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Factors That Affect the Ability of Novice Science Teachers to Teach for NOS Understanding

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To the Graduate Council:

I am submitting herewith a dissertation written by Bennett Alexander Adkinson entitled "Factors That Affect the Ability of Novice Science Teachers to Teach for NOS Understanding." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

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Factors That Affect the Ability of Novice Science Teachers to Teach for NOS Understanding

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Abstract

Novice science teachers face a multitude of instructional, curricular, and institutional constraints that affect their classroom decisions. Emphases from their teacher training programs interact with and compete against the realities of professional teaching. This qualitative comparative case study attempts to look at the interactions of novice science teachers with the reform-based practice of nature of science (NOS) instruction. Teacher training programs teach their pre-service science teachers about NOS and try to emphasize the importance of NOS understanding on student scientific literacy, but little is known about how science teachers view and approach NOS once they are free from the constraints of their teacher training programs and are instead faced with the constraints of a real science classroom, administrators, state curricula, and other factors. This study examined seven novice science teachers over one school year in order to investigate how NOS instruction occurred and what factors affected that instruction. Interviews, classroom observations, and questionnaires were utilized in order to create rich descriptions and discussions concerning NOS. Motivational Systems Theory (Ford, 1992) provided a theoretical framework to describe the goal creation, motivation, and goal achievement concerning NOS for each novice science teacher and for cross-case analysis. Findings revealed complex interactions between many factors. Context beliefs concerning mandated state curriculum standards and high-stakes testing proved to have a great effect on NOS goal setting and NOS instruction, but overall positive capability beliefs, context beliefs, and emotional connection to NOS were demonstrated as requirements for appropriate NOS goal setting and motivation. A relationship between viewing NOS as a part of mandated science curriculum standards as opposed to an external institutional goal and increased NOS classroom instruction was noticed. Skill-related factors also affected NOS instruction, though their impact went largely

unnoticed by participants. Views of NOS deduced from rubricated leading questions were shown to vary significantly from verbally articulated NOS understandings, suggesting the importance of discussion and explanation in NOS training. The vocalized understandings of NOS presented by the participants, which were often diminished, invented, and conflated, significantly affected the instruction of consensus NOS tenets. Implications and suggestions for further research are described.

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Chapter 1: Introduction

The first years of teaching for a science teacher are an extremely important transitional time. The novice teacher must change from a student of teaching to a teacher of students. Novice teachers must negotiate and manage a multitude of instructional, curricular, and institutional constraints (Britton, Raizen, Paine, & Huntley, 2000) in order to survive and succeed as a teacher.

Since 1987, the number of first-year teachers in the United States has increased by 400% and the most common experience-group of teachers has shifted from 15 years of experience down to first-year teachers (Ingersoll & Strong, 2011). As of 2008, one quarter of all teachers in the United States have five years or less of experience (Ingersoll, 2012). Specific to science, due largely to increased course requirements for high school graduation, the number of science positions has increased 86% in the last 20 years (Ingersoll & Merrill, 2010). This increase in science positions was filled and continues to be filled largely by novice science teachers.

Induction is the name commonly given to the first few years of a teacher's career, lasting from entry into the profession until the teacher achieves some degree of familiarity and ease in professional work (Fulton, Yoon, & Lee, 2005). Through various means and levels of struggle, novice teachers are inducted into the community of practice (Saka, Southerland, & Brooks, 2009). During the induction years, the practices and cognitive modes of teachers are "conceptualized, constructed, and crystalized" (Luft, 2007, p. 533), thus making induction a critically important time for teachers, their students, and educational research.

School districts and individual schools have adopted induction programs in order to help novice teachers with the transition into the profession. These programs vary significantly by

structure, content, longevity, and funding, but by and large the most common version of new teacher induction in the United States consists of a one-to-one mentoring model where an experienced teacher is paired with a novice teacher in order to help the new teacher survive the year (Fulton et al., 2005).

Quality of induction programs aside, the survival of novice teachers is a recurring theme in studies of teacher induction (Bang, Kern, Luft, & Roehrig, 2007; Ingersoll & Strong, 2011; Luft, 2009). Teacher attrition is a matter of great concern to the educational community. Researchers have found that 14% of novice teachers quit after their first year (Ingersoll, 2002) and upwards of 50% leave the profession within five years (Ingersoll, 2003a; Ingersoll & Strong, 2011: Wilson, 2000). Teacher attrition is costly, both financially for districts who must recruit and induct replacement teachers and educationally for students who encounter a revolving door of novice teachers (Fulton et al., 2005; Saka et al., 2009).

Teacher attrition is especially problematic for science education. Attrition rates among novice science teachers are higher than the national norms for novice teachers, thus placing science education in a perpetual struggle to recruit and keep qualified teachers (Ingersoll & Perda, 2010). Because science struggles with teacher retention, the majority of studies of novice science teachers focus on attrition (Bang et al., 2007; Hampden-Thompson, Herring, Kienzl, & National Center for Education, 2008; S. White, Tesfaye, & American Institute of Physics, 2011).

Beyond studies of retention and induction programs, science education research and science teacher educators should also be concerned with whether novice teachers are successfully implementing the practices, philosophies, and pedagogies of their teacher training. Reform-based practices, such as nature of science instruction, argumentation, and inquiry are stressed in teacher education programs (Southerland, Smith, Sowell, & Kittleson, 2007), but little

is known about their inclusion in the classrooms of the novice science teachers who studied them. Teacher educators would like to believe that their former students understand and value the lessons of their training, but without deep inquiry into specific cases of individual teachers, it is hard to know what practices novice science teachers value and demonstrate in their classrooms. In that vein, it is important to understand the factors that facilitate or inhibit the implementation of reform-based ideas by novice science teachers. This study focuses on one of these reform-based practices, the nature of science.

Nature of science (NOS) is a topic of significant interest in science education research (Alters, 1997; Lederman, 2007). Possession of an informed understanding of NOS is viewed as an integral part of scientific literacy, the seminal goal of science learning (Abd-El-Khalick, Bell, & Lederman, 1998; Meichtry, 1992). NOS refers to “the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge” (Abd-El-Khalick et al., 1998, p. 418). NOS serves to differentiate science from other ways of knowing and is stressed in current reform documents (American Association for the Advancement of Science, 1989, 1993; National Research Council, 1996, 2007), science methods courses (Southerland et al., 2007), and science education literature (Lederman, 1992, 2007; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003).

Studies concerning student understanding of NOS consistently reveal that students across all levels do not possess an understanding of NOS that aligns with that of scientists and science educators (Abd-El-Khalick & Lederman, 2000b; Duschl, 1990; Lederman, 1992, 2007). Science education literature holds science teachers accountable for the lack of student understanding of NOS in light of findings that most teachers do not possess an informed view of NOS and that NOS instruction does not receive adequate classroom attention (Bell, Lederman, & Abd-El-

Khalick, 2000; Bell, Matkins, & Gansneder, 2011). Despite evidence that possessing an informed understanding of NOS is not enough to ensure proper NOS instruction (Lederman, 1999), most NOS studies have concentrated on improving teacher NOS understanding (Abd-El-Khalick & Akerson, 2004; Buaraphan, 2011; Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001; Palmquist & Finley, 1997; Scharmann, Smith, James, & Jensen, 2005). NOS research has mainly concentrated on pre-service teachers (Akerson, Morrison, & McDuffie, 2006; Hanuscin, Akerson, & Phillipson-Mower, 2006; Lederman, 2007; Liu & Lederman, 2007), with some interest in in-service teachers who participate in professional development programs (Donnelly & Argyle, 2011; Hanuscin, Lee, & Akerson, 2011; Kokkotas, Piliouras, Malamitsa, & Stamoulis, 2009; K. White, 2010) or return to the university to earn master's degrees (Akerson, Cullen, & Hanson, 2009).

However, studies concerning the NOS related practices of novice science teachers are rare. In fact, little research has been done specifically on novice science teachers, beyond studies of persistence and induction programs. Novice teachers who were trained in reform-based practices that include NOS should be considered as a valuable resource for research (Luft, 2007). Novice science teachers can provide validation of the practices of teacher training programs as well as give insight into issues involving inclusion of reform-based practices into classroom settings. For these reasons, this study will focus on NOS instruction as a part of the novice science teacher's induction years.

The transitional years of novice teachers are influenced by a multitude of sources and concerns. Classroom decisions are affected by state and district curricula, student behavior, administrative expectations, training, standardized testing, past experiences, and many other issues (Southerland et al., 2007). Help can come from mentors, coworkers, administrators, and

others, but in the end, novice science teachers are left to make many classroom decisions on their own (Ingersoll & Strong, 2011). The role that NOS is granted in the classrooms of novice science teachers is dictated by a complex combination of factors, goals, beliefs, and emotions. The goal of this study is to investigate the practices of novice science teachers related to NOS and the factors that affect novice teachers' implementation of NOS instruction. Viewing instruction aimed at increasing student understanding of NOS as an achievable goal, this study will utilize Motivational Systems Theory (Ford, 1992) to discuss novice science teacher motivation, beliefs, and practices.

Background

As science understanding came to be viewed as a cultural imperative, the expectations of students and teachers in science classrooms dramatically changed during the 1980s and 1990s. Reform documents of that time specifically advocated to transform science education from an emphasis on creating scientists to making science, scientific thought, and scientific reasoning accessible to all students (Duschl, 2008). Scientific literacy was presented as an educational objective to better prepare citizens to make informed decisions concerning personal and societal issues in the increasingly technological world. *Science for All Americans* (American Association for the Advancement of Science, 1989) pleaded the case for a switch in science educational practices toward an understanding of the nature of science and scientific literacy. Slowly and thoughtfully, the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) and the *National Science Education Standards* (National Research Council, 1996) were produced to better define the changes that would be needed to improve scientific literacy for American schoolchildren.

The *National Science Education Standards* open with a "Call to Action" (National Research Council, 1996, p. ix), describing dramatic changes that need to be made in order to improve science education. The *National Science Education Standards* emphasize a new way of teaching and learning that requires changes in what students learn, how performance is assessed, and how teachers are educated (National Research Council, 1996). Moving beyond didactic teaching and fact recall, the *Standards* call for teachers to instead focus on helping their students acquire scientific knowledge, scientific understanding, and scientific abilities. The changes suggested in the *National Science Education Standards* are not law and do not require a specific curriculum, but they do serve to inform and influence state and local policies, science educator training programs, and science education research. Sixteen years after their publication, the *National Science Education Standards* (National Research Council, 1996) still inform much of science education and will continue to do so even after the Next Generation Science Standards are published in the fall of 2012.

Chief among the reform efforts presented by *Science for All Americans* (American Association for the Advancement of Science, 1989), the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993), and the *National Science Education Standards* (National Research Council, 1996) is a call for science classrooms to actively teach the nature of science (Donnelly & Argyle, 2011). These documents establish that all students should acquire an understanding of science as a way of knowing and all the constructs that build it up as well as be able to separate science from other ways of knowing in order to become scientifically literate. The *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) dedicate an entire chapter to NOS, citing that students often hold distorted views of science and that these are not corrected through traditional

presentations of science facts and instead require explicit NOS instruction. The *National Science Education Standards* (National Research Council, 1996) consider the "History and Nature of Science" to be one of eight content standards, alongside physical science, life science and other normal expectations of content.

The emphasis given to the nature of science in reform documents succeeded in solidifying NOS as a concept in science curricula and science methods courses, but it did not necessarily guarantee that NOS was taught in the average science classroom. Science education research adopted NOS as a focal point that still exists today (Lederman, 2007; Niaz, 2008) in order to assess NOS understanding, instruction, and best practices. Studies examining student performance and understanding of the nature and development of scientific knowledge are limited (National Research Council, 2007), with the focus having instead stalled at issues with teacher implementation of nature of science instruction. Successful strategies for teaching the nature of science have been identified (Clough, 2006; Khishfe & Abd-El-Khalick, 2002; Lederman & Abd-El-Khalick, 1998), but they have only been implemented on small scales. Getting the average teacher to successfully teach NOS in the classroom has proven to be a challenging task for science teacher educators and science education researchers.

Statement of Problem

Dating back to the 1950s, the earliest studies of NOS (Mead & Metraux, 1957; Wilson, 1954) demonstrate that student understanding of NOS was severely lacking. These studies repeatedly show that students believed that "scientific knowledge is absolute and that scientists' primary objective is to uncover natural laws and truths" (Lederman, 2007, p. 836), a view that is far from consistent with the accepted views of NOS (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Smith, Lederman, Bell, McComas, & Clough, 1997). Throughout the decades

and into current research, studies have consistently shown that students' views of NOS have not changed much (Abd-El-Khalick & Lederman, 2000b; Bell, Blair, Crawford, & Lederman, 2003; Duschl, 1990; Lederman, 1992; Ryan & Aikenhead, 1992). Despite the current reform efforts, most students still hold views of NOS that are generally considered naïve and counter to the accepted view (Halloun & Hestenes, 1998; Kang, Scharmann, & Noh, 2005; Lederman, 2007).

The failure of students to possess adequate understanding of NOS has been documented across assorted definitions of NOS and across various assessments of NOS (Kang et al., 2005; Lederman, 2007; Mackay, 1971). Therefore, in the current decade science education research has placed less emphasis on mass testing of student NOS understanding and a greater move toward the identification and testing of factors that may affect change in NOS understanding (Lederman, 2007). In this light, research concerning science teachers and their ability to successfully teach NOS has gained interest in science education research. This is not to say that teachers are necessarily the reason that student views of NOS are inadequate, but teachers are viewed as intermediates to addressing the problem.

Studies have shown that students do not develop adequate understanding of NOS by merely doing science (Aydeniz, Baksa, & Skinner, 2011; Bell et al., 2003) or by participating in inquiry-based classroom science experiences (Khishfe & Abd-El-Khalick, 2002). Instead, developing informed views of NOS in students requires an explicit and reflective pedagogy (Khishfe & Abd-El-Khalick, 2002; Lederman, 2007). Explicit and reflective NOS instruction requires explicit discussion of NOS concepts followed by questioning that encourages and allows for student reflection.

Despite pedagogical understanding of what is required for students to gain appropriate NOS understandings, gains are not being made and science teachers are not consistently teaching

NOS (Akerson, Buck, Donnelly, Nargund-Joshi, & Weiland, 2011). Research addressing the teaching of NOS has looked at teacher understanding of NOS (Abd-El-Khalick & Lederman, 2000a; Akerson et al., 2006; Blanco & Niaz, 1997; Donnelly & Argyle, 2011), teacher beliefs in the importance of NOS instruction (Lederman, 1999; Lederman & Latz, 1995), and teacher skill and ability to translate NOS understanding into classroom practice (Abd-El-Khalick et al., 1998). These studies reveal that teacher motivation to teach NOS is complex and requires further study. More research is needed into the factors that influence teacher integration of NOS topics into their curricula and classroom practices, in order to successfully improve student understanding of NOS (Lederman, 1999).

Purpose of the Study

This study considers the extant body of NOS knowledge concerning student understanding, classroom practices, and teacher beliefs. It acknowledges that a variety of factors can influence the successful implementation of NOS content into the science courses of novice science teachers and seeks to study these in detail. The purpose of this study is therefore to investigate the NOS practices of novice teachers and to explore the factors that facilitate or impede the implementation of NOS instructional practices.

To further this purpose, this study seeks to analyze the motivations, goals, beliefs, and other constructs proposed by Motivational Systems Theory (Ford, 1992) that affect successful NOS-based instructional practices for novice science teachers. Considering the role of the individual teacher in the call for explicit and reflective teaching of NOS (Khishfe & Abd-El-Khalick, 2002), this study seeks to get to know the novice science teacher from a variety of angles. Interviews, classroom observations, questionnaires, and document analysis will be used to create case studies of novice science teachers concerning their NOS practices. Each case will

be discussed individually for its individual narrative value and all cases will be discussed comparatively for consensus and validity.

Additionally, the purpose of this study is to contribute to the discussion of strategies and factors that help novice teachers successfully integrate NOS content into the science content of their science course curricula. The importance of student achievement of adequate NOS understanding should not be downplayed, but this study focuses on science teachers, who serve as gatekeepers and intermediaries to that goal. This study seeks to raise awareness of issues that influence and affect the ability of novice science teachers to implement successful NOS teaching strategies in their classrooms.

Research Questions

The following questions will be used to address the purpose and guide the implementation and discussion of this study:

1. What are the factors that facilitate or impede novice science teachers' ability to promote student NOS understanding?
    a. What are the personal factors?
    b. What are the contextual factors?
2. How do personal and institutional goals concerning NOS affect classroom practice related to NOS?
3. Considering all factors, do novice science teachers teach for NOS understanding? If so, how?

Significance of the Study

This study seeks to contribute to the body of knowledge concerning the challenges that teachers face when teaching NOS content in the science classroom. It seeks to do so via several unique ways. First, this study's population is novice science teachers, a significantly understudied population. Second, it utilizes a novel theoretical framework that appears to have never been used with NOS studies to date. And last, it takes into account a changing definition of NOS that more accurately reflects the creation of scientific knowledge than previous studies.

In-depth explorations of NOS related instructional intentions, actions, and factors that affect these have not been the focus on much research in science education (Schwartz & Lederman, 2002). Of the few studies that do address implementation issues of NOS content, most have centered on two groups: pre-service teachers (Abd-El-Khalick et al., 1998; Lederman et al., 2001) and in-service teachers who are returning to graduate school to earn a master's degree or who are participating in an elective NOS professional development activity (Akerson et al., 2009; Donnelly & Argyle, 2011; Posnanski, 2010). While the findings of these studies have significance, they do have their limitations. In most cases, the participants had very recently studied NOS and were aware that the investigators were interested in NOS (Abd-El-Khalick et al., 1998). Additionally, the pre-service teachers were assessed during a short student teaching experience and were therefore battling the desire of their professor for NOS inclusion against the constraints of a mentor teacher and inexperience. While in-service teachers have experience, the reverse could easily be true. Experienced teachers have years of ingrained understandings, beliefs, and behaviors that could impact the implementation of NOS in the classroom.

Considering the diversity of these two previously studied groups, this study seeks to look at a different group of teachers. Novice teachers who were trained to be teachers under the

guidance of a master's degree program and a prolonged internship experience provide a unique population to study. This population entered its educational training with no prior teaching experience. Their teacher training was grounded in reform-based practices and current science education research. They were taught and reflected upon NOS in their science methods courses, but they have now entered the workforce and are free to experience the freedoms and constraints of the public school system.

