activities created more questions than answers. She was often told to go find the answer to a question. During her middle school science experience, she wanted to know why the water fountain was colder in the sixth grade wing. Her eighth grade science teacher told her to design an experiment and go figure it out. She said, "I tried but never really figured it out, and I blamed the plumbing in the old building they were housed in."

Michelle's understanding of NOS is unique in that her prior job, research experience, formal education, and K-12 science experiences helped her to understand NOS.

In What Ways Do Michelle's Classroom Practices Align with the Central Principles of NOS? (Observation Checklist/Field Notes/Lesson Plans/Interview)

Michelle's loud greetings and conversations with fellow teachers were heard during the class changes as she stood at her door and watched her classroom and the hallway. She greeted almost every student, and occasionally had individual conversations with them. For example, one student had a very good soccer game so she greeted him with congratulations on the win. The class I observed was the third block, from about 12:15 to 1:35 PM. My first observation began on a Friday, one week prior to spring break. Murphy Middle School does not have bells to indicate class changes; they are regulated by good clocks and flexible teachers.

Day One

Every day, class began with a warm-up, usually a thoughtful, opinion-type question the students had to answer. This day's question was "How is water quality important, and what impact do you have on water quality, both positive and negative?" This was an independent written prompt for the students to reflect on in their science notebooks. Michelle wanted the students to spend about 10 minutes thinking about a current social problem that is related to the science curriculum. This activity was very high on the central principles of NOS: relating science class to current issues, allowing students time to reflect, and encouraging the understanding that there were several correct answers. The teacher asked the students to share their answers with someone at their table, and then choose the best answer to share with the class. It was a very good, nonthreatening way for students to express their thoughts with the entire class.

After the warm-up, it was time to correct homework, which took about 10 minutes and was a teacher directed activity. The students read the questions and gave the one correct answer to each problem. These were mostly knowledge-based questions that involved definitions or listing examples. There was no reflection or opinion, and there were no evaluative questions. This activity was very low on the central principles of NOS.

Next, the students listened to directions for an inquiry activity involving a lot of movement within the classroom and some mixing of solutions. The teacher wanted to explain the process before the students began. This teacher led activity was low on the central principles of NOS, but necessary for the success of the activity.

The hands-on inquiry activity lasted the majority of the class time, about 52 minutes, and was very high on the central principles of NOS. The students were asked to determine the location of point source pollution. There were 48 wells in the community, but the government had funding to test only 12 wells. The students had to research the location of the probable sources of water pollution. Each student was given a map with the location of all of the wells, industries, farms, wastewater treatment center and other information. One student wanted to know if this was a real situation. The teacher responded that it could be, but it was only a simulation.

The students worked in groups of three or four, and were allowed to use reference books from the classroom. Michelle gave each student a supplemental book to read about point source pollution. It was very quiet for a few minutes while all the students read. Conversations began and decisions had to be made about which wells would be tested for contamination. At one point Michelle said to the entire class in her loud voice, "I don't hear enough talking between groups; share your information like real scientists." After that I heard a lot more science conversation. As the class period progressed, some groups realized that they had tested the wrong wells and asked the teacher for permission to test more wells. She denied the request, stating, "This would not happen in the real world, so you will have to deal with it somehow." She suggested they write about it in their reports, and indicate where they thought the contamination was located. Every student seemed to be working and later trying to interpret data, which is high on the central principles of NOS.

Michelle spent approximately 78% of her class time engaged in activities that ranked high on the central principles of NOS. She involved the students in a real world simulation that utilized their collaborative problem solving skills. This day's lesson illustrated that Michelle has a good understanding of NOS as demonstrated through her classroom practices.

Day Two

Class began with Michelle's daily routine of standing in the doorway between her class and the hall to monitor and greet students as they entered her classroom. Again, Michelle's class began with a thoughtful, open-ended question that related to what they were studying. The warm-up question was: “Where do we get our water from, and why is it important?” She allowed five minutes for the students to respond independently to the question, and five minutes for discussion. Later, during the interview, I asked her why she asked such open-ended questions for the warm-up. She said it was a mini assessment of their knowledge and it generated student discussion. This activity was high on the central principles of NOS because it involved high cognitive demand and fostered positive communication among students which demonstrates inquiry-based instruction. Michelle demonstrated inquiry-based instruction which is high on central principles of NOS, in this lesson.

After the warm-up, the teacher took about 20 minutes to explain the activity at the outdoor habitat. Today the students were going to look at the quality of the water in the pond. She took time to show the students some water quality testing equipment they had not used before: a Sechi disk, a turbidity tube, an electric pH meter, and a dissolved oxygen (DO) kit. Most of the time was devoted to a teacher directed lecture with very little student interaction, but I felt it was necessary that the students understand the equipment in order to ensure a successful investigation. This was very low on the central principles of NOS.

Most of the lesson was at the pond in the school’s outdoor habitat. The students spent approximately 50 minutes testing water quality. Murphy Middle School received a grant to create an outdoor learning habitat that covers about one third of an acre in front of the school. It included a pond, and a trail with all the indigenous plant species labeled. At the pond, each group of two to three students was assigned different water quality tests. One group tested the DO in the water, while another group tested the turbidity of the water. Every group tested the temperature at a different location in the pond, and identified the macroinvertebrates in the water at the same location. Each group would later share the results and come up with a conclusion about the quality of the water.

Most of today's class, 75%, engaged students in high central principles of NOS activities. The students engaged in a collaborative investigation that explored a real science problem. Each group was responsible for sharing vital information that other groups did not have. Students were teaching other students at the pond how to use new equipment. I even heard one student comment to a friend, "I felt like a real scientist testing the water." Today's classroom practices demonstrated high central principles of NOS.

Day Three

Today was very different from all of the other observation days because it was student teacher day. All eighth grade students had an opportunity to apply for a teaching position for a day. Each student had to complete an application and get three recommendations to be eligible for a "teaching job" at Murphy Middle School. Michelle was the faculty member sponsor for the day. Michelle's student teacher was Angela, a bright, well prepared, 13-year-old African American. She and Michelle were dressed in coordinating outfits. Michelle and Angela had several planning meetings prior to Angela's teaching day. Michelle said repeatedly, "This has been a collaborative lesson plan." Michelle still took her regular post at the doorway greeting students, while Angela walked around the room making sure all of the equipment and tools for the day's lesson were in place. The warm-up included the following questions: "What is the difference between a multicellular and unicellular organism? How would you define a living thing?" This was a five minute, independent writing activity, followed by a five minute discussion led by the student-teacher. Interestingly, the students responded quite well to the student teacher, who was a classmate of theirs. She led a robust discussion, most of which focused on the definition of a living thing. One student said, "For something to be living means it really only needs to grow." Angela, fully prepared, replied, "Well, that means bread dough, when it is rising, is alive." That got the class involved in a lively debate. This 10 minute activity was high on the central principles of NOS because it was student directed, there was positive communication among students, and it involved high cognitive demands.

Angela created a PowerPoint presentation so that students could complete some Cornell Notes. Cornell Notes is a prescribed method of note taking during lectures that helps increase student recall. This activity had all of the students working well and listening to Angela. She added many points to the presentation that were not on the slides. It was totally student led, but done in the lecture format with students writing down information. I believe this 14 minute activity was fairly low on the central principles of NOS, even though it was student led.

The next 50 minute activity was a hands-on, classifying activity to determine if water quality was healthy based on bioindicators. The students were required to identify the living organisms in the water and then count the different species and determine if the body of water was healthy based on the organisms that were present. Each group had to share its findings with the whole class, so the class could determine if the water was healthy. Many of the students had to spend time learning how to use the dissecting microscopes. The students enjoyed this activity. Angela was proficient with the microscopes, and assisted many groups with the equipment. This activity was high on the central principles of NOS.

Once again, Michelle's classroom practices demonstrated high principles of NOS 75% of the classroom time. She maintained these practices by allowing collaborative groups, a student-led class, shared data, data interpretation, and observation of the natural world.

Day Four

Michelle's daily routine continued as she stood in the doorway between her classroom and the hall, greeting and talking with fellow teachers and students. Her loud voice was usually heard over all of the other conversations. This day's warm-up question was again highly cognitive and demanding: "Which is smaller, a cell or an organism? Explain your choice." This warm-up took a bit longer than others, because the students got into a debate about the question. One student claimed that she read somewhere that nerve cells could be as long as your leg or arm and that clearly made them larger than even the smallest organism. Another student stated confidently that he saw a website where one virus organism was smaller than most cells. These comments started a lot of talk about the reliability of information on websites and in the media. Michelle recognized that this was good science talk, but the class had a lot more material to cover, so she asked the students to continue this discussion at home with their parents. This activity was very high on the central principles of NOS because of the debate about the reliability of the information, and the real world links to science.

The next activity was administrative, and I did not even consider it on the central principles of NOS inventory. The students were turning in projects; they had created an underwater amusement park. The criterion was to create a model of an amusement park using the properties of the ocean. Some examples were storm patterns, seasonal temperature ranges, or currents. This activity took about 10 minutes because Michelle required them to sign a sheet stating that they did or did not turn in their projects, due to some trouble she had experienced in the past with students saying they had turned in their projects when they had not done so.

After this activity, the teacher gave notes via a PowerPoint presentation. The students took Cornell Notes using the PowerPoint presentation. This took about 25 minutes, and Michelle engaged the students by providing the concepts orally before being showing them the answer on the next slide. This activity was highly engaging and most of the students were participating; however, it was low on the central principles of NOS, as there was only one correct answer, and the activity was teacher led.

Next, a few student groups presented their underwater amusement park projects. The presentations were 100% student led, but the content was weak, and most students were not engaged in any activity, including listening.

For the last 20 minutes of class, Michelle engaged her students by having them write a creative story. She provided a list of terms from cellular biology for them to use in their stories. One group wrote a story about a superhero that traveled into a cell and encountered a lot of adventures in the chloroplasts, nucleus, and cell membrane. The students worked in small groups to create these stories, which is high on the central principles of NOS. One group enjoyed the activity so much that they insisted that Michelle share it with the language arts teacher, thus demonstrating another high central principle of NOS: integration of subjects.

On this day, the students were engaged only 40% of the class time in high central principles of NOS. However, I still felt that the debate at the beginning of class was one of the richest NOS discussions I experienced during my observations of Michelle's classroom. According to Michelle, the debate did not end with that discussion. During the interview, she indicated that the discussion continued on another day in her class.

Does Michelle's Physical Environment Reflect or Contest the NOS? (Classroom Observation)

Michelle's classroom was arranged to encourage conversation. The old black-top lab tables were arranged facing each other in pairs, with reference books, markers, pencils, calculators, and scissors in the middle of the tables. The physical arrangement of the tables is high on the central principles of NOS. The school was undergoing a renovation (it is over 50 years old), so there were many extra boxes from the sixth grade science hall located in the back of her room. At first glance, the room seemed disorganized, but it was really just a bit cluttered with science equipment. Fortunately, the room is large, and the students still have a lot of room to move about, regardless of the extra boxes.

Michelle had many science tools in her room, including an entire book shelf stocked full with reference books and magazines. Near the front of the room was a grocery cart filled with science equipment such as balls, jump ropes, wire, batteries, and empty two liter bottles, among other things. Additional research tools included a student computer and many microscopes set up for student use. Two of the walls allowed for displays of student work, and school and classroom announcements. The other two walls had counter space for the labs and four sinks. Michelle allowed students to choose what they would like to display in the classroom. Only student created work was displayed in this room; there were no professionally made posters. Most of the front wall was covered with a white board that contained the calendar, important announcements, the daily schedule, objectives for the day, and assigned homework. One of the counters held large crates with folders full of student papers. Every nine weeks, the students cleaned out their notebooks and place all of their work into the folders on the counter. At the end of the year, students reviewed their work and used the papers to study for the end-of-year science test. There was also a large science storage room shared by three other science teachers, and connected to each of their rooms.