The aim of this study is to add depth to the discussion of factors that affect teacher abilities to teach for NOS understanding. Previous research into factors that affect teacher abilities to teach for NOS understanding, not only targeted a different population, but also lacked rigor and justification. In studies by Abd-El-Khalick, Bell, and Lederman (1998) and Lederman, Schwartz, Abd-El-Khalick, and Bell (2001) significant effort was placed into detailing if pre-service teachers taught for NOS understanding, but investigation into factors that affect this implementation was limited to a single interview at the end of each study. The findings were therefore not additionally observed or triangulated through any other means. Despite their shortcomings, the authors of these studies report a multitude of factors that possibly affect implementation of NOS-based instruction, many of which hinged on beliefs and emotions connected to motivation. Accounting for these psychological factors, this study includes Motivational Systems Theory (Ford, 1992) as a theoretical framework to guide this inquiry into the complexities of teacher motivation and ability to implement NOS teaching. Motivational Systems Theory considers a multitude of internal and external factors in discussing human motivation and goal achievement, all of which will be useful in discussing whether the goal of explicit and reflective NOS instruction is achieved. Motivational Systems Theory is a new

framework for discussions of NOS teaching that will add depth and rigor to the exploration of factors that affect teaching for NOS understanding.

Additionally, this study seeks to take into account an evolving definition of NOS that has never been used in previous studies. Previous studies of factors that affect teaching for NOS understanding are over 10 years old and predate the current popular questionnaire for assessing NOS understandings (VNOS) (Lederman et al., 2002) and changes to the definition of NOS that have been suggested since the questionnaire's creation. There is no consensus definition of NOS in science educational literature, but rising NOS descriptions place significant importance on argumentation as a part of NOS as well as a means for students to gain NOS understandings. This study aims to investigate NOS under the newest conceptions of NOS, in order to further match research on the teaching of NOS to current conceptions of NOS.

Therefore, this study is significant because it utilizes an unused, but detailed and relevant, theoretical framework to address current conceptions of a relevant issue as it affects an understudied population. Since many science teachers are novice teachers and NOS understanding is viewed as greatly important to students becoming scientifically literate, the ability of novice science teachers to successfully include NOS in their instructional practices is a relevant and significant avenue for this project to follow.

Delimitations

The primary focus of this study is novice science teachers and the factors that affect their implementation of NOS instruction. This study does not examine whether the classroom applications of NOS affect student understanding of NOS. This is intentional, in order to narrow the scope of the study. At the present, I am interested in whether NOS instruction is making it into the classrooms and factors that affect this, because past research has shown that without

explicit NOS instruction changes in student NOS understanding rarely occur (Bell et al., 2003). If successful NOS instruction is reported and observed, then this may open avenues for future research.

The data collected for this study will focus on the words, lesson plans, and classroom practices of the participant teachers. It will not include the ideas and behaviors of other stakeholders and players. As factors that impede and facilitate NOS instruction are determined and analyzed, additional research into specific factors may extend the scope of the study. There is potential that teacher beliefs about their abilities or about the responsiveness of their teaching environment may affect their ability to teach for NOS understanding, but examination of the "realities" of those beliefs may be difficult or impossible. Considering the role of beliefs in constructed realities, this delimitation is of little concern, because if teaching for NOS understanding is limited by a teacher's belief about his/her environment, then the teaching will be limited, whether the environment is actually limiting or not.

Limitations

This comparative case study will focus on novice secondary science teachers who have undergraduate degrees in science fields and master's degrees in science education. This is an intentional pool of participants in order to limit the case and to increase the significance of the study.

The population of this study received their master's degrees from the same southeastern university and continues to teach in surrounding school districts. This, paired with the small sample size, limits the generalizability of this study. Where the generalizability may be limited, I hope that the picture portrayed by the data and analyses will be deep and vivid enough to contribute to the discussion of teachers and their teaching of NOS.

Assumptions

The main assumptions of this study revolve around NOS. For starters, we assume that NOS understanding is measurable. The VNOS-C (Lederman et al., 2002) will be used, because it has been validated for pre-service and in-service teachers. We do, however, assume that the internal validity of the test will not be compromised by the potential that the participants may know the desired answers to the test. We also assume that instruction in NOS must be explicit, an assumption that is validated via literature review (Bell et al., 2003; Bell, Lederman, & Abd-El-Khalick, 1998; Khishfe & Abd-El-Khalick, 2002)

As this is a comparative case study, no assumptions about the comparability of the participants are needed. Each case receives its own description and analysis. Both commonalities and differences between participants do exist and will be explored.

Positionality

It should be immediately apparent that I greatly value nature of science instruction as a means to achieve scientific literacy for students. The lack of student understanding of what science is and the pervasive, positivist teaching of science as a collection of facts is greatly troubling in a world where students need to make informed, thoughtful decisions for their own betterment and the betterment of society. I value NOS as a tool to help students become better reasoners and critical thinkers. I am at a point now in my understanding of quality science education, where I could never teach science content that does not include explicit connections to NOS.

This is not to say that I cannot sympathize with and relate to teachers who hold naïve conceptions of NOS or do not adequately teach NOS in their classrooms. Just a couple years ago, I was that teacher. I thought I was a relatively good science teacher. My students succeeded on

standardized tests and my open-ended challenge tests. I focused on conceptual understanding over fact reiteration and pushed my students into inquiry-based laboratory experiences where they had to design and problem-solve on their own. While I was the self-proclaimed king of inquiry, I never once questioned what science really is. I certainly never made my students question the nature of science. Our inquiry generally pushed towards confirmation of pre-existing norms and never required argumentation or explanation other than possible error. This is the reality of my teaching past which does affect how I now view science, science teaching, and science teachers.

As an observer of possibly struggling novice teachers, I intend to provide little feedback in regards to NOS. I recognize that this may be hard, as with some of them I may be viewed as an authority figure or as a helpful resource. I desire to be careful with my questioning and comments, so as to not taint their ideas with my own. I do not desire to hear them repeat back my dogma. Instead I am interested in the teachers' understandings of and honest opinions about NOS and any perceived issues that relate to the implementation of NOS instruction in their real-world classrooms.

Chapter 2: Literature Review

Introduction to Nature of Science

In 1960, the National Society for the Study of Science detailed the aims on which science education in the United States should focus:

> *There are two major aims of science teaching; one is knowledge, the other is enterprise. From science courses, pupils should acquire a useful command of science concepts and principles. Science is more than a collection of isolated in assorted facts . . . A student should learn something about the character of scientific knowledge, how it has been developed, and how it is used. (Hurd, 1960, p. 34)*

This statement and the rest of the report from which it came serve to explicitly place the construct that we now refer to as the nature of science as a major theme of science education. The report acknowledges that science education of the day tended to focus on science as a body of knowledge at the loss of education into how and why science operates (Hurd, 1960). Similar arguments were made by many science educators of the time. For example, Schwab (1962, p. 24) noted that science is taught as an “unmitigated rhetoric of conclusions in which the current and temporal constructions of scientific knowledge are conveyed as empirical, literal, and irrevocable truths.” Such a notion of science was not perceived as being in line with the science in practice by scientists, so the science education community felt it appropriate to intervene and address this limitation in the nation’s science classrooms by developing curricula, research agendas, and professional development that emphasize the effective teaching of NOS.

Over the next 20 years, significant efforts sought to establish NOS instruction as a major goal of science education. NOS featured prominently in science education research (Aikenhead, 1973; Jungwirth, 1972; Lucas, 1975; Mathis, 1976), curricula (Rutherford, Hoton, & Walton, 1970), and books (Martin, 1972; Robinson, 1968). By 1968, Kimball wrote that the objective to

help students develop adequate understandings of NOS is “one of the most commonly stated objectives for science education” (p. 110).

This was not, however, a new goal for science education. Interest in helping students develop adequate understanding of NOS can be traced back to the beginning of the 20th century (Central Association of Science and Mathematics Teachers, 1907). Interest in and emphasis on NOS instruction is continuous and growing. The most recent reform movement (American Association for the Advancement of Science, 1989, 1993; Millar & Osborne, 1998; National Research Council, 1996) mirrors and magnifies the NOS push of the 1960s and ‘70s, which only mirrored those previous to it.

In spite of the significant and constant interest from reform documents and science educators concerning NOS, debate over the very nature of science has been raging for over a century. Attempted definitions of NOS have come and gone without general consensus. Although a great diversity of ideas concerning NOS still exists, science educators have come close to consensus with regards to NOS elements that are relevant to K-12 education (Smith, Lederman, Bell, McComas, & Clough, 1997). Similarly, science educators have spent considerable effort studying the teaching and learning of NOS. As a result of these efforts there is a significant body of knowledge with regards to defining NOS and appropriate instruction of NOS.

The next sections provide a review of literature on these key themes: discussions of NOS definition, research on the teaching and learning of NOS, and issues with NOS implementation.

Defining NOS

Science educators have engaged in discussions concerning different aspects of NOS for over a century, but a consensus definition of NOS is still elusive to philosophers of science,

sociologists of science, and science educators. A unified definition of NOS would, however, greatly serve the science education community that has placed so much emphasis on developing student understanding of NOS. General explanations of NOS have categorized it as “the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge” (Abd-El-Khalick et al., 1998, p. 418). This general description succeeds at separating NOS from basic science content knowledge, but it does little to define what NOS is or to separate it from other ways of knowing.

Although debate about NOS has been around for decades, philosophers of science, historians of science, and science educators have not been able to agree on a specific definition for NOS (Abd-El-Khalick et al., 1998; Osborne et al., 2003). Despite the prolific use of science in modern society, there exists a lack of agreement concerning what science is and how it works (McComas, Almazroa, & Clough, 1998; Welch, 1984). Over the last century, even the broadest conceptions of NOS have changed to accommodate for philosophical debates concerning scientific observations, scientific theories, and how tradition and individuals influence these. Duschl and Wright (1989) describe a succession of NOS theses that have risen in popularity: Classical Empiricism, Logical Positivism, World View, Scientific Realism, and Neo Empiricism. Neo Empiricism speaks to the importance of empirical evidence while making concessions for society and the individual. Most current conceptions of NOS fall within Duschl and Wright’s Neo Empiricism thesis, but this does not solve the definition debate. Neo Empiricism merely sets the stage for the content of the debate.

Within the contemporary argument of defining NOS, much of the debate is ontological and deeply philosophical. The debate over whether there is an objective reality or phenomenal realities and mental constructions is an example of the philosophical issues that frequent NOS

discussions among scholars (Lederman, 2007; Turgut, 2011). Lederman (2007), however, argues that the contentious parts of the NOS definition debate are not relevant to K-12 understanding and that researchers should be able to come to some consensus about the more simple concepts of NOS that are relevant. McComas, Almoazroa, and Clough (1998) similarly state that the philosophical issues and content of NOS may always be contentious, but that the NOS views that are relevant to increasing scientific literacy are far less controversial. Consensus has not fully been achieved, but this has not stopped the creators of reform documents and NOS researchers from developing their own working definitions (Osborne et al., 2003). Much can be garnered from comparisons between NOS conceptions.

In a position paper concerning disagreements in NOS definitions, Smith et al. (1997) state that some level of agreement must exist, because the U.S. National Academy of Science was able to consolidate the input of thousands of scientist, teachers, science educators, philosophers of science, and sociologists of science into a cohesive NOS plan in the National Science Education Standards (National Research Council, 1996). McComas and Olson (1998) extend this argument by comparing eight curriculum standards documents from six countries and noting striking similarities that seem to imply a certain level of consensus not only in the United States, but also internationally.

The overlap that McComas and Olson (1998) noted in eight international science education standards documents represents a form of consensus that portrays science and scientific knowledge as tentative, evidence-based, and socially influenced. Specifically, McComas and Olson (1998) found overlap concerning:

- Scientific knowledge while durable, has a tentative character
- Scientific knowledge relies heavily, but not entirely on observation, experimental evidence, rational arguments, and skepticism

- There is no one way to do science (therefore, there is no universal step-by-step scientific method)
- Science is an attempt to explain natural phenomena
- Laws and theories serve different roles in science, therefore students should note that theories do not become laws even with additional evidence
- People from all cultures contribute to science
- New knowledge must be reported clearly and openly
- Scientists require accurate record-keeping, peer review and replicability
- Observations are theory-laden
- Scientists are creative
- The history of science reveals both in evolutionary and revolutionary character
- Science is part of social and cultural traditions
- Science and technology impact each other
- Scientific ideas are affected by their social and historical milieu (McComas et al., 1998, p. 513)

The above list represents the achievement of some level of agreement in defining what should be taught to school-age children about the nature of science. Though this list is extensive, there is the risk that instead of consensus it represents a compromise that has been met to produce timely reports (Osborne et al., 2003).

Five years later, Osborne, Collins, Ratcliffe, Millar, and Duschl (2003) utilized a three stage Delphi questionnaire to solicit consensus from 23 philosophers of science, historians of science, sociologists of science, scientists, science education researchers, and expert science teachers concerning "ideas about science" that are important to contemporary school science curricula. Their responses were coalesced and reassessed by the panel for further agreement. The outcome of the study was a set of nine themes about the nature of science:

- scientific methods and critical testing
- science and certainty
- diversity of scientific thinking
- hypothesis and prediction
- historical development of scientific knowledge
- creativity

- science and questioning
- analysis and interpretation of data
- cooperation and collaboration in the development of scientific knowledge (Osborne et al., 2003, pp. 706-709)

The above list of "ideas about science" may not be easily accessible to classroom teachers without prolonged explanations, but its creators felt that the validity of its consensus creation was worthwhile and further sought to compare it to McComas and Olson's (1998) list of consensus topics from standards documents. Osborne et al. (2003) felt that eight of their nine themes corresponded to eight of McComas and Olson's (1998) largest themes (Table 1). (According to Osborne et al. (2003), diversity of scientific thinking was the only theme that did not have an apparent partner, even though McComas and Olson (1998) specifically offer that "There is no one way to do science," a view that closely parallels their discussion of diversity of scientific thinking.) Since these two conceptions of NOS (McComas & Olson, 1998; Osborne et al., 2003) were derived via different means, their parallels do lend credibility to the conception of a consensus definition for NOS. As the themes align and research continues, the possibility of agreement does seem possible.

Table 1

Comparison of NOS themes revealed in Lederman, et al. (2002), McComas & Olson (1998), and Osborne, et al (2003)

Lederman, et al.	McComas & Olson	Osborne, et al.[a]
Tentative	While durable, has a tentative character	Science and certainty
*Empirical *The distinction between observation and inference	Relies on observation, experimental evidence, rational arguments, and skepticism	Analysis and Interpretation of Data
Theory-laden	Observations are theory-laden	
Partly the product of human inference, imagination and creativity	Scientists are creative	*Creativity *Science and questioning
Socially and culturally embedded	*People from all cultures contribute to science *Science is part of social and cultural traditions[b] *Scientific ideas are affected by their social and historical milieu *The history of science reveals both in evolutionary and revolutionary character	Historical development of scientific knowledge
The lack of a universal recipe-like method for doing science	There is no one way to do science (therefore, there is no universal step-by-step scientific method)	Diversity of scientific thinking
The functions of and relationships between scientific theories and laws	Laws and theories serve different roles in science, therefore students should note that theories do not become laws even with additional evidence	
	*New knowledge must be reported clearly and openly *Scientists require accurate record-keeping, **peer review** and replicability *Science is a part of social traditions[b]	Cooperation and collaboration in the development of scientific knowledge
	Scientists require accurate **record-keeping**, peer review and **replicability**	Scientific Methods and Critical Testing
	Science is an attempt to explain natural phenomena	Hypothesis and Prediction
	The history of science reveals both in evolutionary and revolutionary character	
	Science and technology impact each other	Science and technology[c]

[a]Comparisons of Osborne, et al. to McComas & Olson were done largely by Osborne, et al.
[b]This theme is intentionally listed twice, because it can pair with both other definitions, but not for the same reason. The first is passive, the second is active.
[c]This theme was not one of the 9 original consensus themes, but did emerge with high ratings

A De Facto Definition of NOS

Many definitions of NOS were created to provide a framework for a test that was designed to assess understanding of NOS (Chen, 2006a; Rubba & Andersen, 1978). Popular tests not only contributed to research on and improvement of NOS understandings, but also contribute to the discussion of an NOS definition. As these tests are used and reused in research projects, the NOS definitions at their foundation gain face validity and acceptance.

The View of Nature of Science questionnaire (VNOS) is one such test that gained popularity as it met the assumed need to NOS assessments that were open-ended, descriptive, and valid for multiple populations (Lederman, 2007; Lederman et al., 2002). With the success of VNOS in published literature, it could be argued that the definition of NOS presented by Lederman et al. (2002) is the de facto definition of NOS in science education research. According to Chen (2006a, p. 805), the VNOS is the "most popular pencil and paper tool" used to assess NOS understanding. Every researcher who uses the VNOS acknowledges the tenets of NOS that are presented in the VNOS as important and relevant to the field. Southerland et al. (2006) even go as far as referring to the NOS aspects presented in the VNOS as consensus topics within science education literature, connecting them to reform documents (American Association for the Advancement of Science, 1993; National Research Council, 1996) and other authors (McComas et al., 1998).

Lederman et al. (2002) claim no direct theory or framework for the creation of their NOS aspects, but examination of Lederman's previous NOS research reveals a tentative and evolving definition of NOS that is influenced by the Nature of Scientific Knowledge Scale (NSKS) (Lederman & O'Malley, 1990), then by Duschl (1990) and Matthews (1994) (Lederman, Wade, & Bell, 1998). Though not citing them as theoretical influences, Lederman et al. (2002) do note

that the NOS aspects featured in the VNOS are emphasized in both American and British reform documents (American Association for the Advancement of Science, 1989, 1993; Millar & Osborne, 1998; National Research Council, 1996).

Lederman et al. (2002, p. 499) present their definition of NOS as a simple list if "important aspects of NOS" that are "accessible to K-12 students and relevant to their everyday lives." NOS is described through an understanding that scientific knowledge is:

- tentative
- empirical
- theory-laden
- partly the product of human inference, imagination and creativity
- socially and culturally embedded

Additionally, the VNOS values:

- the distinction between observation and inference
- the lack of a universal recipe-like method for doing science
- the functions of and relationships between scientific theories and laws

The definition of NOS presented by the VNOS appears simple (to understand and to teach) but serves to deeply encapsulate the tenets of science and purposely separate scientific knowledge from other ways of thinking and knowing.

First, scientific knowledge is described as empirical. The empirical nature of science acknowledges that the development and defense of scientific knowledge is based on observations. This gives scientific knowledge its reliability and durability. An understanding of the distinction between observation and inference and the distinction between scientific theories and scientific laws are subsequently presented as important to NOS, as they equally create and explain scientific knowledge (Lederman, et al., 2002).

The generation of scientific knowledge is also described as creative and imaginative, as opposed to completely rational and objective. The "theoretical and disciplinary commitments,

beliefs, prior knowledge, training, experiences, and expectations" (Lederman et al., 2002, p. 501) of scientists are acknowledged for their influence on what is observed, how it is observed, and how it is interpreted. Additionally, Lederman et al. (2002) discuss the impact and embeddedness of social and cultural issues on scientific knowledge. Some of these influences include power structures, politics, and religion. Instead of commenting on the appropriateness of cultural and social effects on scientific knowledge, Lederman et al. (2002) merely acknowledge their influence and therefore their connection to NOS.