Michelle and the other science teachers regularly used the outdoor habitat for their classes. The habitat covers about one third of an acre of land, and is available to all the classes at Murphy Middle School. It contained a pond, trails, and an amphitheatre. All the indigenous plant species on the trails are labeled. The space is also available to the community; I have seen community members walking through the trails and even weeding the area. Currently, the school is trying to attract butterflies by planting three different species of milkweed. This habitat was very high on the central principles of NOS and encourages teachers to move science beyond the classroom.

Michelle's room and her use of the outdoor habitat reflect high central principles of NOS. The social layout of the tables and the accessibility of the tools of science encourage collaboration and investigation.

What are the Enabling or Constricting Factors That Translate into Michelle's Classroom Practices? (Interview)

Michelle feels fortunate to be at Murphy Middle School because of the administration and the classroom she has been assigned. She believed that the principal has everything to do with the overall climate of the school, and her principal has created an open, wonderful climate at her school. The principal welcomed Michelle's suggestion of a new science elective, CSI, a course that quickly became the most popular eighth grade elective. Michelle's colleagues permit flexibility so she can complete an activity, or keep a few students in her class past dismissal time.

Michelle also believed that the space she teaches in facilitates NOS classroom practices, even though it is in an old building. She enjoyed the large room that allows her to teach science in a collaborative and fluid way. The outdoor habitat at Murphy Middle School has allowed Michelle a unique approach to teaching real-world science.

Michelle acknowledged that her school offers many enabling factors that assist her in translating NOS into classroom practice; however, she was concerned about the trailer she will teach in next year due to the renovation. Even though it is a temporary situation, Michelle is concerned that the trailer will constrict her teaching and restrict her activities next year.

Summary

Michelle demonstrated her understanding of NOS through her classroom practices better than she does through her written or verbal responses (see Table 7). This perplexes me somewhat, as I try to understand how this all fits together. Her written and verbal understanding of NOS was toward the more informed side of the scale, but is not as significant as the 75% demonstrated in her classroom practices. During one class, she confided to one student that she, too was ADD, but that was not an excuse for incomplete work. Perhaps this affected her ability to express her full understanding of NOS on the written test.

Michelle ranked highest on questions two and three on her understanding of NOS, which focuses on the formation of scientific knowledge, how models are used, and the relationship between a law and a theory. She also ranked high on question five, which focused on the creativity and imagination scientists use during the formation of scientific knowledge. She demonstrated an understanding of this question in her classroom by allowing students the freedom of creativity and imagination when conducting investigations. Yet, on question four, which addresses similarities and differences between art and science, her rating was heavily on the less informed side of the scale, conflicting with her classroom practices. She encouraged creativity and thinking outside of the box. Perhaps the only answer to this is that she misunderstood the question, even during the interview.

Table 7. Michelle Classroom Practices as Aligned with the Central Principles of NOS

Central Principle of NOS Science is:	Example From Classroom Observation	Literature Cited
1. Tentatively based.	Discussions from warm-up questions.	Science is tentative and does not answer all questions (AAAS, 1990; NCR, 1996).
2. Empirically based.	Data collected from 2 activities on water quality.	Science is based upon empirical observations (NSTA, 1982).
3. Subjectively interpreted.	Discussion on how scientific information is validated.	Science is embedded with personal beliefs (NCR, 1996).
4. Creatively and imaginatively inferred because it involves humans.	Well water activity.	Science is creative and uses imagination (AAAS, 1990).
5. Distinctively a combination of observations and inferences.	Determining water quality from observations and interpreting what it means.	Science is a blend of observations and scientific predictions (AAAS, 1990).
6. Socially and culturally embedded.	Discussion of the influences of media on science.	Science is socially, culturally, and politically embedded (AAAS, 1990; NCR, 1996).
7. Separately understood from technology (but impacts each other).	Tools used for testing water quality.	Science and technology impact each other in order to gather an understanding of the natural world for its own sake (NSTA, 2000).
8. Related kinds of scientific knowledge, laws, and theories.	NOT OBSERVED	Science is unified by theories, laws, and concepts understood by scientific knowledge (Kimball, 1968).
9. An understanding of how scientific knowledge is formed.	Well water activity. Decisions determined a course of action for the activity.	Science must demonstrate how scientific is practiced by showing how scientific knowledge is formed (Cuningham, 1995).

Cross-Case Comparison

While all of the participants have different educational backgrounds and unique experiences that helped them form their understanding of NOS and how they express it in the classroom, it is important to examine the data collectively and identify any patterns that emerge. All of the schools where the teachers taught were at least 40 years old and served a student population of which at least 55% qualified for free or reduced-price lunches. Two of the four schools were undergoing renovations, and another, Burrows Middle School, was slated for renovation beginning in 2008. All of the student populations were predominantly ethnic minorities, and three of the schools had high LEP populations.

There were only a few common characteristics among the teachers. Michelle and Sam are in their late twenties or early thirties, while Shanice and Marcus are near forty. All of the teachers were initially alternatively certified, second-career science teachers. Their careers prior to teaching varied. Michelle and Sam both held degrees in parks and recreation, although Sam never entered that career path, while Michelle worked as a park ranger for five years.

All of these teachers had at least one K-12 science teacher who helped shape their career choices. Although each teacher in this study came to teaching from a different career path, all are devoted to teaching middle school science in schools where at least 55% of the students receive free or reduced-price lunches. All of the teachers engaged their students with hands-on activities, and avoided an approach to science, which focused on limited long, technical reading passages. All of the teachers in the study are highly involved at their schools in leadership positions, and all demand rigor from their students, while enjoying the middle school age student.

In this cross-case comparison, I will examine each research question, comparing each participant's data and looking for emergent patterns or themes. The research questions are:

1. What are second-career, alternatively certified science teachers' understandings of nature of science (obtained through the *VNOS B Test* and an interview)?
2. How did these second-career, alternatively certified science teachers acquire their understanding of NOS (obtained through the questionnaire and interview)?
3. In what ways do second-career, alternatively certified science teachers' classroom practices align with central principles of NOS (obtained through the classroom observations, interview, and lesson plans)?
4. How does the physical environment reflect or contest the nature of science (obtained through the classroom observations and interviews)?
5. What do alternatively certified science teachers note as enabling and constraining factors in translating their knowledge into classroom practices (obtained from the interview)?

What Are the Teachers' Understandings of NOS? (VNOS B Tests/Interviews)

Question One (Do Theories Change?)

Collectively, the participants have a less informed understanding of the concept that theories can change. Marcus was the only participant who had a more informed understanding of theories and the understanding that theories change, due to paradigm shifts in society. The prevailing opinion among the participants was that theories must be proven in order to be accepted by the scientific community. This is a less informed view of the understanding of NOS as indicated in Figure 2.

Marcus's educational background included a bioethics course and a science methods course, with a strong link to direct instruction on NOS, and instruction on inquiry science. Michelle, who was near the middle of the NOS scale, falling between a less informed and a more informed understanding of theories also participated in the direct instruction class on NOS, and the inquiry course. She had been exposed to ethics as they pertain to science in the parks and recreation field, which might explain her greater understanding of theories. Shanice and Sam both remained on the less informed side of the NOS scale. The two teachers who received direct instruction about NOS were on the more informed side of the NOS scale while the two teachers who did not receive direct instruction about NOS remained on the less informed side of the NOS scale.

Question Two (How Certain are Scientists about the Structure of an Atom?)

The participants were divided in their understanding of this question; there was no detectable pattern to their responses. Three of the four participants wanted to explain the structure of an atom, and how our understanding of the structure of the atom evolved from Rutherford's experiment. Most of the participants did not address the question directly. According to author of the *VNOS B Test*, Abd-El-Khalick (1999), models describe concepts such as the structure of an atom, and the participants should indicate this in their answer. One half of the participants failed to state that models are used as representations of many science concepts. Responses to this question fell in the middle of the scale of understanding, with two participants, Michelle and Marcus, near the more informed side and two participants, Shanice and Sam, near the less informed side of understanding (see Figure 2).

Again, Michelle and Marcus had the greatest understanding of the concept of models being used to represent unseen structures in science. Both Michelle's and Marcus's courses at the local university included direct instruction on theories, laws, NOS, and inquiry. This seemed to impact their understanding of the question, whereas the responses of the other two participants, Shanice and Sam indicated little understanding of the concept.

Question Three (What is the Difference, if any, Between a Theory and a Law?)

The participants tended to have either a less informed or a more informed understanding of this question, as indicated in Figure 2. Again, no real patterns emerged from the data. Some individuals still clung to the notion that theories and laws have a hierarchical relationship, and that theories can be elevated to law status once they have been proven.

Michelle and Marcus had a more informed understanding of how theories and laws are related. They both provided clear, accurate definitions of a theory and a law. Both had the same course at a local university that addressed laws and theories in depth. In this study, direct instruction seemed to increase the teacher's knowledge and understanding of theories and laws.

Question Four (How are Art and Science Similar/Different?)

All participants indicated that creativity and imagination are necessary in both art and science (see Figure 2). Most also agreed that society, politics, and finance influence both of these fields. They arrived at individual conclusions as to how art and science are different; most of them were on the less informed level of the understanding of NOS. One participant never answered the question. The remaining participants focused on the explanation of science without addressing art.

Michelle had the least understanding of this question, and I struggle with an explanation, because she demonstrated science as creative and requiring imagination during her instruction. After examining the data several times, I can only surmise that she did not express herself fully, or perhaps did not understand the question.

Question Five (Do Scientists Use Creativity/Imagination?)

Together, the participants had a more informed understanding of this question (see Figure 2). Three of the four participants designed, implemented, and analyzed some type of original scientific research, directly involving them in the importance of creativity and imagination in an investigation. Each of them indicated during the interview that in order to arrive at the most holistic conclusion from any investigation, a variety of data collection methods was desirable so that the problem could be interpreted through multiple sets of data. A large data base may result in a more complete conclusion of the investigation.

Question Six (How Can Scientists Have Different Conclusions?)

This question had the clearest pattern of similar answers. All of the participants had a more informed understanding of this question (see Figure 2). The teachers collectively understood that scientists bring their own perspectives and experiences to scientific research that influences any decision or conclusion they reach. Each scientist has individual experiences, which create bias or cause opinions to form, affecting their work. Prior to teaching, three of the four participants designed, implemented, and analyzed some type of original scientific research, which was influenced by their own experiences.

Summary of *VNOS B Test*

Two questions on the *VNOS B Test* demonstrated a pattern of similarity in this study: questions five and six, which dealt with scientists and their interpretation of scientific knowledge. All of the participants clearly understood that scientists can draw different conclusions from the same data, and that scientists use creativity and imagination throughout their investigations. The teachers all participated in some scientific research, and experienced first-hand how individuals interpret information uniquely depending on their experiences and perspectives.

Each teacher discussed a specific, critical event that led to this conclusion. Shanice spoke of the debates that occurred among the scientists at her internship. Sam recalled his college ocean research experience, where students often debated the methodology and results of their investigations. Michelle told me about research experiences that included public participation concerning four wheeling on the beach.

Marcus's experience was a compelling example of how individuals can be influenced by their perspectives. His marketing research team was split in its focus, with one faction evaluating the effectiveness of the product, while the other debated its cost.

Another notable pattern on the *VNOS B Test* was the understanding of theories. Two of the four participants, for a variety of reasons, did not understand theories, or how they are related to laws. Shanice believed that theories were stagnant and not at all related to laws. Sam believed that theories and laws have a hierarchical relationship, especially once theories are "proven" correct after a certain period of time. Michelle and Marcus had a more informed understanding of theories but still wanted them to be "proven." They understood that theories are only explanations of how and why something happens, while a law explains what has happened. Marcus and Michelle completed the same university class in which NOS and the methods of teaching inquiry science were explored, as well as theories and laws. This may explain their more informed understanding of theories.

How Did These Teachers Acquire their Knowledge of NOS? (Questionnaire/Interview)

All of the participants underrepresented their experiences in the written questionnaire. Most of the teachers did not give themselves credit for their accomplishments until we discussed it in the interview. For example, Sam, Shanice, and Marcus did not believe they had participated in research. During the interview and in further discussions, I found that each of them had participated in some form of research. Three of the four participants designed, implemented, and analyzed their research, the exception being Marcus, who implemented and analyzed, but did not design research.

All had first hand experience of science being messy. For example, Marcus said, "Someone like me can go into a research situation and influence the whole group, if you are confident with your voice, even if it isn't the right thing to do." Understanding the complexity of science helped the teachers when they asked their students to participate in scientific investigations. Most of the participants agreed that science is packed with emotions, although they were sometimes conflicted about this point.

All of these teachers had wonderful K-12 science experiences, and each participant recalled a different critical event. Marcus enjoyed the thought-provoking discussions and the one field trip to the prairie. He remembered a conversation about how society tries to preserve an environmental habitat, such as the prairie, and at the same time commercializes it by building roads through the center of it. Shanice enjoyed memorizing the names of all the bones in the human skeleton and receiving a perfect score on the test. Michelle's eighth grade science teacher allowed her to design and explore science on her own. She tried to discover why the sixth grade hall had cooler water than the eighth grade hall. Sam had an environmental science teacher who created original lessons and demanded critical thinking of his students. Sam claimed, "He brought each lesson to life and made it real for us." Each participant was touched by a K-12 science experience that excited their interest in science.

They all experienced a critical event in college that increased their knowledge of NOS. Marcus stated that the pivotal point in his science teaching experience came when he understood inquiry as explained to him in a graduate class on scientific methods. Science became political for Michelle in her ethics class, where several points of views were expressed on rights of the waterways. Shanice's internship with the pharmaceutical company involved interaction with scientists and assisting with the design, implementation, and analysis of research. Sam had the summer cruises, where he designed, implemented, and analyzed research on ocean data.

Along with their educational experiences, all had prior jobs that influenced how they acquired their understanding of NOS. However, Michelle and Shanice each had a critical experiential event that helped to shape their prior knowledge. Michelle worked as a park ranger and had to deal with science and society on a daily basis. The response to her decision to keep an area free of four-wheelers showed her that science does not exist in a vacuum on a lab counter somewhere, but could have real meaning to the community. Shanice learned how science and society coexist during her experience at the pharmaceutical company, where she experienced how a new product is researched, tested, and then marketed to the public. Sam and Marcus did not recall such events at their prior jobs.

In What Ways Do the Teachers' Classroom Practices Align with the Central Principles of NOS? (Classroom Observations/Lesson Plans/Interview)

The second-career, alternatively certified teachers from this study shared a few common classroom practices. They all demonstrated hands-on activities during at least two of the four observation days. They also allowed collaboration in the classroom that encouraged sharing of scientific information. Each teacher got the students to share information differently. Sam had the most innovative method of exploring new equipment in science class. He called it the hands-off rule, where he offered no help for the first five to ten minutes, when students were exploring new tools of science. They were allowed to help each other, collaboratively. Shanice allowed students who were proficient at a skill to teach the class, as she did when one of her students taught the others a computer skill. Michelle reminded her students to talk about the scientific investigation and share like real scientists. Marcus's class rule was to "Ask three before me" during lab, encouraging student-to-student collaboration.

All of these teachers used the popular science term *inquiry* during their lesson plans and during the interview; however, I only saw inquiry in Michelle's and Marcus's classes. Michelle's students tested pond water in the outdoor habitat, using a variety of indicator tests to gauge water quality. In Marcus's physics class, students designed a bottle rocket to learn about force and distance.

Marcus and Michelle also demonstrated science so that students could see how it related to them by asking them to solve a problem in a familiar situation. Shanice and Sam engaged the students, but their middle school students had difficulty relating to many of their classroom practices. For example, Sam had the students examine creek water looking for microorganisms, while Michelle had the students looking for macroinvertebrates in the school pond water and relating their findings to the quality of the water. Shanice had the students comparing cell organelles from two different pictures of an animal cell when Michelle had her students creating stories using cell organelle terminology. While Shanice and Sam had their students engaged in science activities Michelle had her students relating to science within the real world and higher level activities. However, all of the participants tended to use more of the central principles of

NOS in classroom practices where they showed a more informed understanding on the *VNOS B Test*.

The lesson plans required by the school district are not very detailed and do not use language that demonstrates NOS. While I thought this tool could reveal some useful information for this study, it did not. The lesson plan format asks for the objective according to the state, materials needed, homework, purpose of the lesson, warm-up, lesson modeling, guided practice, independent practice, and assessment of the lesson. The purpose of the lesson is typically described thusly: "The student will learn [a certain topic or skill]." Most of the lesson plans I reviewed contained one sentence under each category listed above. Due to the format, the lesson plans could not be used to determine whether the classroom practices aligned with the central principles of NOS.

Do the Teachers' Physical Environments Reflect or Contest NOS? (Classroom Observations)

All of the teachers in this study had classrooms that reflected NOS. It is notable that the female science teachers arranged the desks in nontraditional configurations, while the male teachers' classroom seating arrangements were traditional rows. Michelle had her tables in groups of two, facing each other, and Shanice had two giant U shapes, one inside the other. Michelle arranged hers for collaborative work, while Shanice arranged hers for freedom of movement within the classroom. Sam has a smaller classroom, with 35 large, eighth grade students taking up much of the room. He claims his table arrangement is the only way to allow movement and maintain order in the small space. He said he tried the tables in groups, and it just did not work in his space. Marcus likes the students in rows in his classroom. He claimed that the students listen better in this formation, and they can get into groups of four very easily by turning their chairs around.

All of the classrooms displayed student created work: posters, models, and other projects. Marcus and Shanice had posters that depicted “Science for All,” with pictures of women, minorities, and disabled individuals all involved in science activities. All of the teachers provided the students with tools of science. The equipment was available in all the rooms except Sam’s, due to lack of space and cabinets. Resource books and science magazines were available to the students in all of the rooms where I observed.

As a group, the teachers’ physical environments reflected the central principles of NOS and seemed to encourage students to participate in science activities. The classrooms were inviting to students and displayed student work.

What are the Enabling and/or Constricting Factors that Translate Knowledge into Classroom Practices? (Interview)

All of the teachers had complaints about the facilities they were housed in. Some problems were simple; others were complex and most likely irreparable. Two of the four schools were undergoing renovations that may alleviate some of the constricting factors. All of the schools are very old, and were originally built to house fewer students.

The teachers agreed that the administration can act as an enabling or constricting factor. Most of the teachers in this study felt that their administration trusted them, and allowed them freedom to try new teaching methods, including going outside for practical science instruction.

Instruction time was a constricting factor for everyone except Michelle. All the teachers felt that 65-85 minutes every other day was not enough time to teach science effectively. They also agreed that the practice of double-blocking tested content areas such as mathematics and language arts should be extended to science, as it will be tested beginning the next school year.

The female participants felt that they were surrounded by supportive and caring colleagues; the male participants did not express this view of their colleagues. Michelle and Shanice said that working in a supportive and nurturing environment was an enabling factor in their teaching practices.

Summary

Many second-career, alternatively certified science teachers have initial issues concerning their effectiveness in the classroom (Lederman, 1999; McCann, et al., 2005; Ramano & Gibson, 2006). According to Veal (2002), alternatively certified teachers are an "untapped reservoir of knowledge." (p. 56). As this study has revealed, the four participants bring many strengths to their classroom practices.

This study explored five essential research questions. Each teacher in this study has a unique understanding of NOS, as expressed by the *VNOS B Test* and individual interview that allowed the participants to explain their written responses. Michelle and Marcus possess a greater understanding of theories and laws, while Shanice's and Sam's *VNOS B Tests* and interviews revealed an unsophisticated understanding of theories and laws. All of the participants have a more informed understanding of how scientists can draw different conclusions from the same data. They all agreed that scientists use creativity and imagination in their work.

The second research question explored how the participants acquired their NOS knowledge. All of the teachers in this study had some form of scientific research experience that helped them understand how scientific knowledge is formed. Each understood the importance of creativity and imagination in the scientific process. Michelle and Marcus had direct instruction at a local university on how theories and laws work.

Based on this case study, each teacher experienced a unique, critical event that informed his/her acquisition of NOS knowledge. These events occurred in their scientific research experiences, their own K-12 science experiences, their college or university science courses, and their prior job experiences. Some the events were more significant than others. For example, Marcus's understanding of how to engage students in inquiry, acquired during a graduate course at a local university, dramatically altered his teaching style.

The third research question examined was classroom practices and how they aligned with the central principles of NOS. My observation of each teacher's classroom instruction techniques revealed that every teacher demonstrated hands-on activities at least 50% of the time, in classrooms that were inviting and science activity oriented. Each teacher used various instructional strategies that aligned with the central principles of NOS, especially collaborative small group activities and student led discussions.

All of the teachers in this study created a physical environment that reflected the NOS as outlined on the data analysis tool (Appendix E). Research question four examined how the physical environment reflected or contested the NOS. The participants all had examples of science throughout their classrooms, access to the tools of science, student-created work on the walls, and access to research tools within the classroom.

Research question five explored the constricting and enabling factors that either help or hinder the translation of NOS into classroom practices. All of the participants in this study believed that the restricted time schedule, i.e., a single block as compared to the double-blocked time for mathematics and language arts, was the most constricting factor for translating NOS into classroom practices, given the amount of curriculum they were expected to teach.

After two or three years in the classroom, and some important university pedagogy courses, all of the teachers in this study understand and enjoy middle school students, and demonstrate many central principles of NOS in their instructional practices.

Chapter five provides a discussion and interpretation of the teachers' differences, with respect to their understanding of NOS, how they acquired it, had they demonstrate NOS in their classrooms, how the physical environment enables or constricts them in teaching, and any factors that may affect their using NOS practices in their classroom, as well as the implications of the findings in this study for the field of teacher education. The limitations of this study will be explained, and further investigations as they have emerged in this study will be presented.

CHAPTER V

DISCUSSION, CONCLUSIONS, IMPLICATIONS FOR TEACHER EDUCATION AND SUGGESTIONS FOR FUTURE STUDY

This chapter begins with a brief overview of the goals and specific research questions that were answered by the four participating lateral entry middle school science teachers. Discussion of the findings presented in chapter four follows the brief overview. Conclusions from this study are presented. Implications from the results of this study to the field of teacher education and suggestions for future studies are offered. A brief summary of the study concludes the chapter.

The purpose of this study was to examine the strengths second-career alternatively certified science teachers bring to their middle school classroom practices by examining their (1) understanding of nature of science (NOS) and (2) prior educational and research experiences.