Another important component to Lederman et al.'s (2002) definition of NOS is the tentative nature of science. Scientific knowledge is described as never being absolute or certain; all scientific knowledge, including theories and laws, is subject to change. This is not solely due to the inferential, creative, and socially influenced nature of science, but largely due to the nature of theories and laws themselves. As laws and theories should account for all instances, there is always the possibility that a future instance may not be able to be accounted for. Just this possibility alone, according to Lederman, et al. (2002) removes the logical discussion of absolute certainty and proof from scientific knowledge.

Lastly, the Lederman et al. (2002) definition of NOS describes that there in no one specific way to do science. Scientists "observe, compare, measure, test, speculate, hypothesize, create ideas and conceptual tools, and construct theories and explanations" (Lederman et al., 2002, p. 501), but they do not do these in any particular order or process. The myth that there is one scientific method is perpetuated in school science (McComas, 1996), but fails to account for untestable science fields, like observational astronomy and much of evolutionary biology.

For the VNOS assessment of learner conceptions of NOS, Lederman et al. (2002) created a definition of NOS that represents what its creators consider an informed understanding of

NOS. Through the popularity and repeated use of the VNOS test in current science education literature, the definition of NOS presented in the VNOS has risen to a certain level of acceptance among the science education community. Despite its popularity, the definition of NOS presented by the VNOS is not a true consensus definition (see Table 1). However, the definition of NOS advanced by Lederman, et al. (2002) does help to explain NOS and serves as a foundation for further discussion of NOS and factors that contribute to and partially compose NOS. In the years since the creation of VNOS, there has been some discussion of further needed refinement of our understanding of NOS and of what we teach to our students. This suggestion is explored in the next few sections.

Reframing NOS

Within science education, there has been some effort to restructure and redefine NOS in order to more closely parallel actual scientific processes and more closely link NOS to scientific literacy. There is a push for NOS understandings to be more functional and not just declarative (Ford, 2008; Rudolph, 2000) . Allchin (2011) questions the power of popular consensus-based lists of NOS tenets, like that proposed by Lederman et al. (2002), to influence students' abilities to deduce the reliability of scientific claims. Helping students achieve an understanding of Lederman's NOS tenets, according to Allchin (2011), fails to extend learning into applicable knowledge that could be used to analyze and evaluate. Merely learning the current NOS tenets may fail to help students think like scientists and therefore may fail to be helpful to scientific literacy and socio-cultural issues.

Lederman et al.'s list of NOS tenets is missing some important elements in the development of scientific knowledge that may help students functionally connect with science. The list fails to expound upon the development of scientific knowledge beyond initial creation.

Though admitting social influence on claims creation (theory-laden, creative, social and cultural embeddedness), the tenets do not extend to the acceptance phase of new knowledge. Peer review, criticism, bias, collaboration, skepticism, authority, and credibility are all largely ignored (Allchin, 2004b, 2011). These extensions of NOS all relate to the process of new scientific claims being defended and potentially accepted into scientific norms. Scientific knowledge is subjected to a battery of tests before it is truly considered scientific. Science does not just stop after the first observation and the subsequent first inferences and explanations. The process is collaborative, expansive, and tentative (Allchin, 2004a).

Osborne et al. (2003) include “cooperation and collaboration in the development of scientific knowledge” as one of their important “ideas about science,” with the intent to counter the misconception that science activity is “the retreat of the lone genius” (p.709). Instead, evaluation of new knowledge claims via peer review is portrayed as being integral to the establishment of reliability and validity claims and therefore to science itself. McComas and Olson (1998) likewise mention peer reviews as required of science and comment on the necessity of rational arguments and skepticism. These concepts are, however, missing from Lederman et al.’s (2002) list of NOS tenets, therefore potentially failing to accurately portray science as socially constructed.

The above discussion of missing social components is not intended to downplay the NOS tenets suggested by Lederman et al. (2002) in the least. Though the consensus tenets may not be immediately relevant to a discussion of the reliability of a scientific claim, they are nonetheless important for students to understand. Students do need to know the difference between laws and theories. Students should discuss durability in light of tentativeness. An understanding of the theoretical, cultural, and creative underpinnings of scientific claims reduces the authoritative,

positivist perception of science that could harm a student's ability to judge new claims or feel capable of individually contributing to scientific knowledge. Lederman et al.'s (2002) NOS tenets do serve a purpose toward helping students understand science. They just don't paint the full social picture.

It has been suggested that in order to bridge the gap between the consensus tenets of NOS and the reality of scientific literacy, argumentation could be considered an additional aspect of NOS. Argumentation encompasses the social construction of scientific knowledge and is viewed as integral to science and science education (Tippett, 2009). Scientists actively engage in discursive practices such as assessing alternatives, weighing evidence, interpreting texts, and evaluating the potential viability of scientific claims (Latour & Woolgar, 1986), all of which constitute argumentation. Through argument, scientific claims are warranted and rebutted and hence "quality control" is maintained (Driver, Newton, & Osborne, 2000; Erduran, Simon, & Osborne, 2004). Argumentation is a part of the nature of science that augments the pre-existing tenets of NOS and should not be ignored in educational settings (Driver et al., 2000).

Argumentation as NOS

Argumentation is central to any discussion of the philosophy of science (Newton, Driver, & Osborne, 1999). Modern conceptions of NOS have disregarded the notion that science portrays truth about nature via observations and objective deductions of those observations, in favor of notions of science that are much more subjective and socially influenced. As theory and culture affect observations and inferences (Kuhn, 1970; Lederman, 2007), the development of scientific knowledge is grounded through processes of argumentation (Newton et al., 1999). The construction of scientific theories concerning nature is rarely conducted through general agreement; instead, arguments are "central to the everyday discourse of scientists" (Erduran et

al., 2004, p. 917). Scientists construct logical arguments to defend the links that they create between evidence and created explanations. Even observations and evidence require argumentation to defend reliability and validity (Newton et al., 1999). Through peer-review, counter-arguments, and experimental replication, critical scrutiny through logical argumentation is a major part of science discourse and NOS.

Beyond initial data gathering, most of science is built around argumentation. Arguments take place in the minds and writings of individual scientists, between members of a research group before submission to research journals, within the scientific community through peer review and post-publishing debate, and in the public domain amongst the media and average citizens. Disputes over scientific claims often take many years to be resolved, a notion which only emphasizes the importance of argumentation to NOS. Argumentation is a major process in the creation of scientific knowledge (Abi-El-Mona & Abd-El-Khalick, 2011) and is therefore a part of the nature of science. However, argumentation has received limited attention from previous NOS studies. Inclusion of this aspect of NOS in this study will add to the literature on NOS instruction.

Teaching NOS: The Implicit vs. Explicit Debate

There is general consensus among science educators that students across all age groups do not possess an adequate understanding of NOS (Abd-El-Khalick & Lederman, 2000b; Akcay, 2006; Duschl, 1990; Lederman, 1992, 2007). The failure of students to possess adequate understanding of NOS has been documented across different definitions of NOS and across various assessments of NOS. Therefore, in the last two decades, science education research has placed less emphasis on mass testing of NOS understanding and a greater move toward the identification and testing of factors that may affect change in NOS understanding (Lederman,

2007). This coincided with the publishing of evidence from the National Assessment of Educational Progress (NAEP) in *The Science Report Card: Elements of Risk and Recovery* (Mullis & Jenkins, 1988) that indicated that the content and structure of elementary and secondary school science curricula were not in line with the ideals of the scientific enterprise and the first round of national reform documents (American Association for the Advancement of Science, 1989) calling for the teaching of NOS in American schools.

Curricula quickly embraced NOS, but not always with success. One curriculum in particular, the Biological Science Curriculum Study's (BSCS) *Science and Technology: Investigating Human Dimensions* (1990), was designed to emphasize thinking skills over memorization, promoted engagement in experimental design and implementation, provided a historical perspective on the development of scientific ideas, and presented science as a social endeavor. Despite its intention to promote an adequate understanding of NOS among students, students involved in a large-scale field test of *Science and Technology: Investigating Human Dimensions* showed significant decreases in their NOS understandings in 2 of the 4 target NOS tenets and faired statistically worse than the control group in one tenet on the post-test (Meichtry, 1992). Discussion of the short coming of the NOS-based curriculum focused on the spatial presentation of NOS material that seemed to lack adequate connection to other content or activities. Studies like this one contributed to the growing body of work concerning whether NOS concepts should be taught explicitly or can be acquired implicitly.

The implicit approach views NOS understanding as an affective learning outcome (Abd-El-Khalick & Lederman, 2000a). Viewed as similar to a learner's attitudes toward science or dispositions toward science, proponents of the implicit approach believe that appropriate NOS understanding can be achieved through learning science process skills and conducting scientific

investigations. Conversely the explicit approach views NOS understanding as a cognitive learning outcome that requires explicit instruction and discussion (Abd-El-Khalick & Lederman, 2000a).

Some confusion between the two can occur if they are viewed too simply, i.e. that hands-on science is always implicit and that lecture and discussions are always explicit. Abd-El-Khalick and Lederman (2000a), in a critical review of literature on the implicit vs. explicit debate note that inquiry activities that lead into discussions about NOS topics should count as explicit instruction and that discussions about the history of science that are devoid of discussion about specific NOS aspects, fall within the implicit approach.

The debate between the implicit teaching of NOS and the explicit teaching for NOS was a major topic of discussion in science education and still lingers some today. Famous in the debate between implicit and explicit NOS instruction was a case in 2007 where the same data was used to make a case for both sides of the issue. Palmquist and Finley (1997) studied the NOS conceptions of pre-service teachers and found that positive changes could be achieved via a two-semester science methods course that did not directly address the nature of science. Citing that little time was spent explicitly teaching NOS topics, Palmquist and Finley felt the gains provided evidence that methods courses that focus on conceptual change and cooperative learning can implicitly improve views of the nature of science. Bell, Lederman, and Abd-El-Khalick (1998) countered, using the same data to make a case for explicit teaching of NOS. Discussion of gains in student understanding was separated by tenets, and the tenets that received the most explicit NOS instruction yielded the highest change in student success. Through the peer review process, Bell et al. succeeded in laying down the groundwork for the success of the explicit approach.

Soon thereafter, Khishfe and Abd-El-Khalick (2002) provided a controlled quasi-experimental approach to directly address the explicit vs. implicit debate within NOS research. For direct comparison, the study compared an explicit and reflective inquiry-oriented instructional approach to an implicit inquiry-oriented instructional approach. Two groups of sixth-grade students received the exact same content and participated in the exact same inquiry activities on the exact same time frame. The two classrooms shared comparable demographics and comparable pre-test NOS views. The only difference was that the explicit group received references to and discussions of NOS aspects as they related to their studies. From the outset, a majority of the students (85%) on both sides, possessed naïve views of NOS. At the end, little change was noted in the implicit group, while substantial gains were made with the explicit group. Specifically, the implicit group saw a gain in only one of the four target NOS topics: the difference between observation and inference saw an 11% increase. The explicit group saw substantial gains in all four NOS topics, including a 31% increase in the same category as the implicit group's only increase. Khishfe and Abd-El-Khalick concluded that their study adequately demonstrated "that an explicit and reflective inquiry-oriented approach is more effective than an implicit inquiry-oriented approach in enhancing sixth graders' views of the target NOS aspects" (Khishfe & Abd-El-Khalick, 2002, p. 573). They went on to state that though they are interrelated, "engaging in inquiry and learning about science process skills are not the equivalent to learning about NOS" (Khishfe & Abd-El-Khalick, 2002, p. 573), a point which stands in contrast to the presuppositions of the implicit approach. Though inquiry is often assumed by the implicit approach, Khishfe and Abd-El-Khalick argue that attempts to teach NOS should be contextualized within the content and woven into inquiry activities. Though lacking

statistical significance due to population size, the inquiry activities of their intervention proved highly successful when paired with explicit NOS discussions.

Khishfe and Abd-El-Khalick (2002) showed that an explicit and reflective approach to NOS instruction works for K-12 students. This approach had been verified with pre- and in-service teachers previously, but their 2002 study was one of the pioneer implementations with younger students. With the success of their concept, Khishfe and Abd-El-Khalick wanted to define and clarify their process. Specifically, Khishfe and Abd-El-Khalick wanted to make sure that their "explicit and reflective" procedure does not get confused with didactic teaching. They argue that, "explicit and reflective" does not entail drilling and memorization nor does it emphasize gaining objectives in a step-by-step manner (Khishfe & Abd-El-Khalick, 2002). Instead, their goal is that NOS be intentionally targeted through a teaching method that focuses on student reflection. More precisely, they state that, "The term refers to providing students with opportunities to analyze the activities in which they are engaged from various perspectives (e.g., a NOS framework), to map connections between their activities and ones undertaken by others (e.g., scientists), and to draw generalizations about a domain of knowledge" (Khishfe & Abd-El-Khalick, 2002, p. 555). With this understanding, "explicit and reflective" instruction has become a catchphrase for current NOS instruction research.

The explicit and reflective NOS instruction technique has now been studied in a variety of contexts. Explicit and reflective NOS teaching have demostrated positive student gains in undergraduate biology classes (Bautista & Schussler, 2010), science majors serving as undergraduate teaching assistants (Hanuscin et al., 2006), pre-service elementary teachers in science methods courses (Scharmann et al., 2005), in-service science teachers (Morrison, Raab, & Ingram, 2009), and K-2 students (Quigley, Pongsanon, & Akerson, 2010).

The case for implicit NOS has not been as impressive. Specifically, students involved in prolonged inquiry-based projects as science laboratories have failed to demonstrate positive change in NOS understandings (Aydeniz et al., 2011; Bell et al., 2003; Karakas, 2011). Students did report gains in understandings of the processes of scientific inquiry, but consitently failed to make gains in understanding of various aspects of NOS. Studies have consitently shown that engagement in authentic scientific inquiry is not enough to ensure informed views of NOS. Though inquiry is important to science as a whole, it only affects NOS understandings when paired with explicit and reflective practices (Khishfe & Abd-El-Khalick, 2002; Yacoubian & BouJaoude, 2010).

Concerning methods to improve student NOS understanding, explicit approaches have proven to be more successful than implicit approaches. Specifically, approaches that claim to be explicit and reflective have demonstrated great gains in NOS understanding across a variety of student ages (Bautista & Schussler, 2010; Yacoubian & BouJaoude, 2010). Current research into the teaching of NOS concepts has accepted explicit and reflective as the preferred method for NOS instruction and is seeking further methods to increase NOS understanding. Some of these options are explored in the next section.

Teaching NOS: Conceptual Change Model

In Meichtry's 1992 report on the failures of the implicitly-based BSCS *Science and Technology: Investigating Human Dimensions* curriculum, the author made several recommendations for the teaching of NOS concepts. On top of calling for explicit representation of NOS topics in curricula and conversation, Meichtry also argued for the importance of "conceptual change based on a constructivist view of learning which emphasizes the assessment of students' prior knowledge" (1992, p. 405). Meichtry felt this was important to helping

instructors assess where student knowledge is coming from and to help them design strategies to help students restructure their conceptions.

Similarly, at the conclusion of their successful implementation of an explicit and reflective NOS strategy for sixth grade students, Khishfe and Abd-El-Khalick (2002) posited additional ways to potentially improve upon their explicit and reflective model. Their chief suggestion was to implement their approach within a conceptual change framework. By considering initial student views of NOS as deeply ingrained alternative conceptions, additional considerations would have to be taken in order to address change.

The conceptual change model (Posner, Strike, Hewson, & Gertzog, 1982) was originally proposed in 1982 to address alternative conceptions in the science classroom. Alternative conceptions (Franke & Bogner, 2011), sometimes called misconceptions (Gooding & Metz, 2011), are any of the varied and interesting ideas about specific science topics that students bring with them to the science classroom. Students can acquire alternative conceptions from a variety of sources, including their parents, other teachers, or from their own creativity. No matter how students acquire their alternative conceptions, they often come to the science classroom with ideas that are contrary to the accepted scientific norm (Artdej, Ratanaroutai, Coll, & Thongpanchang, 2010; Valanides & Angeli, 2008). Contrary to the empty vessel assumption of educational days gone by, conceptual change theory recognizes that our students come to us with conceptions that are deeply seeded and are resistant to change. In choosing to consider views of NOS as a cognitive learning outcome and comparable to “normal” science content, the NOS views that students bring to the classroom can be better understood. The troubles of the science community to successfully improve student views of NOS can be attributed to the ingrained

nature of their prior conceptions and thus the conceptual change model could potentially be a useful medium for improvement.

The conceptual change model, proposed by Posner, Strike, Hewson, and Gertzog (1982) and furthered by Beeth (1998) and Vosniadou, Ioannides, Dimitrakopoulou, and Papademetriou (2001), proposes that in order to address alternative conceptions, teachers need to explicitly elicit the alternative conceptions of their students and provide the students with ample opportunities to metacognitively explore their commitment to those conceptions. Conceptions should be judged as to whether they are intelligible, plausible, and fruitful (Posner et al., 1982). They argue that with proper guidance, students become discontent with their alternative conceptions and can be led toward accepted scientific conceptions. Conceptual change will then be accomplished if the new conceptions hold true for the student with regards to intelligibility, plausibility, and fruitfulness.

In support of the argument that student views about NOS are deeply engrained and that conceptual change theory may be necessary for successful transformation, Tsai (2006) found that in-service teachers enrolled in a science education course struggled to change their views about NOS. Tsai reported that the teachers initially held radically empiricist views about science. At the end of the course, which featured direct instruction about philosophy of science, the teachers demonstrated more agreement with constructivist views about science, but clung to their empiricist views as well. The teachers somehow assimilated the new information with their previous conceptions and produced responses to the NOS survey that were both adequate and naïve at the same time.

Following his own suggestion, Abd-El-Khalick, with Akerson (2004), attempted to incorporate a conceptual change framework into a science methods class that had previously

included only explicit and reflective NOS practices. Compared to the previous course taught by the same instructor, substantial improvement in NOS understanding was noticed. These changes were attributed to the use of the conceptual change framework. The initial NOS views of the students were elicited and actively discussed in the class in the context of real world examples and the modern, accepted views. The students demonstrated discontent with their original conceptions and were allowed to struggle with their conceptions to the point where most made positive conceptual changes. Additionally Abd-El-Khalick and Akerson (2004) found that students who made the greatest gains possessed a deep processing orientation, attributed importance and utility to gaining the content, and held religion and science separate as different ways of knowing.

Teaching NOS Through Argumentation

As argumentation has come to be seen as a core epistemic practice in science (Bricker & Bell, 2009), it also came to be appreciated as an essential pedagogical tool for science educators (Chin & Osborne, 2010). Science educators argue that, if students are to become scientifically literate and participate in science discourse, then they should be learning science via means that are similar to the operations of real scientists. One such option for learning is argumentation. Argumentation allows students to work with content to explore NOS through science in the making (Driver et al., 2000) and presents a more authentic image of the nature and practice of science (Chin & Osborne, 2010).