Veal (2002) suggested that researchers examine how alternatively certified teachers (ACTs) learn to translate their content and experiential knowledge into classroom practices. This multiple case study has shown that four second-career alternatively certified middle school science teachers demonstrated varying degrees of several central principles of NOS through their classroom practices. These data demonstrate that the science teachers who were participants in this study acquired their NOS knowledge from a complex combination of their research experiences, their K -12 science experiences as students, and formal direct instruction of NOS that they received. According to national statistics, ACTs are being hired in increasing numbers due to teacher vacancies across the country (Feistritzer, 2006). There is a gap in the literature with respect to understanding the positive attributes that ACTs bring to the classroom. Much of the current literature focuses on the deficits of ACTs, rather than the strengths they bring to the classroom (Darling-Hammond, 2000; Laczko-Kerr & Berliner, 2002). This study helps fill the void in the literature, providing evidence that ACTS bring positive attributes to the teaching profession.

While examining the practices of second-career alternatively certified teachers, the goal of my research was to convey how the four teachers demonstrated the central principles of NOS in their classrooms practices. Teachers who understand and demonstrate NOS in the classroom have students who are more scientifically literate (Akerson et al., 2000; Cunningham, 1990; Khisfe & Abd-El-Khalick, 2000). According to the *NSES* standards (NRC, 1996) and the guide lines in *Science for All Americans* (AAAS, 1990), science teachers should have a sophisticated or well informed understanding of NOS. I examined each teacher's understanding of NOS using the *VNOS B Test* and the background questionnaire, and then further probed each teacher to determine how they developed their understanding of NOS through an interview. I observed teachers' classroom practices and studied their physical classroom environments to see how these practices and classroom environments either reflected or did not reflect the central tenets of NOS. I asked teachers to explain what they believe helped them or restricted them from converting their knowledge about NOS into classroom practices.

Van Driel et al., (2001) claimed that teachers' beliefs and knowledge are closely connected and therefore impact their classroom behaviors.

The central principles or tenets of NOS in this study defined science as being: (a) tentatively based, (b) empirically based, (c) subjectively interpreted, (d) creatively and imaginatively inferred because it involves humans, (e) distinctively a combination of observations and inferences, (f) socially and culturally embedded, (g) separately understood from technology but impacted by technology (the corollary is also true; technology is impacted by science), (h) individually different science content areas yet they are related kinds of scientific knowledge, laws and theories, and (i) uniquely an understanding of how scientific knowledge is formed. The following research questions were addressed in my study:

1. What are second-career alternatively certified science teachers' understandings of nature of science?
2. How did these second-career lateral entry science teachers acquire their understanding of NOS?
3. In what ways do second-career alternatively certified science teachers' classroom practices align with central principles of NOS?
5. How does the physical environment reflect or contest the nature of science?
6. What do alternatively certified science teachers note as enabling and constraining factors in translating their knowledge into classroom practices?

Four second-career alternatively certified science teachers were selected from a volunteer pool of 10 alternatively certified middle school teachers from the same large southeastern school district. All of the participants in this study were teaching at schools where 55% or more of the students received free and reduced-price lunches. The student population of the four schools selected for this study consisted of 58% to 90% ethnic minorities and three of the four schools have many Limited English Proficiency (LEP) (see Tables 2 & 3) students (15 – 21%).

Science classes in this school district do not meet daily. The middle schools in this school district were on block schedules (A and B days) with science classes meeting every other day for approximately 70 minutes. State science testing will occur at the end of school year 2008 for eighth graders as mandated by *No Child Left Behind* legislation. Two of the four schools, Burrows and Huntington, struggled with low reading and mathematics state test scores, while Murphy and Branch Middle Schools met or exceeded the district average scores on the state reading and mathematics tests.

All of the participating teachers have bachelor's degrees in science and are now fully licensed to teach middle school science. They all taught integrated science courses that follow a state directed curriculum based on the national science education goals. Three of the participants taught eighth grade science while Marcus taught seventh grade science. Michelle was the only participant who has now earned a master's degree in teaching. All the participants had been teaching middle school science two or more years when my study began and all of the teachers had careers in science-related fields prior to beginning their teaching experiences. Each teacher in this study participated in some research experience either during their prior career or during their years in college.

Each research question is further examined below. I report the findings and offer my interpretation of the findings as they relate to the current literature for each of the research questions.

Discussion and Interpretation

Research Question 1: What is the Understanding of the Nature of Science?

These data were obtained from each participant's written answers to the *VNOS B Test.* The *VNOS* follow-up interview allowed the participants to expand on and explain their written answers on the *VNOS B Test*. The *VNOS B Test* contains six questions that assess an individuals' understanding of NOS. The discussions and interpretations that follow are grouped by themes that each of the six *VNOS B Test* questions addressed.

Question One and Three (Theories and Laws)

On the six question *VNOS B Test*, questions one and three assessed the participants' understanding of theories and laws. Question one addressed the concept of whether or not theories could change and question three asked if theories and laws are related. According to McComas (2004) and Brickhouse and Bodner (1992) students are not likely to fully understand NOS until they are directly instructed about NOS. Additionally, McComas (2004) stated that teachers must be taught how to use the NOS principles in order to implement them effectively in classroom practices.

According to my interpretation of teachers' responses to both questions, one and three, on the *VNOS B Test*, two of the teachers had a less informed understanding of this concept of NOS and two of them had a more informed understanding of theories and laws. Based on my interpretations, Marcus and Michelle both had an overall informed understanding of NOS as indicated by their *VNOS B Test* scores and interviews. Both Marcus and Michelle had a greater understanding that theories can change and a better developed understanding of how laws and theories are related, which I attributed to the direct instruction they received in a science methods course that they described to me during the second interview. In this particular university course they received direct instruction on NOS, which included topics such as theories and laws, and discussed how to implement inquiry methods into their classroom practices.

Sam's *VNOS B Test* and interview demonstrated a less informed understanding of theories and laws, and Sam stated he had never had a course on NOS or inquiry. Shanice described a short one-hour workshop led by the school district on NOS, as her only exposure to formal instruction on NOS. She also demonstrated a less informed understanding of NOS. Clearly, this introduction to NOS did not have much of an impact on Shanice's understanding of NOS. Shanice and Sam had a less informed understanding of the concept about the relationship between theories and laws and never indicated receiving direct instruction on theories and laws or how to translate these concepts into practices in the classroom.

Question Two (Structure of an Atom)

Question two on the *VNOS B Test* asked the participants to explain the structure of an atom and how scientists developed certainty about the structure of an atom. This question also asked the teachers what specific evidence scientists found that helped determine what an atom looks like. This question was very interesting because three of the four teachers never answered the question as the author intended. Abd-El-Khalick

(1997) designed this question to determine if teachers know how and why models are used in scientific explanations. The only participant who clearly expressed that models are used to represent unseen structures in science was Michelle. None of the other participants in this study indicated that models are an important use of representation in science. However, Marcus and Sam seemed to understand how Rutherford discovered the structure of the atom through the design of his experiment. Marcus described in detail Rutherford's experiment of the bombarding alpha particles into the gold foil and concluded that atoms have a densely compacted nucleus but are mostly composed of space. In my interpretation, Marcus's explanation demonstrated an informed view of this question. Sam and Shanice both understood the structure of an atom but could not fully describe the specific evidence to support the structure of an atom. Sam recalled some details of Rutherford's experiment; therefore, Sam's understanding of this concept was between less informed and informed. Shanice had a less informed understanding of this principle because she did not offer any evidence that she understood how scientists developed their understanding of the structure of an atom.

According to Abd-El-Khalick (1997), participants who understand the use of models and explain how models are used to demonstrate the structure of an atom have a sophisticated understanding of this concept. I cannot point to any knowledge or experience that Michelle acquired that led her to this deeper understanding. Perhaps she received indirect instruction in one of her many other workshops, such as AVID or Paiedia or IB training.

Question Four (Similarities/Differences in Art and Science)

Question four examined how art and science are similar and how they are different. According to *Science for All Americans* (1990), science and art are both creative endeavors. Three of the four participants had an informed understanding of this principle or tenet as anticipated due to their research experiences and prior career experiences. Michelle, however, struggled with the comparison of the two disciplines and never answered the question well at all. Michelle's answer to this question perplexed me. As I continued to question her during the interview I tried to further probe Michelle about this question and she continued to state, "Some kids have a knack for science and can figure stuff out." Later she stated that science is an art, which meant to her that you needed a special talent or a gift to be good at science. I struggled with the analysis of this data, only to surmise that Michelle never really understood the question as the author intended. However, Michelle demonstrated that both science and art are creative enterprises in her classroom practices by having the students complete the underwater parks project and that is why I am puzzled by her inability to articulate her understanding of this NOS principle on either the written test or the interview about the *VNOS B Test* responses.

Question Five (Scientists' use of Creativity and Imagination)

VNOS B Test question five asked how scientists use creativity and imagination during investigations. All four participants in this study had an informed understanding of this concept. All of the participants had research experience, and I contend that being immersed in a research experience involves understanding how scientific knowledge is formed. Veal (2002) found that ACTs often bring with them real-world science from their prior experiences, and that includes how scientific knowledge is formed. According to three of four participants in this study, their research experiences demonstrated creativity during the process of forming scientific knowledge.

Both Marcus and Sam had the greatest understanding of this concept. According to Veal (2002), Sam's significant scientific research experience aligned with his informed answer to this question. Marcus had limited research experience (marketing research), but his constant reading of research and scientific studies may have increased his understanding of this concept. Michelle, who had a master's degree, and had performed original scientific research as a park ranger, had an informed understanding of this question; however, Michelle was not as well informed as Sam. Sam's extended research on the vessel may have impacted Sam's understanding that science involves creativity and imagination more than Michelle's research experience at the state park. Veal (2002) claims that scientific research influences an individuals understanding of NOS. I found this somewhat perplexing. According to Veal (2202), Michelle should have a greater understanding of this question; however, her overall understanding of NOS as tested and observed in her classroom practices was greater than that of Sam's overall understanding of NOS.

Question Six (Scientists Drawing Different Conclusions from the Same Data)

This case study revealed that all four teachers had an informed understanding of question six: How are different conclusions possible if scientists are looking at the same experiments and data? These findings were typical according to Veal (2002), who claimed that ACTs often bring to the classroom an understanding of real-world science knowledge. I conclude, since all of the participating teachers in this study experienced some type of research, they brought real-world science knowledge into the classroom, as demonstrated by their informed understanding of this concept of NOS, and as suggested by Veal's research (2002).

According to the answers on the *VNOS B Tests* and the *VNOS* interview questions, Michelle and Marcus clearly had a deeper understanding of NOS. Shanice and Sam had some understanding of NOS. Figure 2 lists the VNOS B Test questions, and compares the participants' answers. Interestingly, all of the participants shared an informed understanding of questions five and six. Sam answered question five just as the author had intended. Both Sam and Shanice answered question six precisely as the author intended.

Research Question 2: How Did the Participants Acquire Their Understanding of NOS?

All four of the teachers in this study had critical events in their prior careers and science experiences, including their K -12 and university science classes. Chambers (2002) indicated that individuals who change careers often transfer prior experiences to the field of teaching. A recent study by Haggard et al., (2006), found that second-career ACTs felt as though they were entering the classroom with specific skills: (a) good content knowledge, (b) real-world knowledge, (c) patience, (d) good organizational skills, and (e) good collaborative skills. Each participant clearly recalled a critical event from prior work and science education experiences, and they could describe it in detail. Two specific events that had the most impact on the teachers' acquisition of their understanding of NOS were participating in scientific research and direct instruction of NOS. Some of the findings from this study agreed with the findings of Haggard et al., (2006), while others did not. Michelle indicated on the background questionnaire that she felt she had real-world knowledge from her previous job. However, Shanice did not feel that she brought real-world experience with her to teaching. She had compartmentalized her experiences and perhaps as she gains knowledge, through acquiring her Master's degree she may merge these experiences with her classroom practices (Pajares, 1992). Shanice is currently working on her Master's degree while teaching.