Teaching and assessment of argumentation skills are usually discussed in terms of Toulmin's (1958) book *The Uses of Argument* (Duschl & Osborne, 2002; Erduran et al., 2004; Newton et al., 1999). In this book, Toulmin (1958) divides argumentation into six parts: claims, grounds, warrants, backings, rebuttals, and qualifiers. Claims are conclusions made that need to

be established. Grounds are facts or data (qualitative or quantitative) that can be used to support a claim. Warrants are the reasoning or connection of grounds to claims, and backings are fundamental ideas or accepted means used to justify warrants. Rebuttals are the restrictions, exceptions, and errors of the claim. Lastly, qualifiers specify the conditions under which the claim can be understood as valid. This model of natural argumentation is used to describe student arguments and influence future arguments. Arguments containing elements further along Toulmin's model are generally discussed as more advanced, as are arguments that attend to other positions via counterargument (Kuhn, 2010) .

Argumentation in science courses is commonly taught as a "set of skills that could be developed through explicit directions and scaffolds regarding the strategies of argumentation" (Berland & Hammer, 2012, p. 69). Explicit instruction has demonstrated gains in student argumentation performance (Nussbaum, Sinatra, & Poliquin, 2008; Sampson, Grooms, & Walker, 2011). Specifically, Chin and Osborne (2010) recently found that student success with argumentation and scientific discourse was moderated by "scaffolding student questioning, teaching the criteria for a good argument, and providing a structure that helps them to organize and verbalize their arguments" (p.883).

In addition to increasing student reasoning skills and providing context for science content learning (Duschl & Osborne, 2002), the teaching of and use of argumentation in the science classroom has potential to be a great asset to the teaching of NOS content (Khishfe, 2012). Argumentation can serve to move science education from a positivist conception of right concepts objectively deduced from data toward the socially-constructed portrayal accepted by NOS consensus. Argumentation specifically allows for claims that challenge the status quo and counter-arguments that purport different claims, both of which support the tentative nature of

science. The need for scientific arguments to contain grounds is evidence for the empirical nature of science. The theory-laden, creative, subjective, and socially and culturally imbedded natures of science are evidenced in the flexibility and creativity of grounds, warrants, and backings in scientific arguments. There would be no reason for argument if all evidence directly corresponded to truth, but instead social factors influence how evidence is interpreted. Classroom discussions of argumentation can help students understand the nature of science (Khishfe, 2012). Key questions in the teaching of argumentation that can connect to explicit and reflective NOS instruction include:

- How is it possible that the same data can be used to support different sides of a scientific argument?
- What parts of an argument allow for user creativity?
- Why does scientific argumentation require empirical data (grounds)?
- What theories are the different sides of this argument operating under?
- What part(s) of Toulmin's model correspond to observations? Inferences? Theory?

The conditions of a good argument are a large part of what constitutes NOS. An understanding of NOS will help students make better arguments and help them interpret the reliability of scientific claims. Argumentation is not only a part of NOS, but it is also an avenue for instruction in NOS. Therefore, the use of argumentation in the science classroom will be intentionally noted in this study.

Disconnect Between Reform Efforts and Teacher Practice

The reform efforts in science education that championed improvements in student NOS understanding called for major changes to take place in American schools. They were written into curricula and focused on during teacher training programs and professional developments for in-service teachers. Despite significant effort, interest, and investment, the reform efforts have not resulted in sustained fundamental changes in classroom science practices (Settlage &

Meadows, 2002; Smith & Southerland, 2007; Southerland et al. 2007; Yerrick, Parke, Nugent, 1997) .

Reform efforts are not being practiced in science classrooms with the frequency and effort that science educators would like (Southerland et al., 2007). This has led to a discussion of factors that are affecting the enactment of reform-based practices. Factors external to the teacher certainly have an impact on the enactment of reform in science classrooms. Administrative support, funding, availability of materials and space, and available teaching and planning time can all impact instructional practice and reform implementation (Sandall, 2003). Accountability measures and authoritarian instructional policies, like No Child Left Behind (NCLB) and high-stakes testing have been shown to "narrow teachers' professional judgment, discourage their reform-oriented instruction, and focus on lower order learning opportunities such as bookwork and lecturing" (Saka et al., 2009, p. 1000). Reform documents are sometimes described as being incompatible with state curricula and high stakes testing that are perceived to focus primarily on science content (Smith & Southerland, 2007; Aydeniz & Southerland, 2012). Reform efforts are unlikely to be accomplished under dichotomous power structures.

External factors are not, however, the main barrier to reform-efforts (McLaughlin, 1987). Directly blaming external factors may actually create a false dichotomy, because many classroom decisions ultimately boil down to teacher beliefs. Few power structures specifically reject the implementation of reform-based practices, instead the perceptions of the individual teacher concerning reform and teaching practices influence what actually happens in the classroom (Clark & Peterson, 1985; Johnson, 2006).

Beliefs and values concerning students, teaching, and the goals and purposes of education and science create internal barriers within teachers that account for much difficulty in

implementation of reforms (Anderson, 2002). One internal barrier to reform change is teacher fear of change and accompanied risk aversion (Southerland et al., 2007). Another possible barrier is the possibility of a fundamental conflict between teacher view of science and the views presented in the reforms (Southerland et al., 2007). Teacher beliefs concerning the ability to affect student learning, known as self-efficacy, also influence the implementation of reform (Tschannen-Moran, Hoy, & Hoy, 1998). Content knowledge and pedagogical content knowledge are major players in self-efficacy and implementation in general (Wallace & Kang, 2004). Without knowledge of NOS (or other reforms) implementation is unlikely. Ultimately the understandings, beliefs, values, and motivations of the science teacher appear to have great influence on implementation of reform-based practices (Southerland et al., 2007). Some conglomeration of all these concepts, specific to each individual science teacher, culminates in a lack of success for implementation of reform based practices in American schools. These concepts are overly general and are derived from large studies of in-service teachers of varying degrees of experience. The goal of this study will be to discuss similar ideas, but with a focus on NOS and novice teachers.

Pre-service Teacher Issues with NOS Implementation

Instruction in NOS is a major component in reform efforts, but little is known about the issues that affect its implementation in science classrooms. Research directly concerning factors that affect novice teachers' ability to teach for NOS understanding has not been properly researched. A few studies have, however, discussed the issues that affect pre-service teacher implementation of NOS into their student teaching experiences (Abd-El-Khalick et al., 1998; Bell et al., 2000; Lederman et al., 2001). Though the subjects and findings of these studies may

not perfectly correlate to this study, they do serve to inform an understanding of factors that could affect NOS implementation.

Abd-El-Khalick, Bell, and Lederman (1998) conducted a study in which they collected data on the NOS practices and beliefs of 14 pre-service teachers before, during, and after a 12-week student teaching experience. All of the pre-service teachers had received explicit instruction in NOS, and the interest of the study was to see if and how that translated into their practices. Analysis of lesson plans and classroom observations revealed that the pre-service teachers rarely planned for or attended to NOS in their teaching. This stands in stark contrast to the 12 of 14 who stated that NOS instruction was important and the 12 of 14 who felt that they had taught NOS. The discrepancy between belief and practice was explained by interview evidence that the pre-service teachers felt NOS could be learned implicitly by doing science, despite the fact that they had received explicit instruction themselves stating that NOS needed to be taught explicitly. When confronted with evidence that they were not properly teaching NOS, the pre-service teachers narrated a multitude of constraints that mediated their ability to teach NOS. Their perceived issues focused around the themes of:

- Viewing NOS to be less significant than other instructional outcomes
- Preoccupation with classroom management and routine chores
- Discomfort with own understanding of NOS
- Lack of resources and experience for teaching NOS
- Cooperating (mentor) teachers' imposed restraints
- Lack of planning time
- Grasp to concept of implicit learning by doing (Abd-El-Khalick et al., 1998)

Lederman et al. (2001) sought to expand on the findings of Abd-El-Khalick et al. (1998) during and after an intervention designed to improve pre-service teacher understanding of NOS and influence their belief in the importance of NOS as a learning outcome. The study of seven

pre-service teachers, revealed four main factors that contributed to inclusion of NOS in the classroom:

- knowledge of NOS
- knowledge of subject matter
- pedagogical knowledge
- intentions toward the teaching of NOS (Lederman et al., 2001)

Regardless of NOS views or content knowledge, the pre-service teachers did not teach NOS unless they valued it as an instructional objective. Additionally the pre-service teachers cited availability of NOS teaching resources, mentor teacher support of NOS, and the significance placed on NOS instruction in their graduate studies as factors that facilitated successful NOS teaching. Factors that were cited as impeding NOS teaching included struggles with implementing regular content instruction in the allotted time, additional time needed for NOS, state-wide testing that does not include NOS, and constraints of their master's degree program itself (Lederman et al., 2001).

Based on Abd-El-Khalick et al. (1998) and Lederman et al. (2001), much is revealed about the implementation of NOS by pre-service teachers. Pre-service teachers who were extensively trained in NOS and knowingly were studied by researchers who were known to be greatly interested in NOS managed to struggle at implementing successful NOS instruction in their classes. The pre-service teachers maintained the incorrect perception that NOS could be taught implicitly and when confronted with their inconsistent NOS practices cited a multitude of possible influential factors. These factors make logical sense, but were solicited only as perceptions through interviews and have not been definitively confirmed for larger populations. It should also be noted that the teachers in these studies were pre-service, and therefore are affected by a multitude of factors that novice and experienced teachers do not have to face. Each group has its own merits and issues, and each deserves its own body of research. Novice teachers

represent a population of growing interest in science education and will therefore be the focus of this study.

Novice Teachers

Novice teachers, who are no longer pre-service teachers-in-training but are not yet expert teachers or even comfortable in their professional work, represent a distinct population in need of significant research (He & Cooper, 2011; Rodriguez, 2007). In science, an emerging field of interest in teachers during the induction phase of teaching is built on the acknowledgement that "beginning science teachers are different from their pre-service and in-service counterparts and deserve some undivided attention" (Luft, 2007). Induction represents a significant transition for novice teachers (Saka et al., 2009), where the guidance of teacher training programs is missing, but familiarity and control are missing as well. Novice teachers are expected to "undertake the full responsibilities of an experienced teacher from their first day on the job" (Menon, 2012, p. 218). Novice teachers must attend to instructional, curricular, and institutional constraints as well as effectively interact with a variety of different groups, including students, parents, other teachers, administrators and state officials (Menon, 2012). Novice teachers report receiving little, if any, help from their more experienced colleagues (Flores, 2001) and are therefore often left to navigate this important transitional time largely on their own (Ingersoll & Strong, 2011).

Many challenges confront novice teachers. Meister and Melnick (2003) identified managing student behavior, dealing with heavy workloads and time constraints, and managing relationships with parents as the major challenges that novice teachers face. These findings are backed up by other studies (Avalos & Aylwin, 2007) and are further exacerbated by ineffective mentoring and a lack of effective collaboration in school culture (Ulvik, Smith, & Helleve, 2009). Additionally, novice teachers are often placed at difficult schools, with the most

challenging students, and are given inadequate supplies and administrative support (Achinstein, 2006; Ingersoll & Strong, 2011; McCormack & Thomas, 2003). In reports on novice teacher commitment to teaching and attrition (Fantilli & McDougall, 2009; Flores, 2001; Kyriacou & Kunc, 2007), contributing factors include perceived degree of support, availability of time for successful performance, satisfaction with student behavior and progress, issues with differentiation, effective parental communication, and happiness in private life. With all the issues that novice teachers face, it is no surprise that Flores (2001, p. 139) describes the experience of novice teachers as “sudden, stressful and tiring,” citing a huge gap between novice teacher expectations and reality.

The issues that novice teachers face are complex, multifaceted, and importantly are often not directly connected to teaching and learning (Menon, 2012). Despite the fact that induction is a time when “science teachers’ practices and cognitive modes are conceptualized, constructed, and crystallized” (Luft, 2007), the factors that affect this development extend beyond basic educational theory. The extent to which problems that novice teachers face affect their classroom practices is little studied and worthy of greater attention.

Most research on novice teachers and teacher induction is limited to teacher attrition and retention (Bang et al., 2007; Ingersoll, 2003b), but there are efforts to change this trend. In 2007, Luft wrote a guest editorial for the Journal of Research in Science Teaching calling for increased attention to “beginning, induction, or newly qualified science teachers.” Luft (2007) suggests many lines of study, but one in particular called for a focus on the beginning teachers themselves:

> *These studies are indepth examinations that pertain to the diverse sides of teaching, including the cognitive side, which can include the thinking, learning, and decision-making process of new science teachers. These studies may examine the impact of emotions on the decision-making process in the classroom, the accessing and*

modification of content knowledge, the development of pedagogical content knowledge, or the beliefs of new teachers. The first years of teaching are periods of experimentation and modification, as teachers are constantly encountering new experiences, which impacts the formation of philosophies, knowledge bases, dispositions, and abilities that will guide future growth (Luft, 2007, p.534).

The suggestions for further study presented by Luft (2007) are represented in this study. This study aims to look at the goals and beliefs of novice teachers and their enactment in the science classroom. This study recognizes that the first years of professional teaching are a complicated and trying time, but they are also a time of self-discovery and growth. Through open, honest, and deep research, this study hopes to explore the nature of novice teachers' motivations and abilities to implement NOS instruction in their classrooms.

Chapter 3: Methodology

The purpose of this study is to investigate the NOS practices of novice teachers and the factors that facilitate or impede their implementation. In order to properly address this issue, the study was guided by the following questions:

1. What are the factors that facilitate or impede novice science teachers’ ability to promote student NOS understanding?
    a. What are the personal factors?
    b. What are the contextual factors?
2. How do personal and institutional goals concerning NOS affect classroom practice related to NOS?
3. Considering all factors, do novice science teachers teach for NOS understanding? If so, how?

Acknowledging the complexities of human motivation and achievement, this study will be guided by Motivational Systems Theory (Ford, 1992) and a comparative case study methodology. Each novice teacher will be studied individually within his/her own context in order to shed light on the condition of the novice teacher with regards to NOS. Motivational Systems Theory will be used to analyze the realities that the novice teachers have constructed and the relationships of these with their teaching environments.

Theoretical Framework: Motivational Systems Theory

According to Bandura (1997), “people's level of motivation, affective states, and actions are based more on what they believe than on what is objectively true” (p. 2). Despite its overly positivistic conception of reality, the essence of this quote states an important case for this study: beliefs play an important role in human motivation and goal achievement. Beliefs concerning

personal capabilities and external contexts significantly impact behavior, potentially without regard for actual abilities and contextual constraints.

Though beliefs are significantly important, they are only one of many factors that affect motivation and behavior. This study, therefore, utilizes Motivational Systems Theory (Ford, 1992) as a theoretical framework for its ability to account for a variety of factors. Motivational Systems Theory establishes a model of motivation and describes motivation as a critical component of achievement. Achievement is defined as the "attainment of a personally or socially valued goal in a particular context" (Ford, 1992, p. 66) . Implementation of NOS instruction is the overarching goal of interest for this study, and motivation toward its achievement will be analyzed for each teacher.

According to Motivational Systems Theory (Ford, 1992), goal achievement requires four components: motivation, skill, biological structure and functioning, and a responsive environment. Specifically, "a motivated, skillful, and biologically capable person interacting with a responsive environment" (Ford, 1992, p. 70) is essential for personal achievement. Motivational Systems Theory visually portrays this relationship as:

$$Achievement = \frac{Motivation\ x\ Skill}{Biology}\ x\ Responsive\ Environment \qquad \text{(Ford, 1992, p.69)}$$

Though not a truly measurable mathematical equation, the use of multiplication was intentional, to signify the importance of every component. If any component is missing, goal achievement is basically not possible (since anything times zero equals zero). A musically gifted student with no interest in music will never achieve his potential, even with expert instruction, just as a highly motivated football enthusiast who lacks speed and hand-eye coordination will never be a successful wide receiver (Ford, 1992). Similarly, a motivated and skilled science

teacher will not achieve all her classroom goals if her school environment lacks resources and stifles creativity.

In the Motivational Systems Theory model of achievement, motivation is the only component that is controlled within the mind. Human perceptions of the environment, skills, and biology affect motivation and are likewise reflected in the Motivational Systems Theory definition of motivation:

$$Motivation = Goals\ x\ Emotions\ x\ Personal\ Agency\ Beliefs \qquad \text{(Ford, 1992, p.78)}$$

According to this model of motivation, goals can be either personal or institutional, but institutional goals must eventually become personal goals in order to become motivational. Emotions are inherently tied to goals and reflect personal commitment to the idea. Emotions are heightened by belief in the importance of a goal and can provide the energy to accomplish the goal. Personal Agency Beliefs can be subdivided into capability beliefs and context beliefs.

Capability beliefs refer to a person's belief that he/she can successfully accomplish courses of action aimed at a specific goal (Ford, 1992). Ford's (1992) conception of capability beliefs correlates to Bandura's (1977) concept called self-efficacy that was based upon research that demonstrated that humans "act not only because they believe their actions will result in specific outcomes, but also because they believe in their own ability to perform those actions" (Andersen, Dragsted, Evans, & Sorensen, 2004, p. 27). Self-efficacy is built up within the individual based on performance expectations, life experiences, vicarious experiences, verbal persuasion (internal and external), and physiological states/emotional arousal (Bandura, 1977). Positive self-efficacy beliefs have been linked to both successful teaching (Ashton & Webb, 1986; Bandura, 1997; Tobin, Tippins, & Gallard, 1994) and successful science teaching (Hechter, 2011; Lakshmanan, Heath, Perlmutter, & Elder, 2011; Settlage, Southerland, Smith, &

Ceglie, 2009). In one case, teachers with high science teaching self-efficacies were found to be more likely to use inquiry and student-center teaching methods than were teachers with low science teaching self-efficacies (Czerniak, 1990).

Context beliefs also play an important role in motivation. According to Ford (1992), context beliefs are shaped by environments, including physical structures and institutional structures. Ford (1992) presents context beliefs as beliefs about external factors and people that may impact goal achievement. Specific to education, context beliefs can concern administrators, other teachers, students, parents, institutions, organizations, and the physical school environment (Lumpe, Haney, & Czerniak, 2000).Whether real or imaginary, environmental factors and power structures can affect a person's perception of the accessibility of a preferred outcome. Bandura (1997) similarly argues the importance of context and environment on behavior decisions. If a person possesses positive context beliefs, then he/she perceives that the context allows for and supports the actions needed for goal achievement.

The combination of capability beliefs and context beliefs presented by Ford (1992) as personal agency beliefs parallels the often discussed educational concept called agency. Agency refers to the perceived level of authority a person possesses toward achieving a goal in a given context (Malmberg & Hagger, 2009). Through agency, individuals are discussed as active players in the production of experiences, and beliefs concerning one's ability to produce desired outcomes are discussed as being integral to "incentive to act" (Bandura, 2000, p. 75). Agency accounts for all factors that can influence a person's beliefs concerning abilities to achieve. Ford's personal agency beliefs construct accounts for these factors by discussing one's belief in his own capabilities as well as one's beliefs about the environment in which he must operate. All of these beliefs are important, but they do not constitute motivation and goal achievement alone.

In Motivational Systems Theory, Ford argues that motivation depends upon goals that are supported by emotions, capability beliefs, and context beliefs. Only when these factors are present can motivation then play its role in initiating behaviors toward goal achievement. It is the aim of this study to use Motivational Systems Theory to inform methodological components and later discussion. Teacher emotional connection to goals and beliefs concerning capabilities and context will be measured alongside observations of capabilities and context in the classroom in order to discuss goals, motivation, and goal achievement. Specifically, this study will seek out and focus on the goals of novice teachers concerning NOS, their emotions and beliefs concerning these goals, the skills the teachers possess toward achieving these goals, and the responsiveness of the teaching environment to the success of these goals. It is the belief of this researcher, that since student NOS understanding is a cognitive goal, teachers must develop instructional goals concerning NOS understanding and actively work toward achievement of those goals if changes in student NOS understanding are to be achieved. Case specific factors that affect motivation towards and goal achievement of NOS instructional practices will be deduced and explained.

Comparative Case Study

In order to appropriately analyze the complex nature of novice science teachers' goal achievement and motivation toward improving student NOS understanding, a qualitative case study research methodology will be employed. A qualitative case study methodology is appropriate for this study because it establishes an empirical inquiry into a bounded system within its real-life context and is especially suited for situations when the phenomenon's variables and their context are not easily separated (Yin, 1994). Qualitative case studies create an intensive, holistic description and analysis of individual instances (Merriam, 1998). According to

Merriam (1998), case study should be used in situations where researchers value insight, discovery, and interpretation over hypothesis testing.

Case study does not claim any particular methods for data collection or data analysis (Merriam, 1998). Instead, any and all methods can be used within the context to aid in the holistic interpretation of the specific case. A wide net is generally spread in case study research in order to paint a rich, thick description of the case (Bromley, 1986). The value of case study comes from its intimate connection to the phenomenon of interest. Through naturalistic observation, access to subjective factors of participants, and other exploratory means, case study research develops holistic interpretations of specific cases within their own context.

Of significance to all case study research is the intrinsically bounded case (Merriam, 1998). A case must be a single entity or phenomenon around which there are defined boundaries. These boundaries define the context and limit the scope of inquiry. Anything within those boundaries could and should be studied. A case could be selected for many reasons, but often they are selected because they contain situations of concern or interest (Merriam, 1998). The NOS related goals and practices of individual novice science teachers are of significant interest to this study. Each teacher represents a case. Each case encapsulates that teacher's beliefs, motivations, skills, classroom practices, and school environment. The NOS-related instructional practices of each teacher are unique to that teacher's specific case.

Specifically, this study is a comparative case study, meaning that it utilizes more than one case. Each case will be studied and presented individually for its own merits and findings, but subsequently cross-case analysis will be presented in an effort to cast light on commonalities and discrepancies (Merriam, 1998). Though each case is bounded by its own context, generalizations across cases in this study can and will be made. Through comparisons of similar cases, the

precision, validity, and stability of findings can be increased (Miles & Huberman, 1994). This study utilized a comparative case study methodology in order to achieve redundancy and increase generalizability of findings within the bounds of this study (Merriam, 1998).

Epistemology and Ontology

Qualitative case studies accept the underlying assumption of interpretive, qualitative research that reality is “holistic, multidimensional, and ever-changing” (Merriam, 1998, p. 202). Schwandt (2007) argues that there is no direct understanding of the world. Glesne (2011) similarly states that reality is individualistic, socially constructed, and complex. Thus, interpretive researchers reject objective accounts of knowledge and instead seek and value subjective, negotiated understandings of phenomena (Denzin & Lincoln, 2000).

Specifically, Motivational Systems Theory (Ford, 1992) , the theoretical framework for this study, intimately connects goal achievement and motivation to personal beliefs. Regardless of how they are formed and what influences them, the beliefs of the individual determine that person’s behavior and thus her reality. This study values each teacher’s perspective and will attempt to explain and understand the worlds of participants through their own perspectives (Denzin & Lincoln, 2000). One of the major roles of the interpretive researcher is to assess participant interpretations of social phenomenon and to interpret them within the given context (Glesne, 2011).

Developing an in-depth understanding of the complexities of each specific case will require an interpretive ontology and epistemology, where reality is viewed as subjective and is individually analyzed through the human experience. Long-term interactions with each case in its natural setting will allow for descriptive, analytic interpretations of each case’s reality.

Participants

This study utilized purposeful sampling (Glesne, 2011) in order to create an appropriately framed data set. Each case was selected for homogeneous characteristics in order to aid the cross-case analysis of this comparative case study.

Seven novice science teachers were recruited from a pool of recent graduates from a research focused university in the southeastern United States who received master's degrees in science education. All participants possess a bachelor's degree in a science field. All participated in a year-long internship experience at a high school that included significant observation, mentorship, co-teaching, and solo teaching in at least two science courses. The participants also took a variety of graduate science education courses in common, including:

- A science methods teaching course that highlighted reform-based practices
- A curriculum trends in science education course
- An instructional trends in science education course
- A course designed to promote reading strategies for science courses

All participants studied under the guidance of the same faculty advisor who taught several of the above mentioned classes. Explicit emphasis on reform-based practices, including NOS and argumentation, was present in every course. NOS was specifically addressed via reading assignments, reflective writing assignments, and classroom discussion in two classes for at least one week each time. NOS instruction during their graduate school courses included study of NOS itself, NOS instructional practices including *explicit and reflective* NOS instruction, and NOS assessment tools including VNOS (Lederman et al., 2002) and VOSE (Chen, 2006b).

The faculty advisor who taught them NOS also oversaw thesis projects for each participant that consisted of action research in their internship classrooms. Project topics varied, but mainly centered on argumentation, modeling, and NOS.

All novice teacher participants in this study were public high school science teachers in their first, second, or third year of professional teaching at the time of data collection. Each teacher's background and teaching environment is individualistic and is adequately reflected in his/her participant biographies (see next section) and in his/her interpretive case study analyses. Quantitatively the cases represent a diversity with respect to age (24-29), undergraduate major (3 Biology, 3 Chemistry, 1 Physics), and race (6 Caucasian, 1 African American).

This similar, yet diverse, group of participants built the data set for this study. Each participant came to this study via a unique life path that contributed to his/her science teaching experience (He & Cooper, 2011) and the greater story of this study. Each participant is individually discussed in his/her own section of section of Chapter 4, but each deserves an introduction now to aid in context discussion.

Participant Biographies

Ms. Mangrove was a second-year science teacher at Manatee High in Hart County. She taught Honors Chemistry 1, College Preparation (CP) Chemistry 1, and Inclusion Physical Science during the duration of this study. She has additionally taught CP Chemistry 1 and CP Biology 1 during her first year teaching. She also co-taught CP Biology 1, Honors Biology 1, and CP Chemistry during her internship year. For her master's degree project, she studied visualizations of chemical bonding.

Ms. Williams was a first-year science teacher at Westside High in Hart County. She taught CP Chemistry 1 and Regular Physical Science during the duration of this study. She additionally co-taught CP Chemistry 1 during her internship year. For her master's degree project, she studied the effects of modeling on student understanding of chemical bonding.

Ms. Shirley was a second-year science teacher at Creek Side High. She taught Inclusion Physical Science, CP Ecology, and an elective science course called Crime Scene Investigations (CSI) during the duration of this study. She additionally taught Regular Physical Science, Year-long Biology 1, and Regular Biology 1 during her first year teaching. She also co-taught Regular Biology 1 and Inclusion Biology 1 during her internship year. For her master's degree project, she studied student questioning and student-driven classroom practices.

Mr. Solo was a third-year science teacher at Rebel Alliance High. He taught CP Biology 1, Honors Biology 1, and an elective science course called Wilderness Principles during the duration of this study. He additionally taught Ecology, Biology, and Wildlife Principles in his first two years of teaching. He also co-taught Biology 1, Ecology, and Physical Science during his internship year. For his master's degree project, he studied the use of argumentation in science learning.

Ms. Heffernan was a first-year science teacher at Dougie High. She taught CP Ecology and Honors Biology during the duration of this study. She additionally co-taught Biology and Physical Science during her internship year. For her master's degree project, she studied concept mapping and meaningful learning in science courses.

Ms. Platypus was a second-year science teacher at Poison Claw High. She taught CP Biology 1, Honors Biology 1, and a non-science course called Language! during the duration of this study. She taught the same courses during her first year of teaching, but was able to co-teach CP Ecology and CP Biology 1 during her internship year. For her master's degree project, she studied argumentation.

Mr. Stevenson was a first-year science teacher at the School of the Dead. He taught Regular Chemistry 1, Inclusion Chemistry 1, and Regular Physical Science during the duration

of this study. He additionally co-taught Honors Chemistry 1 and Honors Physical World Concepts during his internship year. For his master's degree project, he studied argumentation.

Ethical Considerations

Concern for human subject is of great importance to social science research. Study details, a detailed consent form, interview protocol, questionnaires, and many supporting documents were submitted to the institutional review board of the university and the school districts of the participants for approval. The consent form detailed potential risks and benefits, including efforts to ensure confidentiality (See Appendix A).

Data Collection Methods

Data were collected over the majority of one academic school year. Some of the courses taught by the participant teachers operated on a block schedule while others operated on a "regular" schedule, but in all cases interviews and observations were spread out over the majority of at least one course. The length of this study allowed the researcher to explore repeatedly and deeply into a variety of data sources.

Though case study research claims no particular methods for data collection, it is quite common for qualitative case studies to utilize interviews and observations as data collection techniques (Merriam, 1998). The intensive, holistic description and analysis required of case studies mandates a depth and breadth of data collection that requires multiple data sources (Merriam, 1998). These sources and their subsequent analysis should be recursive and interactive, informing future data collection.

In order to create an in-depth understanding of each case, three data collection methods were used. The common case study methods of interviews and classroom observations were

utilized along with two qualitative questionnaires. The contribution of each of these data collection methods is described in the following sections.

Interviews. This study featured semi-structured interviews as its primary data source. Semi-structured interviews start with researcher initiated guiding questions, but are intentionally left open to potential participant control and deeper probing into topics that arise (Hatch, 2002). Semi-structured interviews require preparation and flexibility in order to be successful and for important information to surface (Chiseri-Strater & Sunstein, 1997).

The semi-structured format of the interviews allowed target topics to be approached as well as allowed the participant to take an active role in the direction of the interview. Motivational Systems Theory guided the line of questioning to focus around goals, emotions, and beliefs, but the specifics of the participant answers determined the flow of the interviews. Participant answers informed subsequent questions as well as future interviews and observations.

Interview 1 focused on teacher created goals and their correlated beliefs. Subsequent interviews probed into institutional goals and then into the goal of main interest, NOS instruction. The slow buildup of intensity of interviews was intentional for several reasons. Teacher created goals were viewed as easier to reveal and allowed for increased trust and comfort to be built between the participants and the researcher. Postponing any researcher advocated NOS discussion until Interview 3 and Interview 4 served to allow NOS to surface naturally by the participants as either personal goals or institutional goals. The delay also allowed for controlled classroom observations prior to full disclosure of this study's NOS intent. (For interview protocols, see Appendixes B, C, D, and E.)

Interviews were quickly transcribed and then analyzed, so that the analyses could inform future inquiry and be available for member checks. Interpretations were shared with participants to assure accuracy and clarity.

Classroom observations. Classroom observations served to compliment and triangulate details that were shared and constructed during interviews. Goals, emotions, beliefs, and skills that were shared during interviews were intentionally monitored for in subsequent classroom observations. The classroom served as a natural environment for the researcher to experience firsthand the contexts that influenced the participants' understandings and motivations (Hatch, 2002). From Motivational Systems Theory, classroom observations allowed for inquiry into capability beliefs and context beliefs that were shared during interviews, but also skills and environmental factors that affected goal achievement. Descriptive field notes were taken during every classroom observation, and time was spent thereafter for reflective and analytic noting (Glesne, 2011).

Classroom observations were additionally used to assess NOS instruction and behaviors consistent with NOS (like inquiry-based laboratory experiences (Lederman, 1999) and argumentation). Observation of explicit NOS instruction held the potential to lead to discussion of NOS goals and motivations in future interview settings.

Classroom observations played a vital role in this study. Though length and quantity of observations varied for each case, a minimum of six hours were spent collecting observational data in each participant's classroom.

Questionnaires. Two questionnaires were utilized in this study in order to collect supportive information and to add depth to the conversation. A demographic questionnaire was distributed, filled out, and collected before Interview 1 (See Appendix F). Using a questionnaire

assured concrete answers to a structured list of questions, removing the risk that they might be missed or modified in semi-structured interviews. This questionnaire included questions about syllabi and goal setting, which served to get their minds oriented towards the topic of goals and served as a trustworthiness check for later interviews.

Later in the study, the VNOS-C Questionnaire (Lederman et al., 2002) was administered to assess participant views of NOS (See Appendix G). The VNOS-C is the most commonly used measure for NOS understanding (Chen, 2006a; Southerland et al., 2006) and was constructed and validated for adult subjects (Lederman et al., 2002). The VNOS-C is an open-ended questionnaire that takes 45-60 minutes to complete. (Version C and all other versions are commonly referred to as the VNOS, which will be practiced for the remainder of this study.) Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) recommend follow-up interviews to allow participants to clarify and elaborate upon their written answers. For a given subgroup it is recommended that 15-20% of respondents are interviewed. This study chose to interview all participants in an effort to gain a more complex and in-depth description of each participant's NOS understanding.

Data Analysis

This study utilized an interpretive methodology and a hermeneutic approach to analysis that featured an iterative cycle (Grbich, 2007). Preliminary analysis of early data was critically reflective in order to build up a picture of what was going on and to inform further questioning. Findings and interpretations were constantly validated through member checks, in order to maintain focus on highlighting the views of the participants. Data analysis was continuous throughout the study, informed by transcripts, field notes, and reflections. Following data collection, thematic analysis and profile creation occurred. Data were "segregated, grouped,

regrouped, and relinked in order to consolidate meaning and explanation" (Grbich, 2007). Themes were inductively coded and triangulated against other data. Coding largely utilized InVivo coding and thematic coding, and was then fit with the Motivational Systems Theory framework. Profiles of goal achievement were created for each novice science teacher. Descriptions and explanations of individuals and of the participant group were developed to answer the research questions.

Trustworthiness

With the rejection of possible objectivity, qualitative research rejects the notion of validity in favor of the concept of trustworthiness (Glesne, 2011). Explanations of trustworthiness allow researchers to claim that their work and findings are plausible or credible (Glesne, 2011). Creswell (1998) outlines eight procedures that contribute to trustworthiness, six of which were used in this study: prolonged engagement; triangulation; peer review and debriefing; clarification of researcher bias; member checking; and rich, thick descriptions. The use of each of this in this study is detailed below.

This study was intentionally carried out over an extended period of time to allow the participants to grow comfortable with the process and develop ontologically more sophisticated in their responses. Five to eight months of interaction and interviews in each case allowed for greater depth of exploration and more data collection and iterative analysis. This prolonged engagement also allowed for the researcher to constantly reflect on bias and adjust accordingly.

Multiple, varied data sources were used to triangulate data. Findings and themes that are present in multiple data sources demonstrate greater trustworthiness. Use of member checking established greater credibility through participant buy-in and agreement. Peer review with experienced professors and graduate program fellows, during organized research meetings,

additionally confirmed analysis and provided external reflection. Verbal explanation of analysis to peers proved useful in the sense making process and added trustworthiness to the findings.

Lastly, thick, rich descriptions helped the trustworthiness of this study. Detailed analysis and openness of data allow readers to enter the research context (Glesne, 2011) and personalize their own explanations and trustworthiness claims. Quotations from interviews, references back to observations, and constant sharing of researcher reflection contributed to the richness of this study's descriptions. Thick descriptions are also used to establish transferability of findings (Guba & Lincoln, 1989). Transferability discusses the applicability of findings to similar settings. Thick descriptions provide a detailed picture in order to facilitate transferability judgments to other settings.

Summary of Methodology

The goal of this study was to investigate the factors that affect the ability of novice science teachers to teach for NOS understanding in their science classrooms. Motivational Systems Theory and a comparative case study methodology allowed this study to assess factors that affect teacher motivation toward and goal achievement of the teaching of NOS content. Access was gained to a thoughtful population of novice science teachers who willingly participated in co-construction of meaningful explanations. Through multiple data sources, iterative analysis, and member checking, understanding was gained and built upon. Case descriptions for each novice teacher were developed and then compared for commonalities. Themes and answers to the research questions were created and are detailed in the following chapters.

Chapter 4: Case Study Analyses

The following chapter presents case studies of each of this study's seven participants. Each case is separate to showcase the different experiences and realities of each individual. Each novice teacher dealt with the issues surrounding NOS instruction differently, therefore each case should be read and appreciated for its individual merits.

The data set for each novice teacher was expansive. The total length of interviews for each participant ranged from 1 hour and 49 minutes to 2 hours and 19 minutes. The classroom of each novice science teacher was also observed for a minimum of 6 hours. Additionally each participant completed the demographic survey and the VNOS questionnaire.

The subsequent case study analyses are guided by the theoretical framework of this study, Motivational Systems Theory (Ford, 1992). The motivation and goal achievement concerning NOS instruction of each participant is examined in the light of the components of the theoretical framework. These components serve to create the structural framework for each case study (See Table 2).

Table 2

Structure of Case Study Analyses, based on Motivation Systems Theory (Ford, 1992)

Biographical Information
Personal Goals
Institutional Goals
NOS Goal
Emotions
Capability Beliefs
Context Beliefs
Motivation
Skill
Understanding of NOS
Classroom Practices
Responsive Environment
Perceived Factors that Affect NOS Instruction
Conclusions on Goal Achievement

Each case study begins with a short biographical information section that includes personal information as well as classroom and school details. Names have been altered so as to protect confidentiality. Considering the small number of science teachers trained each year and the accompanied vulnerability of this participant population, in some cases specific biographical information has been altered or left out in a way that aims to both protect confidentiality and maintain the essence of the participant's reality. The biographical information on each participant is intended to provide a simple, colorful description that establishes the story of each participant and sets up the context for subsequent analysis.

Following the biographical information, the stated personal and institutional goals of the participant will be discussed. These were written about and discussed in the demographic survey (DS) and the first two interviews (I1 and I2), before NOS was ever explicitly mentioned by me. The intent was to discover whether NOS was included in the goals, whether personally created or passed on by greater institutions, that that teacher outwardly acknowledged for his/her classroom.

The structure of each case study then addresses the question of whether the novice science teacher considered NOS to be a goal for the classroom. This question was directly asked in Interview 3 (I3) and readdressed throughout the rest of that interview and Interview 4 (I4). From there, the structure follows the components of Motivational Systems Theory (MST) closely. Emotions concerning NOS are discussed, followed by separate analyses of the two components of personal agency beliefs, which are capability beliefs and context beliefs. According to MST, goals, emotions, and personal agency beliefs combine together to describe the holistic motivation toward a goal, so the next category in the structure is motivation.