Both Cunningham (1995) and Veal (2002) independently concluded that there is evidence that teachers who have participated in scientific research have a deeper understanding of NOS than teachers who have not participated in scientific research. In this case study, all of the teachers had participated in research experiences; three teachers participated in more traditional scientific research, and one teacher participated in marketing research. All of these research experiences seemed to enhance the teachers' understanding of NOS. Both Cunningham (1995) and Veal (2002) reached similar conclusions in their studies.

Shanice experienced scientific research first-hand during her internship at a pharmaceutical company. She saw scientists debating and discussing the interpretation of data. Marcus heard debate among participants in his marketing research group, although the participants were not scientists. These research experiences helped to deepen the teachers' understanding of this principle of NOS.

I found in this study that in addition to research experiences and learning experiences that direct instruction also influenced these teachers' understanding of NOS. At a local university, Michelle and Marcus completed a graduate science education course that covered direct instruction of the NOS and inquiry teaching strategies. This course focused on the nature of inquiry, and how to implement it in the classroom. McComas (2004), Brickhouse and Bodner (1992), and Billeh and Hansan (1975) all agree that teachers who receive direct instruction on NOS have a much fuller understanding of NOS than those who participate only in inquiry activities. Michelle and Marcus had a more informed understanding of NOS than Shanice and Sam.

Sam never indicated participation in a direct instruction course on NOS or inquiry and Shanice had a brief one-hour exposure to NOS through a school workshop. Therefore, it is not surprising that Shanice and Sam had a less informed understanding of these concepts as they pertain to NOS. Clearly, research experience and direct instruction seemed to have an effect on how these four teachers acquired their understanding of NOS.

Wong (2002) found that teachers who use more inquiry in their classroom practices tend to reflect greater knowledge of NOS than those teachers who use less inquiry in their classroom practices. Both Michelle and Marcus taught inquiry lessons during my classroom observations, which reflected a more informed understanding of NOS (Wong, 2002). Michelle took her students outdoors to measure water quality indicators of the school's pond. Marcus's students learned to measure speed by running various distances on the school track.

According to Lederman (1992), knowledge of NOS alone does not translate into incorporating NOS into one's classroom practices. However, I found that the four teachers in this study did demonstrate to varying degrees several central principles of NOS in their classroom practices. Michelle and Marcus had an overall informed understanding of NOS while Shanice and Sam had a less informed understanding of NOS (Figure 2).

Research Question 3: In What Ways Did the Teachers' Classroom Practices Align with the Central Principles of NOS?

According to Standard One of the national standards for teachers set forth by the National Council for Accreditation of Teacher Education (NCATE), teachers must demonstrate their knowledge through inquiry, critical analysis, and synthesis of the subject. Concurring with NCATE, Interstate New Teacher Assessment and Support Consortium (INTASC) states that teachers must have an understanding of the pedagogical content knowledge within their subjects so they can teach and create meaningful learning experiences using the tools of inquiry. Some researchers, including Abd-El-Khalick (1998) and Brickhouse (1990), stated that teachers' understanding of NOS is not translated into classroom practices; however, their research was generally limited to traditionally-educated teachers rather than ACTs. Some researchers contend that ACTs with scientific research experience bring with them a deeper understanding of NOS (Cunningham,1995; Veal, 2002). Chambers (2002) claimed that individuals who change careers, such as ACTs, bring prior knowledge, experiences, and many skills acquired from their previous work to their new jobs.

Kelly and Duschl (2002) indicated that teachers who have an understanding of the central principles of NOS translate those principles into the classroom through collaborative and communicative investigative activities. Both Michelle and Marcus demonstrated inquiry lessons when I observed their classroom practices, which Wong (2002) indicates that teachers who offer inquiry oriented lessons tend to have an increased understanding of NOS. Michelle tested the water quality in the outdoor habitat pond, while Marcus created bottle rockets to test how force changed when the mass or acceleration of the rockets was altered. These teachers demonstrated an informed understanding of NOS through their classroom practices by showing that science is (a) empirically based, (b) creatively and imaginatively inferred because it involves humans, (c) distinctively a combination of observations and inferences, and (d) subjectively interpreted. Windschitl (2004) found that teachers who had significant research experience prior to teaching, or had more advanced content knowledge, such as a master's degree, carried out more inquiry activities. Inquiry based instruction tends to reflect a teacher's increased understanding of NOS (Wong, 2002), which fits the profile of instruction in Michelle and Marcus's classrooms.

Bartholomew et al., (2004) indicated that teachers who allow reflection time support student development of an understanding of NOS. Shanice encouraged reflection when students worked independently. This practice allowed science topics to incubate, giving the students time to think about them. Shanice understood that her students needed time to sit and reflect about a reading or an assignment. She also indicated that this practice helped students who were weak in reading comprehension. Shanice's school, Burrows, had low state reading scores (only 32% passing). Michelle moved at a rapid pace in her classroom and did not allow much reflection time. Yet it was apparent that her students did reflect on their own time, as indicated by the questions they asked during classes that followed.

Both Marcus and Sam encouraged their students to explore new equipment in their classrooms. For example, Sam allowed his students time to learn how to use the microscope to focus on an object. This classroom practice demonstrated high central principles of NOS (Appendix D). The students were more comfortable using tools and had more confidence in their ability to investigate the concepts of science (McComas, 2002).

Matthews (1998) stated that asking stimulating questions and leading engaging discussions demonstrate an understanding of the central principles of NOS. Michelle frequently opened her class with thought provoking questions that asked how or why about a specific science topic. Matthews (1998) contended that students need to struggle with challenging science questions such as the ones Michelle asked her students. One day Michelle asked her students to answer the following questions: (a) "How is understanding water quality important?" and (b) "What impact do you have, positive and negative?" The other three participants did not offer such a motivating start to their classes or use stimulating questions. Their daily routines for beginning class demonstrated classroom practices that ranked low on the central principles of NOS, as they offered only rigid, teacher-led activities, and low cognitive questions with one correct answer. Michelle offered other interesting motivational strategies for her classes.

Michelle demonstrated one motivational classroom practice that was totally student led. The student who led the class, Angela, collaborated with the teacher to create the lesson plan and select the instructional strategy. This lesson involved examining the outdoor habitat pond water for bio-indicators to determine the water quality. Several central principles of NOS were demonstrated during this lesson (using inquiry, hands-on activities, collaboration, and investigating a real-world science situation). Wolff-Michael Roth and Bowen (1995) found that student led classes increased the use of inquiry practices and increased general understanding of the science content knowledge.

On one occasion I observed Shanice allowing a student to facilitate a portion of the class lesson. Shanice celebrated student knowledge, and during one of my observations, encouraged a student to demonstrate a computer skill for the entire class.

Marcus never demonstrated student led classroom practices during my classroom observations. However, Sam employed a student led strategy when some of his students led the class through a lecture and note taking session that was low on the central principles of NOS. While this lesson was student-facilitated it was considered low on the central principles of NOS because the students were reading notes from overheads, and the rest of the class was just copying and did not engage in any student discussions or questions.

All of the participants in this study demonstrated at least two hands-on, collaborative experiences for their students while I was observing in their classrooms. However, this alone does not reveal an understanding of NOS. McComas (2004) believed that hands-on science activities are important, but not sufficient on their own for a full understanding of NOS; students also need direct instruction about NOS. During my classroom observations, I never observed direct instruction on NOS. Occasionally, I heard statements like Shanice's: "There are many different correct answers to this question, so share your answer with your neighbor." Shanice's comments inferred NOS tenets but she never explicitly stated them to her students as NOS principles.

To some extent, all four teachers in this study displayed classroom practices that align with the central principles of NOS by demonstrating: (a) use of inquiry, (b) time to reflect on the lesson, (c) exploration of the tools of science, (d) stimulating and relevant questions, (e) student led instruction, and (f) hands-on activities. My interpretation of the data agrees with Kelly and Duschl (2002) that the teachers in this study demonstrated several classroom practices that align with the central principles of NOS. My data found evidence to confirm both Cunningham (1995), Abd-El-Khalick (1998), and Brickhouse's (1990) conflicting research results. While Brickhouse (1990) and Abd-El-Khalick (1998) found no relationship between a teachers understanding of NOS and their classroom practices, Cunningham (1995) found that some teachers who demonstrate a clear understanding of NOS do indeed have classroom practices that reflect that understanding of NOS.

Research Question 4: How Does the Physical Environment Reflect or Contest NOS?

In addition to examining teachers' classroom practices I also looked closely at the physical environment of the classrooms themselves to see if they were reflective of or contested the principles of NOS. The four teachers' classrooms all had physical environments that made them conductive to good science instruction. These teachers created environments that embraced science for all by making the tools of science available to their students. They demonstrated that science is for all students by displaying student work. All participants embraced collaborative practices, often allowing the students the freedom of choosing their lab groups. Michelle and Marcus extended the physical environment to the outdoors, demonstrating to their students that science goes beyond the walls of the science classroom. Sam and Shanice indicated that students were allowed to go outside, but did not demonstrate this during my observation times.

Cunningham (1998) stated that science classrooms that function more like a scientific community reflect NOS. The physical classroom itself can give us some indication about a teacher's views about NOS. While the male teachers in this study preferred the classroom tables arranged in traditional rows, the female participants arranged their tables for collaboration. Michelle's arrangement of tables in groups of four reflected her classroom practice of collaboration. Two tables put together formed a scientific study group. Michelle claimed, "Students really do learn a lot from each other." I even heard her say to her students, "I don't hear enough talking," referring to student conversation regarding decisions about a simulation activity and what actions they needed to take as a group. Shanice arranged her tables for ease of movement. She believed that collaborative investigation involves movement, and she allowed that freedom within her classroom. While all four teachers embraced the concept of the physical environment reflecting NOS, the two male teachers clung to the traditional notion of arranging the tables in rows. Marcus even claimed that his students learned best when the tables were arranged in rows.

Michelle and Shanice created a physical environment with their table arrangements that mimicked a scientific community, encouraging collaboration. A classroom that simulates a scientific community, according to Cunningham (1995), demonstrates a strong sociological understanding of science (SUS), a significant component of NOS.

Research Question 5: What do the Teachers Note as Enabling or Constricting Factors in Translating Their Knowledge into Classroom Practices?

Van Driel's (2001) study indicated that science teachers' knowledge and beliefs are directly connected to their classroom practices. When asked about factors that enabled or prevented the translation of their knowledge into classroom practices the four teachers in my study noted three important factors: (a) the school administration, (b) collegial relationships, and (c) instructional time for science.

All of the teachers agreed that the administration at their schools assisted them in translating their knowledge into practice by providing professional development opportunities, allowing freedom of instructional choices, and equipping the science laboratory with the necessary tools for doing science. All of these factors are important to translating central principles of NOS into classroom practices (Kelly and Duschl, 2002). According to several studies, changes in science classroom practices are dependent on the resources available and the on-going professional support (Appleton & Asoko, 1996; Glasson & Lalik, 1993; Tobin, 1993; Radford, 1998). The teachers in this study agreed that the knowledge gleaned from professional development helped them learn new instructional strategies for their classrooms. For example, Shanice attributed her classroom questioning techniques, which reflected a more informed view of NOS, to her attendance and participation in an *Active Physics* workshop. Teachers in this study often said they had the freedom to use the outdoors for science instruction, allowing them to bring the real-world experience of science to their students (Cunningham, 1998; Veal, 2002). Teachers cannot include exploration of science without the necessary tools; proper equipment increases a teacher's ability to translate knowledge into classroom practices.