Motivation is the first component of goal achievement to be independently explored. This is then followed by skill toward NOS goal achievement, which is subdivided into personal understanding of NOS and classroom practices concerning NOS. These are followed by a discussion of the participant's responsive environment. Biological structure and functioning, a component of goal achievement that is highlighted by MST, is strategically left out of each analysis, because every participant in this study possesses adequate vocal and ambulatory functions necessary for the teaching of NOS. The penultimate section of each case study is a description of the factors the participant described as affecting NOS instruction. Each case concludes with a summary of that teacher's goal achievement and interactions with NOS.

In every case, the theoretical framework informed the content of every interview question, survey question, and classroom observation. The theoretical framework also informed the analysis and the structure of the analysis. Within each component of the structure of this analysis, InVivo coding and thematic coding were utilized to fully describe the participant's connection to that component. Codes within codes were thus utilized to best describe each participant's interactions with NOS.

Analysis of Ms. Mangrove

The following is an analysis of Ms. Mangrove and her interactions with NOS during the fall semester 2012. The analysis is built upon two surveys, four interviews, and four classroom observations. Extended conversations were held concerning Ms. Mangrove's goals, the institutional goals that affect her, and NOS specifically. These conversations, and the accompanying surveys and observations, were analyzed within the MST framework and coded using InVivo coding and thematic coding in order to create a picture of Ms. Mangrove's motivation toward and actualization of NOS instruction. These codes were used to place

quotations and themes within MST components. The included quotations are just small excerpts of prolonged statements. The quotations were chosen for their poignancy and their ability to support my assertions about the components of the theoretical framework.

Biographical information. Ms. Mangrove is a 26-year-old second-year science teacher. Teaching is technically her second profession, though she served only one year as a research scientist. After graduating with a double major in biochemistry and cellular and molecular biology, she went straight into a job at a prestigious medical research center. She quickly found the work to be too cutthroat and high-stakes for her liking. She also found the scientific practices of several of her co-workers to be questionable. It turned out the only part of her job that she really enjoyed was training new interns. Ms. Mangrove enjoyed working with her interns in order to help them achieve understanding of their equipment and job expectations. To solidify her decision to become a teacher, Ms. Mangrove transformed her other passion, dance, into a teaching job and eventually decided that “I just like teaching” (Mangrove, I1). She decided to combine her love of science with teaching and go back to school for her masters in teacher education.

Ms. Mangrove has a kind, energetic face that glimmers with enthusiasm for her subject areas. She is certified to teach biology and chemistry, but teaches whatever her school asks of her. In her first year of teaching, Ms. Mangrove taught college preparatory (CP) physical science and CP biology 1. This year, her second, she taught CP chemistry, honors chemistry, and an inclusion physical science class. She approached each class differently depending on the course objectives and the needs of her students. She claimed to feel most comfortable with CP chemistry, but enjoyed the challenge of honors chemistry as well. Her strong chemistry content

knowledge was constantly demonstrated during class discussions and conversations with small groups of students.

Ms. Mangrove works at a suburban school with a population of 1900 students. The school is known for having strong academics and an involved and concerned parent population. This does not, however, always translate to student success. In the first semester of this study, Ms. Mangrove told of two students who self-selected to “tap out” (I2) of honors chemistry. Contrary to her generally kind demeanor, Ms. Mangrove was rather matter-of-fact when telling me that most of her students were successful except the two students who partway into the semester gave up, stopped turning in homework, and would accept no additional help. She claimed to have tried to help and to schedule after school make-up sessions, but that they would not accept. She admitted that, “It’s sad, but I tried” (I2). Despite her school and her efforts, Ms. Mangrove still struggles with student effort and appreciation of science. These concepts made their way into Ms. Mangrove’s personal goals for her science classroom, which I will now discuss.

Personal goals. In an effort to see whether any form of NOS instruction was a personal goal possessed by the participants, they were asked on several occasions to name and describe their goals for their science classrooms. These lines of questioning were intentionally left open without any mention of NOS for the demographic survey and the first two interviews. As was the case with most of the participants, NOS and NOS-related concepts were not named by Ms. Mangrove among her classroom goals. However, her goals were thoughtful and relevant to science. On the demographic survey, when asked “What are your goals for your science classroom?,” Ms. Mangrove listed three goals. She wrote, “Students see the connections between

the content and the ‘Real World’, Students gain study skills/maturity to succeed in future classes/career/college, Students gain an appreciation for science as a whole” (DS).

Ms. Mangrove expounded on these goals during Interview 1 and unknowingly added a fourth. Concerning connections, Ms. Mangrove expressed a desire to make the content of her classroom relevant to her students:

> *This semester I really want to start seeing connections between what we talk about in class and what they see and experience in their everyday lives. So, I like to talk about, you know, exciting electrons in fluorescent lighting for instance or things like that. How does frost form? My physical science class we talked about, you know, since it's Halloween soon, we talked about dry ice and what happens. What is it called when it skips the liquid phase? And stuff like that (Mangrove, I1).*

After elaborating on her goal of helping her students make connections with the real world, Ms. Mangrove then immediately flowed into a new goal. The ease with which she spoke of it implied that it was an honest goal she has been working on all semester and that she probably thought that she had written it on the original survey. The added goal aimed to help students learn how to apply math to science courses. This goal was rooted in a comment given to her by a practicing chemist. In the summer before this study, Ms. Mangrove and a fellow teacher worked at a laboratory at a research university as part of a program to help science teachers gain laboratory experience that may benefit their classroom practices. This experience was valuable to Ms. Mangrove, but the way that it affected her classroom the most sprouted from a simple conversation with the lead scientist who also teaches college chemistry: “We asked the professor what he wants his students to know. What gaps do you see? And he said, ‘nobody can solve a math problem’” (Mangrove, I1). Based on this conversation, Ms. Mangrove took it upon herself to focus more on algebra skills in her courses. Specifically:

> *I've been trying to like to do a lot of helping them with math. Writing down steps. Developing a process for attacking a problem. . . . I've made it more of a process for*

them, where they have to show me steps and they have to show me work and they can't just write a number down. They have to show me how they are thinking about the math problem (Mangrove, I1).

Ms. Mangrove described her decision to include more math skills in her chemistry class and then seamlessly cycled back to her original list. She then described her next listed goal that concerned study skills and life preparation:

I want them to develop good study skills and practices to accomplish goals and to prepare for future harder high school classes and college and even just in the workforce. You know, you need to be able to motivate yourself and be able to finish something even if you don't want to (Mangrove, I1).

Ms. Mangrove did not differentiate her study skill goal for the different grade levels that she taught. She felt that all students needed guidance concerning study skills and maturation.

Ms. Mangrove's last stated personal goal mutated during the Interview 1. Gaining appreciation of science turned into merely helping students not hate science:

Just to gain an overall appreciation for science. I mean. Or to just overcome their negative opinions about science. Most of the time when students come in, they hate your class before they even started. And you're just like, "why you gotta hate on this?" It's great. It's everywhere and it's interesting, if you think about it a certain way and approach it a certain way. So, just, I want to say that I want them all to be future scientists, but some of them - I mean, if we were all future scientists, I mean there wouldn't be anybody else… (Mangrove, I1)

From there, all of Ms. Mangrove's goals became intertwined:

Since I realize that I couldn't turn them all into scientists, I kinda shifted that goal to well if they're not going to come away loving science and wanting to be in a career in science, at least they can come away knowing "Hey, if I work hard and apply myself I can solve problems and do something that I thought I couldn't" (Mangrove, I1).

Using connections to the real world as a hook for attention at minimum and appreciation at a maximum, Ms. Mangrove intended for her science classes to help give students the skills they would need to succeed in school and later in life. Within this goal framework, mathematical

knowledge and skills were also valued by Ms. Mangrove as useful for achievement in science and life.

In addition to these self-reported goals, I noticed a great emphasis on explanation in Ms. Mangrove's classes. In laboratory report worksheets, Ms. Mangrove repeatedly requested that students explain what they saw and what they concluded. She also constantly spoke about explanations when reminding students to complete their writing assignments. When this was brought to her attention during Interview 2, Ms. Mangrove explained it as if it were an intentional goal of her teaching:

> *I like for them to explain what they see because it requires them to think about what they know. . . . I think that in order for you to truly understand something you have to be able to teach it to somebody else or explain it to somebody else. . . . In the lab they have to explain why something is happening, just so I can, just so they can see that they know why something is happening and so I can see it (Mangrove, I2).*

Ms. Mangrove's intentional emphasis on student explanations pushed her classroom activities toward higher-order cognitive levels. The students were challenged to explain their understanding in writing, and Ms. Mangrove was able to assess more than just their recall of information and therefore scaffold more appropriately in the future. Ms. Mangrove saw math and writing as avenues for demonstrating understanding and building on understanding. Ms. Mangrove's stated personal goals focused on building up the skills, knowledge, and appreciation of science that she felt would benefit her students in school and for the rest of their lives.

Institutional goals. During Interview 1, when questioned whether she believed that her school system would support her personal goals, Ms. Mangrove stated that she felt that her goals were pretty much in line with those of the school system. She then stated the relevant goals that she felt the school system expects of her with an interesting choice of pronouns:

> *Especially this year we've been trying to push more for real-world connections and we are trying to include, well, we didn't talk about literacy. Talk about literacy goals, but they're trying to- (Mangrove, I2)*

According to Ms. Mangrove, her school had put emphasis on providing real-world connections for students in all subject areas. She described this by saying that "we've been trying," thus connecting herself to the act and affirming her connection to the similar goal. Similarly, she started to mention the goal of literacy with a "we clause", but transferred to "they" in the next sentence. She then made it apparent that this is a goal that an institution had put on her, which she was not excited to follow through with. To clarify whether she valued literacy, I asked if it is important to her. She said:

> *Math literacy is important to me. I mean, literacy is, I mean you have to be literate in science because if you were to be a scientist you have to do all your lit reviews and all that other stuff so it definitely is. But at this level, you know, having them write essays during my class time is a little frustrating (Mangrove, I2).*

Literacy was a recurring theme in the interviews with Ms. Mangrove. It was something that she half-heartedly participated in at the beginning of the semester, begrudgingly implemented in her own way in the middle of the semester, and had largely thrown by the wayside by the end of the semester. Citing time concerns and more pressing content, Ms. Mangrove stopped extended writing except on rare occasions where it felt important to content understanding. She felt that something had to give:

> *So much of the burden is just put on the teacher to find all of these extra documents and to grade all these extra essays and to create all of these creative assignments and research papers. And you also have to get through all of this insane content, that's just massive, it's just too too much. Something has to give. Either the literacy standards or the content. And I chose literacy standards. They are starting to slack. Because I've got to get through my content (Mangrove, I2).*

Ms. Mangrove's dedication to literacy cast a similar light on topics to come that she likewise perceived as not befitting the time constraints of the state science curriculum.

Another institutional goal that Ms. Mangrove named was *100-90-90-90*. This was a catchy goal stated by Hart County at the beginning of the year, but the branding proved not to be catchy enough, because Ms. Mangrove could not recall how many 90's the phrase required or what each of the 90's stood for:

> *It's like . . . we want 100% to graduate, and then 90% of those to go to college, and then 90% of that percentage to stay in college, or something like that. I should know that, but I don't quite, because I kind of don't really (Mangrove, I2).*

Ms. Mangrove did not succeed in portraying an accurate understanding of this institutional goal, but this fact largely does not matter. What does matter is that Ms. Mangrove believed that this goal was intended to increase rigor in high school courses, but she could not see how doing so would increase graduation rates and college attendance, so she chose to ignore the goal. According to Motivational Systems Theory, achievement of this goal failed to be accomplished for a large number of reasons. Not only did she not accept the goal as a personal goal or feel any emotional attachment to it, she also failed to understand the goal. Without understanding, capability beliefs and actual skill fail to be realized. All of these factors easily combine to keep the institutional goal of *100-90-90-90* from being achieved in Ms. Mangrove's classroom.

NOS goal. Immediately before Interview 3, each participant completed the VNOS questionnaire. This was the first time that each of them had seen or heard NOS discussed in the context of this study. This delay was intentional in order to see if NOS came up naturally in each participant's discussion of personal and institutional goals. In Interview 3, I directly asked the participants if teaching for student understanding of NOS is a goal that they possess for their

classrooms. Answers varied and were often interesting. Ms. Mangrove's mutating answer was no exception. In response to my question, Ms. Mangrove said:

> *I think it is... It's not a goal that I try to achieve every day. I would say it's a goal I try to achieve in the atomic structure unit. Hehe. And that I unfortunately don't really spend much more time on it. And it's just more of a time issue and an other people tell you what's important kind of issue. Like, you know, you have to spend time doing this and you have to teach them this vocabulary, even though it's not really for your class, it's for English. And you have to teach them to do this. So you kind of get, you have to pick and choose and prioritize what goals you achieve each day. I think. So I have to say no on that one (Mangrove, I3).*

This response demonstrated a great deal about Ms. Mangrove's beliefs about NOS. In describing her NOS instruction and goal setting in this way, Ms. Mangrove expressed that she either values NOS or recognizes that other people value NOS. Because of this, she struggled with admitting that it is not a priority in her classroom. She admitted a personal feeling of guilt for not establishing NOS as a goal and then immediately started into stating her reasons. In the end, she concluded that NOS instruction is not a goal that she possesses. Considering the theory that teaching for student understanding of NOS requires explicit and reflective instruction, it becomes highly unlikely that Ms. Mangrove's student will learn NOS if it is not an explicit goal that she possesses. According to Motivational Systems Theory, motivation cannot exist without a goal and goal achievement cannot exist without motivation. By this explanation, the hope that Ms. Mangrove will teach NOS has crashed before the ship ever sailed. Her case, however, does not end here, because other factors in Motivational Systems Theory affected her lack of goal establishment.

Emotions about NOS. Ms. Mangrove admitted to feeling "a little guilty" about her lack of NOS instruction and even stated that "it's kind of sad to admit" (Mangrove, I3). Such feelings could be explained by an understanding of the value of NOS instruction. This emotional

connection was also validated when she described having “lofty ideas about science” and “wanting to teach it” (Mangrove, I3).

In an attempt to solicit other emotions that the teaching of NOS may carry for her, I asked how she would feel if she was pressed to teach NOS. She used the word apprehensive twice in her reply:

> *I would feel a little apprehensive. Just because I haven't done that before. I know it would be. I would totally have to reformat everything, all my materials that I’ve built up. If I had somebody who's in there with me doing the same thing, I would probably be more ready to do it…. I feel a little apprehensive for those reasons. Students are just trained to plug and chug and I don't know if I necessarily have time based on everything else that I have to do. Just reformatting everything myself is kind of a daunting task (Mangrove, I3).*

Ms. Mangrove admitted to feeling anxious about implementing more NOS instruction into her teaching. She felt unprepared, unsupported, and overwhelmed. Earlier in Interview 3, Ms. Mangrove was able to name only one lesson from that semester where she was confident that she taught NOS and failed to think of any additional topics that could be used to teach NOS. These negative emotions toward NOS that Ms. Mangrove verbalized do not correspond with her positive emotions concerning the value of NOS instruction. The negative emotions concerning her personal NOS instruction likely stem from her lack of confidence in her own abilities as well as the context factors that she perceived as affecting her teaching of NOS. These personal agency beliefs are addressed in the next two sections.

Capability beliefs about NOS. When discussing her classroom NOS instruction, Ms. Mangrove most often spoke about context beliefs that inhibit her from teaching NOS, but she did sometimes speak about her own capabilities. Ms. Mangrove was always a good student herself, so I was surprised to hear her readily admit that she is not prepared to properly teach NOS.

I don't know if I necessarily always understand the content well enough to create nature of science inquiry-type projects. I mean, like earlier in this interview, I couldn't think of another topic that would help me, where I could apply nature of science, so I mean I think I had good training, but I don't know if I had enough to... I don't think I focused enough on nature of science in my intern year to feel comfortable to just jump in automatically (Mangrove, I3).

In the above statement, Ms. Mangrove discussed that she thinks she received adequate training concerning NOS, but perhaps this was not enough. She also recognized that she lacks practice with implementation. Additionally, Ms. Mangrove once again connected inquiry to NOS, affirming the idea that she feels inquiry is needed or important for NOS instruction. Soon thereafter, Ms. Mangrove spoke about her ability to create inquiry experiences in a negative light, saying "To create an inquiry lab, I feel like I would just have to know everything. And maybe that's not true. Maybe I don't need to know everything" (Mangrove, I3).

In Interview 4, Ms. Mangrove lightened her assessment of her ability to successfully teach NOS. She started the conversation about her confidence by admitting that she was unsure. She stated, "I always tried to teach it, but I never felt like I reached as many students as I wanted to" (Mangrove, I4). In her usual fashion, Ms. Mangrove then had to think aloud in order to talk herself into an answer. After discussing borrowed inquiry lessons that "wouldn't always work" and would therefore "ding my confidence a little bit" (Mangrove, I4), Ms. Mangrove decided that she was fairly confident in her ability to teach NOS, but that there was always room for improvement. Specifically she said, "I would say that I am fairly confident, but I am always trying to refine things and make them better" (Mangrove, I4).

Context beliefs about NOS. Ms. Mangrove's discussions of context beliefs focused on living and non-living constraints. Time was the most recurring contextual theme for Ms. Mangrove. Her perception of the demands of the curriculum and the limited amount of time that

she had to achieve student understanding of the curriculum greatly affected her perception of her ability to include activities and instruction that she perceived as going beyond the required content. NOS, like literacy, falls within this category of extra-content concepts that Ms. Mangrove felt must be forfeited for the success of content.

> *At the end of the day your job is to make sure the students learn this content that they are graded on so then you kind of shift over to, "well let's learn to use this equation because that's what you are going to be tested on." So. It's kind of sad to admit (Mangrove, I3).*

She made a similar argument another day that was much more impassioned:

> *There's not always time to. You can't always spend five days on one concept to really let them be fully in-depth investigative and use their increased skills and develop all these creative ideas. You know, you just, you have to move on. You have to stick on pace or else I'll never get through the content. And then they don't pass the class and you get in trouble because they fail their EOC. It's just. You know. Yeah. . . . It's time mainly. External factors (Mangrove, I4).*

The context of the state curriculum standards for the course that she taught greatly affected her classroom practices. The looming end of course test (EOC) that counts as 25% of each student's final grade caused Ms. Mangrove to shift her foci away from other ideas and concepts that she also feels are important. In Interview 3 she said, "As the science teacher . . . I kind of feel like I have these lofty goals. These lofty ideas about science and I want to teach it, but I just . . ." In Interview 4, she similarly stated that "the content standards and the EOC pigeonhole you into teaching certain content certain ways." To her, these certain ways rarely include NOS.

Ms. Mangrove's perceptions about time, the curriculum, and the EOC all stem from the context of her school and its place in the county and state systems:

> *I think that the other teachers in my school want to teach the nature of science more than we do. But, we just really don't feel like we have the support to do that. I think that people who write the standards don't really understand the nature of science (Mangrove, I3).*

I don't think principals understand the nature science and so just from that lack of understanding, I don't think they really support it. Maybe if they did understand, then they would be more prone to like be on our side and more receptive to us when we're like, "hey, you know, you tell us that you want us to teach more in depth but you don't give us time. We need to develop- let the students develop these ideas and investigate them." But I would say teachers are receptive, administration and state level not so much (Mangrove, I3).

The description that Ms. Mangrove gives of her principals and the state, demonstrates that she clearly does not believe that her context is supportive of NOS instruction. At one point, completely unprompted, Ms. Mangrove started discussing things that she felt would need to change in order for her to successfully teach NOS. Two of her points, support and student prior knowledge, address context beliefs:

And also, if like I had administrative support or state support saying like, "all right, let's tone it down on the state multiple choice testing, and let you do... teach more inquiry and nature of science and things like that." And also, I feel like students need to be trained in inquiry. By the time they are in high school they're so used to this like just very structured "you tell me what to do and I do it" thing (Mangrove, I3).

This chain of reasoning blamed her lack of NOS instruction on a lack of support from administration and the state as well as students and their prior training. Coming from both sides, Ms. Mangrove gave up her agency related to NOS. Her connection of inquiry to NOS is noteworthy, because she feels that student understanding of inquiry and the ability of students to utilize inquiry in science learning is necessary for NOS instruction. She feels that the culture of students' prior science learning has not prepared them for NOS instruction in her classroom. Ms. Mangrove's beliefs about the contexts that affect her classroom play an important role in the lack of formation of an NOS goal.

Conclusions on Ms. Mangrove's motivation. Teaching for student understanding of NOS was not a priority goal for Ms. Mangrove. She felt that it is important and could possibly

see it being a goal in the future, but for this semester she claimed that she barely teaches it, does not feel support from the system to teach it, and doubts her abilities to successfully teach it. Ms. Mangrove felt that she learned a sufficient amount about NOS in graduate school, but that she needs more training, more practice, and more support before she will ever successfully teach NOS. Time is the biggest factor for Ms. Mangrove, even to the point where she mentioned the burdens of time constraints on multiple occasions without any prompting. Similarly, she mentioned the exhaustive nature of the state curriculum standards before institutional goals were even discussed. She felt the pressure of the state and her administration to cover the core content of the courses that she taught and for her students to succeed on the standardized EOC tests. She did not see a way for NOS to fit into these time constraints and therefore reluctantly admitted that she does not teach NOS. Taking these issues into light, Ms. Mangrove lacks the capability beliefs and context beliefs required to be motivated to teach NOS. She also felt anxious about her ability to teach NOS. These three missing components of the motivation equation led Ms. Mangrove to not even accept NOS as a feasible goal. She is very practical, and it seems likely that she would not fully develop a personal goal if she did not believe that she was capable of accomplishing it.

Skill for teaching NOS. Ms. Mangrove's stated lack of a goal concerning NOS instruction, as well as her emotions and personal agency beliefs concerning NOS, led to lack of motivation to teach for NOS understanding. This culminated to mean that NOS instruction was very unlikely to occur in her classroom. Without motivation and witnessed attempts to teach NOS, it is hard to comment on the actual skill on this topic that she possessed or the actual responsiveness of the environment in which she was operating. Implied within skill is an understanding of NOS that is in line with the accepted definition of NOS, because it has been

demonstrated that proper NOS instruction is dependent upon the teacher possessing an adequate understanding of NOS (Lederman et al., 2001)**.** I will, therefore, start this discussion of skill with a description of Ms. Mangrove's understanding of NOS and then move to her pedagogical content knowledge for NOS instruction.

Understanding of NOS. In conversation, Ms. Mangrove connected scientific literacy to "appreciating the process of science" (I3). She claimed to focus on student understanding of the scientific process with specific emphasis on experimentation and reevaluation in order to extend previous knowledge. She claimed to teach the process of science by involving the students in laboratory experiments that may or may not be inquiry based. She claimed to not "do much with scientific articles, just from a time standpoint" (I3) which implied that she felt scientific articles could be important to scientific literacy for some people. Ms. Mangrove had a hard time orally defining the nature of science in Interview 3. She said, "Okay, so the nature of science is where you, you um. It's a continual process where you reevaluate previous findings and you retest, you create new technologies or new ways of thinking about in order to better understand" (I3). This definition and the surrounding explanations confused NOS with scientific processes and how scientific knowledge is created. Ms. Mangrove was aware of her confusion and failed to rectify it. As she continued to discuss NOS, Ms. Mangrove focused mainly on two characteristics of science; the need for repetition in science and the tentativeness of science. This personal emphasis in highlighted in the following quotes:

> *An experiment has to be repeated many many many times and gotten the same results many many many times before the vast majority of people are going to believe it (I3).*
>
> *It's a continual process (I3).*

So I just kind of focus there, like "oh you see, you know, we start here but we advance with what we know and we review what we thought we knew and we make the theory kind of fit the evidence, and you know reevaluate the theory based on our new evidence"(I3).

These descriptions of science focused on the empirical nature of science along with a caveat for change, especially concerning new technology and new evidence. Ms. Mangrove was very comfortable with the tentative nature of science to the end that the changing history of atomic theory is the only example of NOS instruction that she remembered having taught this year. With the phrase "before the vast majority of people are going to believe," she additionally hinted at the peer-review process, which I discuss as the argumentation component of NOS. The call for repetition also speaks to argumentation, but from an empiricist, experiment driven perspective:

[Scientific knowledge] is constructed from repetition of experiments and, you know, reevaluating previous findings and using new technologies to retest something or test something in a different way so you can change it or you know disregard it or reformat it (I3).

Despite her confusion with explicitly trying to define NOS and her tentative, empiricist description of science, Ms. Mangrove's answers to the VNOS questionnaire indicated an adequate to sophisticated understanding of most of the tenets of NOS. As a former practicing scientist, Ms. Mangrove expressed an understanding of NOS that takes into account creativity, social and cultural influence, and argumentation. She discussed her direct interactions with bias in a professional setting, and even though she expressed a desire for it to be removed, she did understand that it is a part of all scientific knowledge. She said that "science and scientists strive to be universal and as unbiased as possible. However, I do believe that scientists carry cultural, political, and other biases" (Mangrove, VNOS). She expressed an awareness of the social influences that affect how science is created and the science itself.

Ms. Mangrove also especially valued the theory-laden nature of science to describe phenomena and the tentativeness of science throughout time. She wrote that "science is also continually performed, retested, reviewed, revised" (VNOS). She accepted tentativeness as helping secure better understanding and increasing the predictive power of findings. According to Ms. Mangrove, "theories and laws are important because they help explain the world around us and what we see and why things happen and they help us predict if something is going to happen again" (I4).

Ms. Mangrove did struggle with three of the NOS tenets. One of her struggles dealt with theories and laws. She valued theories and laws, but presented them in a hierarchical manner that theories are not yet fact like laws, but could eventually become laws:

> *Scientific theory is supported by current evidence, but it's still not considered fact and is therefore still subject to investigation. Scientific law has such an overwhelming amount of supportive evidence that it's considered fact and it's not as readily investigated (VNOS).*

Her struggle with the difference between theory and law also revealed an issue with the tentative nature of science. Her general discussion of tentativeness expressed an understanding of science as "continually under revision based on collection of new evidence" (VNOS), but her discussion of the difference between theory and law displayed some underlying confusion. Her discussion of the word fact and subsequent discussion of investigation creates a continuum of science that can be more or less tentative. She never describes laws and facts as being permanent, but her confusion on the issue revealed an emerging understanding that still requires further growth.

Ms. Mangrove also struggled with an understanding of the lack of a universal recipe-like method for doing science. She claimed that experiments are required for the development of scientific knowledge, a view that excludes many facets of science like observational astronomy

and observational biology. Without experiments, Ms. Mangrove questioned how we can truly know things.

Ms. Mangrove demonstrated a layered and complicated understanding of NOS that ranged from naïve to sophisticated for different tenets. Her firsthand experience with scientific research, when working with medical treatments, helped shape her understanding of NOS. Her dealings with other scientists and their biases helped her come to understand the impact of society and culture and the importance of peer review and revision. The empirical nature of her work may also have influenced her naïve views on the importance of experiments.

Classroom practices. Ms. Mangrove's understanding of NOS did not clearly translate into classroom practices. My classroom observations of Ms. Mangrove revealed no specific NOS instruction. There was some emphasis placed on student created explanations of demos and experiments, but these explanations were never extended beyond written exercises and were not explicitly connected to the practices of scientists.

In her last two interviews, Ms. Mangrove mentioned two times where she felt that she taught the nature of science in her classroom. The first of these surfaced in Interview 3. She described how she presents the history of atomic theory to her chemistry classes as a lesson in the nature of science. She claimed to intentionally highlight the tentative nature of science through the changes in atomic theory that have occurred over time. She said:

> *When I present Democritus's idea and I'm like "is this how you guys see the atom currently?" And they are like, "no." So that kind of thing. Lecture and discussion. . . And then how it's just changed, and changed over the years until we got to the quantum mechanical model. So I just kind of focus there, like "oh you see, you know, we start here but we advance with what we know and we review what we thought we knew and we make the theory kind of fit the evidence, and you know reevaluate the theory based on our new evidence." So that's where I kind of hit on the nature of science in chemistry (I3).*

Ms. Mangrove said that she intentionally taught the changes that have occurred in atomic theory. She self-reported that she did so with a PowerPoint lecture and minimal class discussion. She did not claim to directly connect this information to the tentativeness of all scientific knowledge nor did she reference *explicit and reflective* instruction, as the protocol of this study necessitates for proper NOS instruction.

During the rest of Interview 3, Ms. Mangrove struggled to think of any other time than her atomic structure unit when she taught NOS in her classroom. During Interview 4, after some time to rest and contemplate her NOS instruction, Ms. Mangrove additionally claimed to teach NOS concepts during the gas laws unit. When discussing that it is easier to teach NOS in some units than others, Ms. Mangrove said that "with gas laws it's kind of- it's easier to focus on that nature of science and teach it as a process" (I4). I then asked her how she taught NOS during gas laws. She responded:

> *I tried to get them to investigate. I did a lot of demos to just kind of get them to make predictions before we actually saw what happened in that kind of thing. And then use the law to kind of describe what they saw and explain. To the use this theory to explain the phenomena (I4).*

This description of NOS instruction creates scenarios for students to think like scientists and view science as a process, but it does not speak to any specific NOS tenets. Her attempt to connect this type of learning to NOS, harkens back to her confusion between NOS and inquiry. Ms. Mangrove seemed unaware that participation in authentic scientific practices, without explicit and reflective engagement, does not promote growth in student understanding on NOS (Aydeniz et al., 2011; Bell et al., 2003).

Responsive Environment. It is exceptionally hard to comment on the actual responsiveness of the environment in which Ms. Mangrove taught science. Principals rarely visited her classroom and probably never saw her teaching NOS which could have prompted any

direct feedback concerning their beliefs about NOS. As long as NOS instruction does not interfere with successful standardized testing, it is unlikely that NOS instruction could directly affect her employment. This is, of course, all speculation, because Ms. Mangrove's exceedingly limited NOS instruction never presented enough stimuli to solicit a response from her environment. Ms. Mangrove's context beliefs were similarly untestable, because they were rooted in concepts that that could not be directly observed, tested, or questioned. Her biggest context belief was based on the perception that there is not enough time to teach NOS and address the other obligations of her job. The state or her principals never told her that there was not enough time, and this perception could not be properly tested without trying to teach NOS.

Perceived factors that affect NOS instruction. Ms. Mangrove expounded on several factors that she thought affect her ability to successfully teach NOS, but foremost was time. She did not feel that she had time to teach NOS. She openly admitted that, "I don't always feel that I have time to do it. Which is not so good" (I3). When asked about other factors, Ms. Mangrove always came back to time. "It's time mainly. External factors," she said in assorted iterations. She wanted time for preparation and time for training, but most often she focused on curricular constraints not allowing for other content, because there is not enough time:

> *Just the sense of time . . . . You have them for 90 minutes every day, but you have to get through like, sometimes three concepts in a day in order to keep pace with all of these standards you have to get through, and so there's not always time to. You can't always spend five days on one concept to really let them fully in-depth investigative and use their increased skills and develop all these creative ideas. You know, you just, you have to move on (I3).*

Ms. Mangrove also said that "you have to stick on pace or else you'll never get through the content. And then they don't pass the class and you get in trouble because they fail their EOC" (I3). In both of the above quotes, Ms. Mangrove directly blamed the intricacies of the

content standards for constraining the instructional time that could otherwise be spent on different endeavors.

Similarly, Ms. Mangrove felt that the state and local content standards are not supportive of NOS instruction. After claiming that the science teachers in her school want to teach more NOS, she stated that “we just really don't feel like we have the support to do that. I think that people who write the standards don't really understand the nature of science and they don't understand necessarily all of the concepts that they are asking us to teach our students” (I3). On several occasions, Ms. Mangrove speculated that emphasis should be removed from standards and testing to allow time for NOS instruction. In Interview 4, she said, “But if we like really tailored those content standards we could get more time to focus on NOS. If we cut some of the fluff out that we don't really need. Like the regurgitation stuff.” Ms. Mangrove stated a dislike for recall-based testing and the time constraints that this places on her ability to teach NOS. In her mind, the structure of the standards does not support NOS instruction and therefore there is not time for her to teach it.

In her desire to connect NOS and inquiry, Ms. Mangrove also named student training as a potential factor on NOS instruction. The lack of inquiry training and open-mindedness, according to Ms. Mangrove, influenced her ability to teach NOS:

> *I would say student training. They seem to be trained to want to be told the answers… They don't want exceptions to the rules. They want one way all the time, one process, one answer. Which, you know is not like the nature of science. There's a million different ways to approach a problem. There's a bunch of different ways to interpret data (I3).*

Ms. Mangrove sees student desire for memorization and lack of interest in inquiry as a road block to NOS instruction. She felt that this should be addressed in earlier grades, so that students could properly utilize inquiry and therefore learn NOS in her classroom.

Ms. Mangrove sighted several other factors with lesser emphasis. These included her own understanding of NOS, her own ability to create NOS lesson plans, a lack of equipment for high-order inquiry experiments, safety issues concerning chemicals and inquiry, and a lack of proper inter-school collaboration for NOS activities and methods.

Conclusions on Ms. Mangrove's goal achievement. Ms. Mangrove did not achieve goal success concerning NOS instruction. This is largely due to the fact that she did not possess NOS as a goal, but several other factors come into play when analyzing her case within the parameters of Motivational Systems Theory. It is likely that Ms. Mangrove refused to recognize NOS instruction as a goal because she did not feel that she would be likely to succeed at it due to her personal agency beliefs. Ms. Mangrove expressed concern about her ability to properly teach NOS, a lack of support from her administration, and a lack of time for inclusion considering all of the other tasks and goals that were required of her. Ms. Mangrove did not state personal agency beliefs that supported the success of an NOS-based goal. Whether because of the personal agency beliefs or not, Ms. Mangrove also failed to express an emotional connection to NOS instruction that was strong enough to solicit the creation of a NOS goal. Because of these factors and the lack of an NOS goal, Ms. Mangrove lack the motivation to teach for NOS understanding.

Ms. Mangrove also failed to teach NOS successfully, because of her NOS-related skill. Via the VNOS, Ms. Mangrove described an adequate and sometimes sophisticated understanding of NOS, but could not verbally articulate this with sufficient detail and often confused NOS with inquiry. She also never claimed to teach via any means other than indirect experimentation or teacher-centered classroom discussion. Though NOS was not a recognized goal, Ms. Mangrove did claim two casual attempts at teaching NOS, but since these lacked explicit and reflective

components, the likelihood of their success is slim (Bell et al., 1998). Without a proper NOS goal or assessment strategy, the success of NOS instruction in these lessons was unmeasured and therefore not likely a priority for the students.

Ms. Mangrove acknowledged that she should teach more NOS in the future, but she envisioned a great number of changes that would have to take place in her context and in herself in order for this to occur. These factors contributed to the greater discussion of this study and will be discussed in greater detail in future chapters.

Analysis of Ms. Williams

The following is a case study of Ms. Williams that took place over two semesters. It is based on 2 surveys, 7 block-schedule classroom observations, and 4 extended interviews. The classroom observations took place during several different honors and CP chemistry classes, since Ms. Williams taught at a school that followed a block schedule. Most topics discussed below were discussed extensively and repeatedly. Select quotes are included for their summative power and representative nature.

Biographical information. Ms. Williams is a first-year teacher at a 1,500 student high school on the outskirts of Hart County. This school year Ms. Williams taught CP chemistry, honors chemistry, and “regular” physical science. Ms. Williams identifies herself as a chemistry teacher and greatly enjoys her content area. Her chemistry teacher in high school motivated her to major in chemistry. Then she started tutoring and realized she liked that, too. So she decided that teaching was something that she could happily make a career out of. With a minor in secondary education, Ms. Williams was able to go straight from her undergraduate program into the master’s degree program at the university of this study.

Ms. Williams speaks deliberately at a measured pace. Some people might even say that she talks slowly. Ms. Williams also speaks with an accent and vernacular that could be classified by some as either southern, urban, or both. Others may associate her occasional vernacular eccentricities as just being bad grammar, but doing so removes the charm and character. Additionally, Ms. Williams is not easily excited. Her energy level tends to be low and rarely crests to medium, even when students are raucous. This is part of her personality and can be endearing, but it also can influence the pace and energy of her science classroom. In her own words, "it takes a kind of mature student to actually pay attention and especially through chemistry because it can get boring in some spots throughout. Actually, to them, a lot of spots" (I4).

Ms. Williams mentioned that she is a first-year teacher quite a few times in almost every interview. She referred to her being a first-year teacher more than twice as many times as the other first-year teachers. She was keenly aware that she was inexperienced and had room to grow. She knew that she was too lenient with her classroom rules and lost some respect for this. She knew that she was overwhelmed by the enormity of the curriculum standards to the detriment of depth and creativity. She knew that she was barely treading water at times. She knew all these things, and she knew that they will change next year. She planned to personally change them next year. Ms. Williams will no longer be a first-year teacher, and with that I hope some of the traumas and stigmas of first-year teaching also exit.

Personal Goals. In her demographic survey, Ms. William constructed a multifaceted single sentence personal goal for her classroom. She wrote, "My goal for my classroom is to create a place where students can be safe, opened to speak up, and learn science that can prepare

them for the real world as well as college" (DS). She managed to consider classroom environment, content, and forward thinking all in the same goal.