The female teachers in this study acknowledged the importance of collegial relationships at school, while the male teachers did not indicate this as a factor at all. This aspect of teaching demonstrates a collaborative and communicative environment, an important central principle of NOS that is translated into classroom practices, according to Kelly and Duschl (2002).

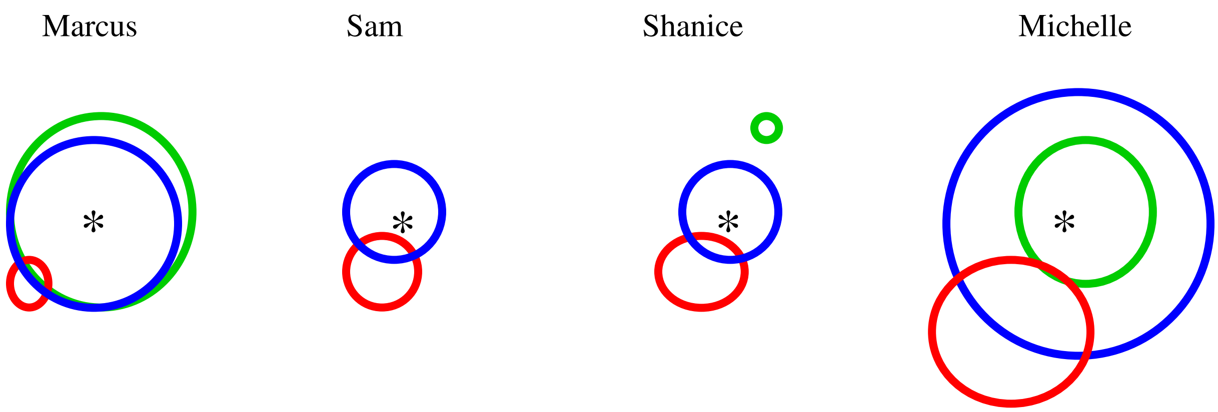
One constricting factor that resonated among all of the teachers in this study was the amount of time allotted for science instruction. According to several studies, science classroom practices cannot change without sufficient instructional time (Appleton & Asoko, 1996; Glasson & Lalik, 1993; Tobin, 1993; Radford, 1998). Each science teacher, in my study, had approximately 70 minutes of instructional time every other day, which translated into 6,300 minutes a year to teach science. That time includes routine interruptions such as fire drills, announcements, field trips, teacher absences, state required tests, and assemblies. All of the schools in this study scheduled mathematics and language arts classes to meet twice as often as science classes, which translated into 12,600 contact minutes a year in mathematics and 12,6000 minutes a year in language arts. This clearly had an impact on translating knowledge into classroom practices.

The findings of my study showed that the teachers' understanding of NOS were most impacted by (a) having had direct instruction of NOS, (b) having participated in research experiences, and (c) understanding and implementing classroom practices consistent with NOS, (see Figure 3). While all of these teachers have some research experience, prior science learning experiences, and some understanding of NOS, Michelle and Marcus showed a more informed view of NOS and demonstrated it in the classroom using inquiry methods. Both received direct instruction on NOS, through a science methods course at a local university. Both Michelle and Marcus demonstrated inquiry lessons during my classroom observations. While Sam and Shanice did not teach inquiry lessons during my observations they did engage their students in many hands-on activities.

The Venn diagrams (see Figure 3) represent how each participants' direct instruction of NOS, research experiences, and classroom practices impacted their understanding of NOS. The size of the circle represents the impact of that area on their understanding of NOS, and the overlapping of the circles represents how the participants related one area to another.

Figure 3. Teachers Research Experience, Direct Instruction of NOS, and Classroom Practices Relationship

Red – Research Experience
Green - Direct Instruction of NOS
Blue - Understanding of NOS as Demonstrated by Classroom Practices



As demonstrated by the Venn diagrams in Figure 3, Michelle's and Marcus's circles of understanding (direct instruction of NOS, research, and classroom practices) are larger and more interrelated, indicating a more informed view of NOS as translated through their classroom practices. According to Sam, he never received any direct instruction on NOS, and Shanice said that she received only a limited amount of instruction during a one-hour workshop. Shanice's limited experience with direct instruction of NOS did not impact her classroom instruction. Neither did she relate the direction instruction of NOS experience to her research. Therefore, Shanice's limited experience with direct instruction on NOS remains an isolated experience and insignificant factor in her understanding of NOS. Sam had a significant oceanographic scientific research experience; however, he had difficulty linking it to his classroom practices. Marcus demonstrated a significant relationship between his direct instruction of NOS and his classroom practices. He claimed this is due to his university course on NOS. Michelle interconnected all her experiences with the greatest demonstration of understanding of NOS through her classroom practices. She demonstrated NOS through inquiry activities and using the outdoor habitat but struggled to verbalize during the interview or write about her understanding of NOS in the *VNOS B Test*.

Implications for Teacher Education

This study is noteworthy and has important findings for those who design, implement and influence teacher education. This study confirmed Lederman's (1992) findings that teachers who receive direct instruction on NOS seem to have a better understanding of NOS, and demonstrated this better understanding through their classroom practices, perhaps to the benefit of their students. Based on the findings from this study, I suggest that all science teachers would benefit from direct instruction on NOS. I would also recommend that teachers examine their understanding of NOS through the *VNOS B Test* and engage in an in-depth discussion of the topic to assess their strengths and weaknesses with regard to the views of NOS. Shanice's limited exposure to NOS, a one-hour workshop, suggests that it did not have a significant impact on her understanding of NOS.

This study also demonstrates that a teacher's involvement in a research experience (ranging from five months to five years) seems to have a significant effect on their understanding of NOS. Thus, I would suggest that every pre-service science teacher perform scientific research during their science teacher education preparation at the university. Many colleges require internships; perhaps all pre-service science teachers should work at a summer internship that engages them in scientific research.

Additionally, the findings from this study indicated that Michelle, the one teacher with a master's degree, had the most informed understanding of NOS and demonstrated the most central principles of NOS in her classroom practices. According to Windschitl (2004) holding an advanced degree increases a teacher's knowledge of NOS. Thus, I suggest that school districts should, in conjunction with universities, offer science teachers an opportunity for advanced study and this advanced study should include a NOS course along with a semester-long research experience in the field.

Two teachers, Michelle and Marcus demonstrated an understanding of inquiry in the classroom through their classroom practices, and also had a greater understanding of NOS. The national science standards call for science teachers to have an understanding of inquiry. I contend that this instruction on inquiry and how to implement it in the classroom should be coupled with direct instruction on NOS to obtain the greatest benefits.

Further Research

As with many research studies, more questions than answers were generated with my study. Some of the questions that remain to be answered and that constitute my suggestions for further study include: (a) what are the traditionally educated science teachers understanding of NOS compared with second-career science ACTs understanding of NOS?, (b) would additional direct instruction of NOS affect these teachers' classroom practices?, (c) does the ethnic background of the teacher (compared to the ethnic background of the students) make any difference in the students' understanding of NOS?, and (d) what are the students' understanding of NOS in the classrooms I observed? I offer a few suggestions for potential studies that have emerged during the course of this study.

According to Lederman et al., (2006) more studies comparing the teaching skills, abilities, and attitudes of ACTs and traditionally certified teachers are needed. This study examined the ACTs' knowledge of NOS and how that knowledge was translated into their classroom practices. This study could be expanded to compare ACTs' understanding of NOS to that of traditionally certified teachers, and how that translates into classroom practices. A comparative study between ACTs and traditionally-educated teachers could confirm or refute other studies' findings of understanding of NOS and how it is translated into classroom practices.

Many ACTs enter the classroom without prior work experience, such as *Teach for America* candidates who enter teaching directly from college. Another study would examine a randomly selected pool of ACTs and compare the classroom practices of those teachers who had scientific research experience with a group of teachers who did not have scientific research experience. This study could be expanded to include some direct instruction intervention after conclusions were drawn from the above study.

In addition to a comparative study of traditionally-educated teachers to ACTs, another comparative study could examine traditionally-educated teachers given varying amounts of direct instruction of NOS. Is there a minimal amount of direct instruction of NOS that affects the classroom practices reflecting the central principles of NOS?

Another question posed by this study involves gender issues. Both female participants felt the need for collegial support in order to better translate knowledge into classroom practices, whereas the male participants did not. This collaborative tendency also emerged along gender lines when it came to the arrangement of classroom tables. The females felt that conversation was a necessary component of the communicative nature of science activities, while the males did not. I offer a comparative study of males and females, and their understanding of NOS.

Examining these teachers' students' understanding of NOS would be an interesting study. Would the teachers' understanding of NOS correlate to their students' understanding of NOS?

A study could be proposed that examines these same teachers ten years from now, assuming they are all still in education. Have their classroom practices changed? Are they delivering direct instruction on NOS? Shanice and Sam said that they were going back to school to get their master's degrees. Did they follow up with an advanced degree, and did that make any difference in their understanding of NOS?

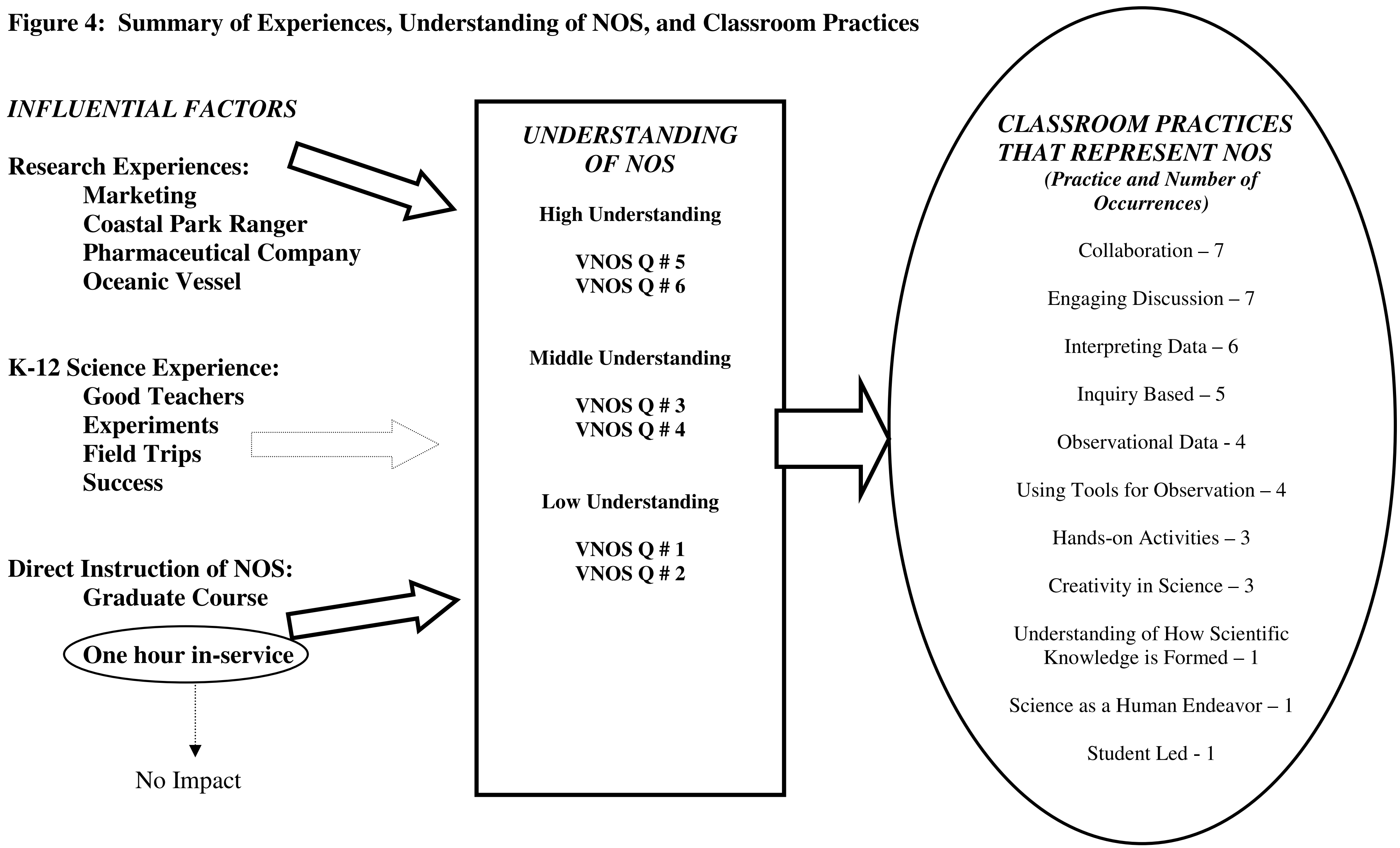
Many suggestions for additional research studies have grown out of the questions raised from this study. I feel certain that there will always be ACTs filling teacher vacancies, so we must find out more about this "untapped reservoir of knowledge," according to Veal (2002).

Concluding Statements

Figure 4 summarizes the findings of this study by showing the three most influential factors in this study: research experience, K-12 science experience, and direct instruction of NOS. The research experience and the direct instruction of NOS are represented with bold arrows because of their importance in influencing how the participants understood NOS. The K-12 science experience was not influential in determining how the participants acquired their understanding of NOS, as demonstrated through the information collected during this study. According to the *VNOS B Test* and interview, the teachers had a less informed understanding of theories and laws and a more informed understanding of the role of creativity and imagination and human interpretation in scientific investigations. Figure 4 indicates that collaboration and engaging discussions were the most observed classroom practice that represents and understanding of NOS, while student led instruction and activities that demonstrated science as a human endeavor were used the least.

From this study, there seems to be a clear difference among the teachers in their understanding of NOS and how it is translated into classroom practices. Michelle and Marcus demonstrated classroom practices indicating a more informed understanding of NOS, including inquiry-based lessons that showed an informed understanding of NOS.

Figure 4: Summary of Experiences, Understanding of NOS, and Classroom Practices



They also had a greater understanding of NOS as indicated by their answers on the VNOS B Test, and the interviews that followed. Michelle and Marcus both received direct instruction on NOS and science inquiry.

It is worth noting that Sam and Shanice had sophisticated scientific research experiences; however, this alone was not enough to promote an informed understanding of NOS, although I believe it did increase their knowledge of NOS.

Lederman et al., (2006) believe that ACTs are doing as well in the classroom as traditionally-educated teachers, after a few years of learning classroom management and other organizational skills. I contend that the teachers in this study brought a unique understanding of science to the classroom due to their experiences and direct instruction. Michelle and Marcus had an informed understanding of NOS, and translated science through their classroom practices in the form of a real world experience for their students. Science teachers' understanding of NOS, and their ability to translate it into classroom practices, is crucial to the success of science students today.

Alternatively certified teachers are filling classrooms at a rapid pace, and the school districts and those who prepare ACTs for the classroom need to better understand strengths and needs. This study examined a group of ACTs and the strengths they bring to the classroom. Abd-El-Khalick and Lederman (1999) concluded that explicitness and reflectiveness with respect to NOS are the most important factors in translating NOS into effective classroom practices. According to this study, direct instruction of NOS along with scientific research experience translates into classroom practices that reflect a deeper understanding of NOS. According to the *NSES* (NRC, 1996), we must train and hire teachers who have an understanding of NOS and who are able to teach NOS in the classroom -- the standard for all science teachers.

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APPENDIX A

BACKGROUND QUESTIONNAIRE

Name ____

Age _______________

Education:
College Attended and Degrees Earned:

____

____

____

Major in College:
Undergraduate ____

Graduate ____

Science Courses completed:
Undergraduate ____

____

Graduate ____

____

Labs:
Undergraduate ____

____

Graduate ____

____

Other college classes related to science (for example: history of science, ethics in science, science education, etc.)
Other education focusing on science (seminars, workshops, non-degree programs)

Work Experience:
Describe the job experiences you have had that included a science component. How many years did you work at each science related job? Please be specific in describing your duties.

Have you ever conducted or participated in scientific research (at work or school)? If so, describe.

Science Experience as a Student:
Please comment on your experiences (positive/negative/neutral) as a science student from your K-12 years and college.

Teaching experience:
How many years/months have you taught school? ______________________________

What area(s) of science do you enjoy teaching the most? _________________________

List your informal science teaching experience (for example: clubs, Boy/Girl Scouts, workshops, etc).

Have you participated in any in-service activities or classes that involved discussions of the history and/or philosophy of science? If so, what topics were discussed?

Have you participated in any in-service activities or classes that involved discussions of the nature of scientific knowledge? If so, what topics were discussed?

APPENDIX B

VNOS B TEST

1. After scientists have developed a theory (e.g., atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach scientific theories. Defend your answer with examples.

2. What does an atom look like? How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?

3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

4. How are science and art similar? How are they different?

5. Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments/investigations, do scientists use their creativity and imagination during and after data collection? Please explain your answer and provide examples if appropriate.

6. Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

APPENDIX C

CLASSROOM OBSERVATIONAL CHECKLIST

Questions students ask Lederman(1995)		
Cooperative learning with collaboration Lederman/Druger (1985) McComas (2004)		
Learning Centers Lederman/Druger (1985)		
Computer for research or data interpretation Lederman (1992)		
Student directed investigation McComas(2004) Inquiry (list skills used) Lederman/Druger (1985) McComas (2004)		
Data Interpretation Van Driel (2001) Lederman/Lederman (2004)		
Addressing Misconceptions Bell (2000)		
Discussion or Debate of current issues Lederman/Druger (1985) Matthews (1994)		
Writing in form of journaling Lederman/Druger (1985)		
Reflection time Bell (2000)		
Integrated or thematic approach LaPlante (1997)		
Problem solving Duschl (1997) Lederman (1992)		
Other		

In the lesson were any of the following taught, either through the lesson or in the directions or discussion: Based on Abd-El-Khalick/Lederman (2000)

Scientific Knowledge is:	**Evidence:**
Tentative – science changes	
Empirically based – data	
Collaborative	
Discipline – classroom management evident Lederman (1992)	
Dynamic – classroom encourages learning & not cause anxiety Bell (2000) Lederman (1992) Lederman/Druger (1985)	
Positive communication with students – good relationship NCR (1996) Bricker (2005)	
Allow questions – trust among students and teachers – no disrespect of others Bricker (2005) Shymanksy/Penick (1978)	
Based on observation of the natural world	
Methodology, but not step by step (scientific method)	
Creative – dynamic and exciting process	
Subjective – a human endeavor	
For all people and students – for all society (not just elite or the brightest students)	
Influenced by society, politics and culture	

Creating an Inviting Science Environment
Based on Bricker (2005)

Physical characteristic	Evidence
Hands on learning	
Tools/equipment to do science	
Samples/examples of science	

APPENDIX D

***VNOS B TEST* ANALYSIS DESCRIPTIONS**

VNOS (B)

Instructions: Answer the following questions, using the back of the page if you need more space. Please note that there are no “right” or “wrong” answers to these questions. I am simply interested in your views of a number of issues about science.

1. After scientists have developed a theory (e.g., atomic theory, kinetic molecular theory, cell theory), does the theory ever change? If you believe that scientific theories do not change, explain why and defend your answer with examples. If you believe that theories do change: (a) Explain why. (b) Explain why we bother to teach and learn scientific theories. Defend your answer with examples.

Note: Parentheticals are not part of the questionnaire.

(This question aims to assess understandings of the tentative nature of scientific claims and why these claims change. It is common for respondents to attribute such change solely to the accumulation of new facts and technologies, rather than the inferential nature of scientific theories and/or paradigm shifts. The question also aims to assess respondents’ understandings of the role of theories in science as well as the theory-laden nature of scientific observations.)

2. Science textbooks often represent the atom as a central nucleus composed of positively charged particles (protons) and neutral particles (neutrons) with negatively charged particles (electrons) orbiting the nucleus. How certain are scientists about the

structure of the atom? What specific evidence do you think scientists used to determine the structure of the atom?

(This question aims to assess understandings of the role of human inference and creativity in science, the role of models in science, and the notion that scientific models are not copies of reality.)

3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

(This question aims to get at a common misconception about the relationship between the products of science. Many respondents believe in a hierarchical relationship between the two whereby theories become laws if and when enough evidence has been accumulated in their favor. Additionally, respondents express many ideas related to their understandings of the nature of science and science process as they attempt to delineate the difference between theories and laws.)

4. How are science and art similar? How are they different?

(This question aims to assess understandings of the role of creativity and imagination in science, the necessity of empirical evidence in generating scientific knowledge, and the cultural and social embeddedness of science.)

5. Scientists perform experiments/investigations when trying to solve problems. Other than in the stage of planning and design, do scientists use their creativity and

imagination in the process of performing these experiments/investigations? Please explain your answer and provide appropriate examples.

(This question aims to assess respondents' understandings of the role of human creativity and imagination in science. While respondents generally recognize that experimental design involves creativity, they rarely say that creativity is used in data analysis in the sense that scientists are, for instance, "creating" patterns rather than "discovering" them.)

6. In the recent past, astronomers differed greatly in their predictions of the ultimate fate of the universe. Some astronomers believed that the universe is expanding while others believed that it is shrinking, still others believed that the universe is in a static state without any expansion or shrinkage. How were these different conclusions possible if the astronomers were all looking at the same experiments and data?

(By posing a scientific controversy and stressing the fact that scientists are using the same data but coming up with differing explanations, this question invites respondents to think about factors that affect scientists' work. The factors range from scientists' personal preferences and biases to differing theoretical commitments to social and cultural factors.)

Appendix E

VNOS B TEST
DATA ANALYSIS

Name ____

Using the following information the VNOS B Tests will be color coded. More informed answers will be highlighted with yellow and novice answers will be color coded pink highlighter and checked on this sheet.

Question 1

After scientists have developed a theory (e.g., atomic theory, kinetic molecular theory, cell theory), does the theory ever change? If you believe that scientific theories do not change, explain why and defend your answer with examples. If you believe that theories do change: (a) Explain why. (b) Explain why we bother to teach and learn scientific theories. Defend your answer with examples.

More Informed Answer

_____ Must answer yes the theories change.

_____ Use words "suggest" and not "prove"

A Why?

_____ There are inferred explanations, not an absolute truth (Chiapetta & Koballa, 2004).

_____ Theories survive tests but can't be positively justified. They can not be established as true or even as probable (in probability calculus); however they are durable due to evidence (Popper, 1963).

_____ Theories change due to paradigm shifts of the truth (Kuhn, 1970).

_____ Scientific knowledge is tentative but durable. Science can not "prove" anything due its induction nature, yet the conclusions are valuable (McComas, 2004).

_____ Science is tentative in nature (AAAS, 1990).

_____ Theories form the framework for current accepted scientific knowledge (Abd-El-Khalick, et al., 2000).

B Why bother to teach and learn theories?

_____ They are reliable and use observable evidence to explain the world around us (NSTA, 2000).

_____ It is the framework for current scientific knowledge (Abd-El-Khalick, et al., 2000).

_____ While theories are tentative and subject to change they are durable and reliable and accepted (AAAS, 1990; Abd-El-Khalick, et al., 2000; McComas, 2004; NCR, 1996; NSTA, 2000; Popper, 1963).

Examples:

Helio-centric model of the earth – at one point in time it was commonly accepted that the earth was the center of the solar system. This theory changed when more evidence indicated that the earth moved and the sun was center of the solar system.

Plate-tectonics – at one point in time there was no explanation for the movement of the land masses (i.e. Pangaea). Wagener proposed an explanation for the movement of Pangaea with plate tectonics

Less Informed answers:

_____ Theories may change.

_____ Theories are educated guesses.

_____ Theories never change.

A Why?
_____ Accumulation of new facts and technologies (Abd-El-Khalick, et al., 2000).

_____ Scientific claims are deductive and are proven to exist.

_____ Theories are unsubstantiated ideas or "simple guesses" (Abd-El-Khalick, et al., 2000).

_____ Scientific knowledge is based solely on evidence.

_____ Using words such as "proof" (Abd-El-Khalick, et al., 2000).

Question 2

Science textbooks often represent the atom as a central nucleus composed of positively charged particles (protons) and neutral particles (neutrons) with negatively charged particles (electrons) orbiting the nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine the structure of the atom?

More Informed answers:
_____ Scientist work is highly creative and has subjective element with the human nature. The work is influenced by the person's experiences and expectations (McComas, 2004).

_____ Creativity and imagination are necessary to create models. Models are inferential in nature. (Abd-El-Khalick et al., 2000)

_____ All scientific knowledge is not obtained through direct observation (Abd-El-Khalick et al., 2000).

_____ Models are created through inference and theoretical entities. (Abd-El-Khalick et al., 2000)

_____ Creativity is a vital yet personal part of the production of scientific knowledge (NSTA, 2000).

_____ Models are created due to knowledge and creativity (McComas, 2004).

Evidence to determine model:

_____ Scientists used knowledge and inference and creativity (Abd-El-Khalick et al., 2000; McComas, 2004).

Example: Einstein's predictions about the impact of massive objects on the path of light were not accepted until there was some evidence in 1919.

Less Informed Answers:

_____ Science is objective without human opinion

_____ Atomic models were developed by direct observation.

_____ Models are exact replications of the structure they are representing.

Question 3

Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

More Informed Answers:

_____ Must explain that they are different but can be related. (NSTA, 2000)

_____ Laws are generalizations or universal relationships related to the way the natural world behaves under certain conditions (NSTA, 2000).

_____ Theories are inferred explanations about some aspect of the world. They explain laws and ***NEVER*** become them (NSTA, 2000).

_____ Laws and theories are individually important kinds of scientific knowledge (McComas, 2004).

_____ Non-hierarchical relationship (Abd-El-Khalick et al., 2000).

_____ Theories are non-observable and laws are observable (Abd-El-Khalick et al., 2000).

An example:

Charles Law - He noted that the volume of a gas increased with the temperature. Charles's Law states that the volume of a given amount of dry ideal gas is directly proportional to the Kelvin Temperature provided the amount of gas and the pressure remain fixed. When we plot the Volume of a gas against the Kelvin temperature it forms a straight line. The mathematical statement is that the V / T = a constant. For two sets of conditions the following is a math statement of Charles's Law:

$$V_1 / T_1 = V_2 / T_2$$

Kinetic molecular Theory - suggests that tiny particles behave like billiard balls and become more active as the temperature rises.

Evolution is mislabeled because it behaves more like a law (it is observable) than a theory (an explanation).

Less Informed Answers:

_____ Theories become laws when they are "proven" or have passed repeated testing (Abd-El-Khalick et al., 2000).

______ Not all theories become laws because they haven't stood the test of time.

______ Evolution is a theory that will become a law when there is more evidence.

Question 4

How are science and art similar? How are they different?

More Informed Answers:

Similar

_____ Must indicate that art and science have creative/imagination (Chiapetta & Koballa, 2004; NSTA, 2000).

_____ Science and art rely on imagination in carrying out their work (Chiapetta & Koballa, 2004).

______ Scientists and artists are very attached to their work (Chiapetta & Koballa, 2004).

_____ Science is creative during the entire process, like art, not just the idea or discovery stages but also during the methodology (McComas, 2004).

_____ Science and art are influenced by society and cultural beliefs (NCR, 1996).

_____ Science and art is influence socially and politically (AAAS, 1990).

_____ Science and art uses visualization in the development (Chiapetta & Koballa, 2004).

_____ Science and art are affected by society which includes social fabric, power structures, politics, socioeconomic factors, philosophy and religion (Abd-El-Khalick et al., 2000).

Differences:

_____ Science uses empirical data and reason while art relies on aesthetics (Abd-El-Khalick et al., 2000).

_____ Science uses many different techniques to solve problems and occasionally develops new techniques for solving a problem (Abd-El- Khalick et al., 2000).

Less Informed answers:

Similar

_____ Science and art are not at all similar.

Differences:

_____ Science is "proven" by evidence and solely based on observations (Abd-El-Khalick et al., 2000).

_____ Science is seeking the objective "truth" (Abd-El-Khalick et al., 2000).

_____ Art is present for us to enjoy (Abd-El-Khalick et al., 2000).

Question 5

Scientists perform experiments/investigations when trying to solve problems. Other than in the stage of planning and design, do scientists use their creativity and imagination in the process of performing these experiments/investigations? Please explain your answer and provide appropriate examples.

More Informed answers:

_____ Science uses creativity and imagination for the entire scientific process not just the idea (McComas, 2004).

_____ Science uses creativity to interpret data and for using different methods to solve problems (Abd-El-Khalick et al., 2000).

_____ Variety of methods can be used to solve problems (NSTA, 2000).

Less Informed answers:

_____ The information found creates the patterns not the individual discovering them (Abd-El-Khalick et al., 2000).

Question 6

In the recent past, astronomers differed greatly in their predictions of the ultimate fate of the universe. Some astronomers believed that the universe is expanding while others believed that the universe is in a static state without any expansion or shrinkage. How were these different conclusions possible if the astronomers were all looking at the same experiments and data?

More Informed answers:

_____ Scientists can come up with different conclusions using the same data because they are influenced by their context (experiences and expectations (NSTA, 2000).

_____ Scientists can come up with different conclusions using the same data because they are performed by humans and it is a human endeavor (AAAS, 1990).

_____ Two scientists may look at the same data and interpret it differently due to their experiences, knowledge, beliefs and expectations. It must also be reviewed and debated among their peers (McComas, 2004).

_____ Various frameworks which differ from scientists due to their educational backgrounds, training at jobs and their philosophical perspectives (Abd-El-Khalick et al., 2000)

Less Informed answers:

_____ One person is wrong and interpreted the data incorrectly.

_____ Focuses on one scientist's inadequacies or differences (.Abd-El-Khalick et al., 2000).

Appendix F
CLASSROOM OBSERVATION DATA ANALYSIS TOOL

I. Instructional Strategies

Strategy	Check	Time	Low on NOS central principles	Check	Time	High on NOS central principles
Lecture			• Teacher-led			• Student-led
			• Involves mastery of content/memorization			• Guest speaker/more informed serving as a resource/facilitator
			• Objective			• Teacher making NOS principles an explicit part of instruction
			• Rigid (one answer)			• Presenting multiple views of scientific findings, knowledge
			• Elitist			• Controversial topics included as part of instruction
						• Socio-scientific issues included (Troy Sadler)
			• Guest speaker as sole more informed/elitist			
Discussion			• Teacher-led			• Student-led
			• Asking one answer or yes/no questions			• Asking students why or how questions
						• Given wait time to reflect and answer
			• Low cognitive questions asked			• Allowing for explanations of creative answers
			• Little to no wait time			• Demanding how science topic

			• Allowing a few to dominate talk			fits into context of today's society(socially/culturally/political)
			• Not allowing diverse opinions to be heard			• Allowing each student to interpret
			• One truth (positivist) point of view			• Discussing difficult controversial topics
			• Keeping all discussions void of context (socially/culturally/political)			
						• Socratic method • Paieda strategies employed
						• High cognitive questions asked
						• feedback and appropriate reinforcement occur
						• student creativity is fostered and encouraged
						• Debating
						• Incubation of topic of discussion - leave the problem for as much time as reasonable

						•
Independent Work			• Book work (or another source) with one correct answer			• Reading a source and interpreting understanding in own words
			• Copying definitions or directly from another source			• Recreating a historical time-line of some development (ie; History timeline of the discovery to DNA to cloning)
			• Creating some work by stating facts			• Writing about a position and how it reflects on society today
			• Reading and taking notes/facts			• Reading and creating questions about reading
			• Word find or fill-in-the blank type worksheet			• Journaling
			• Providing repetitive drills			• Solving a problem posed by science
						• Creativity is encouraged
						• Tying in other core subjects – math, ss, and la
						• Explore new information and relationships.
Small Group			• Competitive environment to finish first			• Each group discovers different parts to a problem
			• List of questions to answer with one correct answer			• Small group discussions on topic that are student led

						• Allowing more students leadership roles and involvement in science
						• Sharing of information
						• Discussing and interpreting findings from an activity
						• Brain storming a topic
						• Role playing a situation – town meeting on water quality
						• Simulation
Homework			• One correct answer			• Open-ended questions with several answers
			• used to separate the smart students – so hard to complete			• Based on current social/cultural/political impact
			• memorization-based • involving mastery			• Subjective • Based on observations and inferences – nature journals • Interpreting/problem solving
			• doesn't allow controversy			
Assessment			• Low cognitive • Fact based			• Verbal – calling on variety of students • Informal during conversation/discussion
			• One word/memorization			• Narrative

	Check	Time	Low on NOS central principles	Check	Time	High on NOS central principles
			• Traditional written- fill in the blank or matching or multiple choice			• Project that is explaining or interpreting data
			• A lot of reading with technical vocabulary			• Activity or lab that demonstrates understanding
						• Socratic seminar

II. **Physical Environment**

	Check	Time	Low on NOS central principles	Check	Time	High on NOS central principles
Seating Arrangement			• Rows for non-interaction with others			• Grouped in clusters for interaction with others
			• Individual desks only for independent work			• Facing students or each other
			• Facing teacher			• Arranged so student movement is encouraged
Examples of Science			• No indication that this is a science room			• Student work present and displayed
			• Little or no student work present			• Walls depicting science of all (women, people of color, disabled people)
			• Walls with science facts only			• Access to tools of science

			• Posters depicting traditional scientists (white, male)			• Access to research tools of science (literature and/or technology)
			• Few to no pieces of science equipment present			• Indication of this being a science room
			• Few to little literature available or technology for students to research • No animals, plants, rocks,			• Animals, plants, rocks, shells or models present

III. Social Community within the Classroom

	Check	Time	Low on NOS central principles	Check	Time	High on NOS central principles
Activities			• Cook-book labs (directions followed with known outcome)			• Collaborative – peer reviewed • High cognitive demand
			• Low cognitive demand • Linear			• Questions created by the activity (not just answers)
			• Done in science lab only			• Different groups doing different investigations
			• Rigid in methodology • Teacher directed			• Multiple methods used to solve the same problem • Flexibility

			• Done individually or partner			• Done indoors, outdoors, at home etc.
Tools			• Follow specific instructions			• Creative
			• Rigid			• Flexible
			• Objectivity			• Student led decisions
			• Reinforcing scientific knowledge already known			• Allow alternative directions
Teacher Talk			• Objective			• Connect science to the world students live in
			• Authoritative • Few questions allowed or encouraged			• Connects science to society • Inclusive
			• Facts and difficult vocabulary			• Subjective
			• Disconnected from the world			• Science is tentative- changing
			• Students must be accurate and precise in vocabulary			• History of formation of new scientific knowledge
						• Creativity and imagination