In her first interview, when asked about her goals, Ms. Williams spoke more simply, broke the chunks apart, and even forgot to highlight the safe environment aspect. She also added that she is "really trying to get them to think more" (I1). She connected this idea to her college readiness goal, because she felt that they will have to think for themselves and be more independent once they enter college. She said, "I don't baby them as much because I'm trying to prepare them for what they'll be faced with that first year in college" (I1). She then followed this statement with a slight laugh, but it was still apparent that she meant it. She expressed that she wished her teachers had pushed her more when she was in high school, so that college would not have been so much of a shock. She may push them, but she expressed another goal that she wants her students to feel that "chemistry is difficult but it is not unachievable" (I1). Preparation, to Ms. Williams, does not mean leaving them to the wolves. She expressed a willingness to scaffold and challenge them toward achievement. "It helps them a lot to know that they can do something that is difficult. It helps with their motivation" (I1).

In order to facilitate achievement of her goal to increase student thinking and critical thinking, Ms. Williams expressed in Interview 1 that she is "trying to question them as much as possible and connect everything that we do currently to things that we have done in the past" (I1). Before her Interview 2, Ms. Williams was evaluated by an assistant principal. This principal watched her teach for a full 90-minute block, scored her against a detailed rubric, and then met with Ms. Williams to discuss the scoring. Ms. Williams told me that her biggest takeaway from this experience was that she needed to ask "better questions instead of recall" (I2). She even attended a "little professional development" (I2) concerning questioning

techniques. She saw this as an opportunity to improve herself. She saw in-depth questions as a means to help pull concepts together for the students. She saw this as a goal for herself and asked to add it to the list she created in the Interview 1. Technically her goal of critical thinking would certainly embrace high-order questioning techniques, but she specifically wanted to challenge herself to ask better questions.

Institutional Goals. In Interview 1, before institutional goals were even solicited for, Ms. Williams expressed that her county was pushing to have students “prepared for whatever it is they want to do whether it is college or university or technical school or anything” (I1). She felt that it was naturally in line with her goals to help students think more critically in order to help them get ready for college. She mentioned this same goal in Interview 2 and described it as being intertwined with her own. She said, “We’re just, you know, trying to get them where they want to go and so they'll be successful whichever route they want to take” (I2). She felt that meeting their goal was easier, since it matched her own.

Ms. Williams had trouble describing an additional pressure that she felt affects her and other STEM (science, technology, engineering, and math) teachers. She could assign no direct institution to it, beyond “higher up” and “like government,” but she described a pressure to get students to “be well-prepared in math and advancing in technology and great in science” and to “build these kids up to what they want them to be and what they want them to do in the future” (I2). She felt that this pressure could translate into making teacher’s feel like it is their fault when students don’t succeed at the STEM desires of the greater powers, even though the teachers are often not the real problem. She admitted that this pressure had little sway on her classroom practices this year, mainly because she was more focused on survival, but she acknowledged that the pressure still looms and will likely have a “tremendous effect” (I2) in the future.

According to Ms. Williams, the state standards and county curricula for the courses that she taught played a major role in her planning and evaluation, but she also acknowledged that she doesn't feel much added pressure from them. She said that they overlap the expectations of most college chemistry courses, so she understands the value of the pressure that they provide. Her discussion of the standards as an institutional goal stands in contrast to her descriptions of focusing on staying afloat and not branching away from the required content because it is extensive.

Ms. Williams similarly contradicted herself concerning the evaluation model. In Interview 1 she claimed that she tries not to think about the evaluations. She claimed that she does take them into consideration, but tries to "include it in all of my lessons so it's not like when evaluation time comes I'm trying to put together this lesson in a way that I never do" (I1). By the third observation, however, Ms. Williams informed me that she was expecting an unannounced observation "fairly soon" and therefore had something cool ready every day. The *dog and pony show* is nothing new to teacher evaluations, but it was surprising to hear from Ms. Williams, since she stated otherwise three months prior.

Connection of NOS to Personal or Institutional Goals. Before the mention of NOS in Interview 3, Ms. Williams never mentioned NOS in her description of her personal goals or institutional goals. She describes critical thinking, but not about grander ideas of science.

Is NOS a goal? When specifically asked if teaching for student understanding of NOS was a goal for her classroom, Ms. Williams answered "Yes. I would say so." She said this in a measured pace, like she was deciding while she was already answering. She went on to explain her answer by saying:

> *I definitely want my kids to kind of understand the thought process behind why scientists think what they think. And I tried to kinda get them in the mindset that nothing is*

> *permanent in science. Like everything can change, and maybe one day they can grow up to be these amazing scientists that change the world (I3).*

She claimed to be interested in teaching NOS to her students. Her claim of what aspects of NOS she taught largely highlighted the tentative nature of science, but the line "the thought process behind why scientists think what they think" could potentially account for many of the other tenets (I3).

During Interview 3, Ms. Williams acknowledged that her university emphasized NOS. She said, "I went to a university that kind of pushed NOS" and that a lot of the "students that were in the education program really wanted and hoped for a lot of inquiry and NOS" (I3). She said that this emphasis is not really an institutional goal, because it does not affect her employment, but she felt that the emphasis had "an effect" on shaping her personal goal. In this sense, she partially blamed her teacher training for her understanding of NOS and its importance, which closely links in with her emotional connection to NOS.

Emotions about NOS. When discussing the emotions involved with teaching NOS, Ms. Williams reaffirmed the idea that the teaching of NOS is a personal goal for her. She said, "I think probably because it's my personal goal, it doesn't really make me nervous or anything. I want my kids, I guess, to have more NOS and to know about the process" (I3). She used the concept of a personal goal to justify her lightened anxiety concerning the teaching of NOS. For her, the personal connection made the idea of implementation less stressful.

Additionally, she claimed that teaching NOS made her feel good as a science teacher. She said, "It kinda makes me feel good when I see them using that same process and they'll just say something and I just won't be expecting it" (I3). In this quote she conflated NOS to include scientific processes and thoughtful student statements, but to her this is a part of NOS and

therefore NOS makes her happy. Founded or not, her perceptions of NOS contributed to her positive emotional attachment to NOS instruction.

Capability Beliefs about NOS. Similar to her claim that the teaching of NOS does not make her nervous, Ms. Williams also described a measured confidence in her ability to teach NOS. She claimed to be "comfortable" in her ability to teach NOS, saying, "I feel pretty comfortable. I always feel like I can be better, especially being a first-year teacher. It's going to be a learning process for me too" (I3). While stating confidence, she also realistically acknowledged her novice-ness and her potential to improve. In Interview 4, she went as far to say, "Whenever it does come up in a lecture or in a question, I enjoy teaching it," referring to NOS. Though speculative, some level of capability belief is conveyed via enjoyment of teaching a specific topic. This conjecture was back up when she was asked how much NOS her students learned. She described her practices and therefore the potential for student learning by saying, "I think I did a pretty good job" and "I think I do a fairly good job." Though she spoke about only a couple of loosely NOS concepts, she appeared confident in her capabilities.

Context Beliefs about NOS. Ms. Williams's comments about context beliefs focused on students, teachers, the county and testing. Concerning students, she felt that the student response to NOS was generally negative. Early in our discussion of NOS, she said, "I don't know if they don't like [NOS] or if they are just being jerks sometimes" (I3). Mostly aimed at one tenet, she said that her students challenged descriptions of inference being used in chemistry, specifically referencing the "discovery" of sub-atomic particles. Apparently the students said things like, "well, how did he know there was an electron and a proton?" and "that's just stupid" (I3). She said that the inability to see everything frustrated them, but it did not really deter her from

continuing to teach NOS. Conversely, she said that sometimes something from NOS clicks and they excitedly “get it,” which motivates her.

Ms. Williams felt that many teachers who went through her same graduate program want to include NOS and inquiry in their classrooms, but she claimed to not know “if the teachers that are currently in the schools want that same push.” She went on to say that “I think some of them are so used to the way things have been done, they don't really want to change” (I3). She did not therefore see much NOS instruction occurring in her school, but described no specific support for or resistance to NOS from other teachers or the administration.

Ms. Williams stated that Hart County Schools probably has a goal for “more NOS and inquiry.” Linking the two together, she reported seeing a push in the “next coming years.” Phrasing them as a possible current goal and future goal, it would be safe to assume that Ms. Williams did not perceive any reluctance from the county level toward NOS implementation.

Ms. Williams never directly referred to the curriculum standards as being opposed to NOS, but she did state that the large amount of content required for the EOC does serve as a limiting factor of her ability to teach more NOS. In this sense, the course content did not directly keeping her from teaching NOS, but it did affect her perception of instructional time, which could have influenced her NOS teaching, especially if she perceived NOS as being external to the content standards.

Considering all of these possible contextual factors, only one was described by Ms. Williams as being truly counter to her plans to teach NOS. The context of student willingness affected her ability to successfully teach NOS, but she did not see it as a fully limiting factor. It was an inconvenience, but it did not keep her from doing what she wanted. She saw obstacles, but Ms. Williams believed that her context as a whole supported NOS instruction.

Conclusions on Motivation. The factors combine favorably for Ms. Williams to be motivated to teach NOS. Ms. Williams believed that her context allowed for her to teach NOS. She believed that her skill at teaching NOS is adequate and does not really worry about it. She believed in the quality of the goal and was emotionally connected to its success. Lastly, she possessed a personal goal concerning NOS instruction. According to Motivational Systems Theory (Ford, 1992), Ms. Williams should possess the motivation that is required to initiate NOS instruction in her science classrooms.

Skill. Ms. William's ability to successfully achieve her goal of teaching for student understanding of NOS was dependent on more than her motivation. She also needed to possess the right skills and implement the right actions in order to be successful (Ford, 1992). NOS instructional theory similarly requires that in order for teachers to successfully teach NOS, they must possess an adequate understanding of NOS as well as follow the accepted practices of *explicit and reflective* instruction. The next sections break down these two components of skill.

Understanding of NOS. Ms. Williams's oral responses to questions about science and scientific knowledge construction were often free-flow and jumbled, but they managed to express an understanding of NOS that is empirically rooted in experimentation, socially embedded, and built around peer-review. At one point while describing how scientific knowledge is constructed, she said, "I would probably have to say through observations and probably prior knowledge, experiences, experiments" (I3). Soon thereafter, she said:

> *I would probably have to say a whole bunch of research, experiments because people want to know that- and by experiments, the correct experiments with not a lot of variables. And I think maybe you get a bunch of people on your side, if they see that your experiment was legit and what you did was, you know, with as little variance as possible. And probably you can just back it up, and then definitely prior knowledge. What people did in the past helps to kind of influence (I3).*

The above quotes are representative of Ms. Williams's descriptions of science and scientific knowledge construction. She emphasized experimentation and argumentation concerning the validity of experiments and conclusions. She did not discuss the subjective side of science where scientists have to make inferences based on their experiments and observations in order to construct explanations. In fact, when asked "what is a theory?," Ms. Williams equated successfully repeated experimentation to theory:

> *A theory to me is something that has been done, I guess, experimentally some way over and over and over and over again and you keep getting the same results over and over and over again. But, it still basically can be proven wrong (I4).*

While she managed to mention the tentativeness of theories at other times, her description of theories themselves bypassed discussion of human involvement in interpretation of results and acceptance of findings. Her description of theories on the VNOS survey similarly linked experiments: "theories are only experiments that have been done many times and produce the same results" (VNOS). Later in the VNOS, Ms. Williams discussed the role that creativity and imagination play in investigations of things that cannot be seen by the human eye, which implies that some interpretation must be needed for theory creation, but never directly discussed it. She also described that different scientists may consider data differently, because "people can think in very different ways" (VNOS). This idea similarly hints at personal interpretation being used in theory creation, but it is once again not explicit.

In her discussion of the role of social and cultural values, Ms. Williams accurately describes their influence on science:

> *I believe the people/scientist want science to be universal, however I don't believe that science can overcome the influence of social and cultural values. Scientist [sic] have their own social and cultural values and it is reflected in everything that they are part of (VNOS).*

Exactly how Ms. Williams perceived that social and cultural values influence scientific theories is hard to pin down, especially considering the emphasis she placed on the role of experimentation. This uncertainty was not entirely cleared up with the VNOS clarification interview questions, but she did use some words that hinted at inference and interpretation in theory development. When describing how science is tentative, Ms. Williams described a scenario where a new experiment produces results that run counter to the accepted theory which would require the scientists to “have to put another theory out there and say, you know, I think this is what happened because I did this experiment and it seemed that, you know, this previous theory was incorrect or partially correct” (I4). The concept of “I think this is what happened” sounds unscientific, but it does connect personal interpretation into the picture of scientific theory creation. Additionally, when describing Thompson’s discovery of electrons, Ms. Williams said, “And so, he assumed that it was something negative in there and stuff like that” (I4), which highlights Thompson’s inability to see the electrons and that he had to infer their existence.

Ms. Williams presented an understanding of science and NOS that was confusing and complex, but sometimes in agreement with reform documents. She knew many of the accepted NOS concepts, but did not always clearly construct these into a coherent structure. Her borderline adequate understanding of NOS is additionally evident in the NOS tenets that she chose to highlight in her discussion of her teaching of NOS.

Classroom practices concerning NOS. Ms. Williams was never witnessed teaching any NOS tenets. An additional observation session was scheduled after her announcement in Interview 3 that teaching for NOS was a goal for her classroom, bringing her total number of observations up to seven, but yet no efforts to teach NOS were witnessed. All evidence of her NOS teaching are from personal accounts during interviews.

When asked when and how she teaches NOS, Ms. Williams described her atomic theory unit. She felt it was the “perfect time to just kind of get them to thinking about” why scientists thought what they thought and how science changes over time. She claimed to highlight the thought process behind the development and evolution of scientific thought, especially in circumstances when technology precludes direct observation. She said, “I just try to tell them, you can't see everything. You have to, you know, think differently. You are not going to be able to touch everything” (I3). She described her teaching of atomic theory as consisting of a PowerPoint full of pictures and conversations about the evolution of the theory over time. In the transitions between theoretical advancements, Ms. Williams described that she would ask questions of her students like “What did he refine about Dalton's theory? Why did he refine it? What made him-what would make them think to do this” (I3)? Also, for this unit, she described a card sorting activity that simulated the periodic table and undiscovered elements that she felt “took them through maybe how science is thought” (I3). Other than this one activity, Ms. Williams described her quintessential unit for infused NOS instruction as being a teacher-centered walk-through of the history of atomic theory. Reflection on NOS tenets was minimal in her description, but the tentativeness of science was portrayed as often emphasized. Ms. Williams explicitly mentioned that it is “a little bit easier to teach that non-permanence in atomic theory versus a lot of other subjects” (I3). She discussed the tentativeness of the history of science as being easier to understand than the tentativeness of currently accepted scientific facts. She said, “It’s kind of hard to teach it, because you are trying to teach them that there is, hehe, that this stuff is what it is” (I3). She laughed while she said it, but she recognized that much of the chemistry curriculum is presented as facts to be memorized and not as parts of a theory that

could change. Her understanding of content as facts led to her decision that in “some units I don’t really bother” (I3) with NOS for fear of confusing students.

Other than her atomic theory unit, Ms. Williams admitted that her teaching of NOS is sporadic. She stated:

> *I can't think of the last time I taught it, because I kind of just throw it in here and there. And sometimes it's not really that I intended it for it to go in that lesson, but a student will ask a question and then I'll say, you know, "oh, why?" And just ask questions that kind of lead to it. . . . It tends to be sporadic, like when a student has a question. I probably should make it more intentional (I3).*

Similarly, she also said, “I really don't plan to teach NOS, but if it comes up, then I throw it in there” (I4). She claimed to teach NOS when students ask questions challenging the logic of scientific information, like the ability of scientists to theorize the existence of electrons and protons without ever seeing them and the eccentricity of transition metal bonding. Concerning the lack of hard rules for transition metal bonding, Ms. Williams invented a hypothetical discussion with her class:

> *And I am just like, "that is the beauty of science. It doesn't always happen how we think or how we predict that is going to happen." I said, "a lot of times when different elements react, sometimes it surprises scientists, because they didn't expect for that element to react the way that it did. Or bond with who it bonded with" (I3).*

Ms. Williams explained her normal NOS instruction as mainly being quick comments to ease student concerns about the unpredictability of science and wonders of the natural world. This, paired with her NOS-themed history of atomic theory unit, may be all of the NOS instruction that her students received. Little about this instruction would be explicit and even less would be reflective.

Responsive Environment. Ms. Williams self-reported teaching some NOS during the course of her first year teaching. Though she admitted that she did not teach it often or in great detail, she did feel that she had taught some NOS. She even felt confident that she did a “fairly

good job of explaining to them how . . . nothing is set in stone in science in general. Everything can change" (I4). During Interview 4, which was within one week of the end of the school year, Ms. Williams reported no environmental objections to her teaching of NOS. Instead, her mentioning that her school district likely encourages more NOS instruction only validated the idea that no one or nothing did anything to inhibit her NOS instruction. It is also evident that she had little to no outside encouragement to teach more NOS, other than the NOS slant of my study which was revealed halfway into the second semester. Her environment was not particularly responsive to her stated NOS goal, but it also was not restrictive. This relatively neutral environment had little influence on the unsuccessful goal accomplishment.

Factors that affect NOS instruction. Ms. Williams's goal of teaching for student understanding of NOS was not fully realized because she rarely taught NOS with explicit intent and never allowed for proper student reflection on its concepts. Similarly, she never described bringing the misconceptions of her students concerning NOS to light and properly confronting them. NOS was relegated to one History of Science (HOS) lecture and sporadic responses to student questions.

In defense of her limited NOS instruction, Ms. Williams readily faulted the required emphasis on the state content standards. Concerning her self-proclaimed sporadic teaching of NOS, Ms. Williams said, "Because there is such a focus on trying to get through your content and get them to know how to do this and know how to do that, that I really don't plan to teach NOS" (I4). The feeling that they have to get through all of the content and that "they need to pass the EOC" (I4) kept Ms. Williams from teaching more NOS, which she considered outside of the required content. She connected NOS instruction with student understanding of science, but "it's not really that they are pushing for them to understand" (I4). Instead, Ms. Williams felt that there

is “a big push for them to know how to do it on paper” (I4). In this case “it” refers to the science content that kept Ms. Williams from teaching more NOS. Additionally, Ms. Williams felt that there will be “even more pressure” to focus on the required content after the transition next year from a county chemistry EOC to a state EOC.

Similarly, Ms. Williams expressed that if NOS content were included in the state content, she would definitely teach it more often. As it stands now, however, she is not likely to plan for NOS instruction, “because they're not going to be tested on it and their scores reflect our scores and all that” (I4). She recognized that she is unlikely to waiver from the required content, because her job and her compensation are dependent on the scores of her students on the EOC which addresses only certain content. If NOS is not a part of this required content, she is unlikely to focus on it.

Time is another negative factor that Ms. Williams discussed. The goals of content coverage and EOC success are time consuming to the point where Ms. Williams feel that there is “just no time really” for extra NOS attention. She felt that extra time or lessened standards could allow for more NOS instruction. She said,

> *I would probably think Hart County could cut out some standards and get more... Less concepts to cram into one semester or one year and kind of focus on quality and not quantity. … but so that you can really go into it and not just surface it* (I4).

When discussing factors that affect NOS instruction, Ms. Williams also expressed that her school district would probably be more open to NOS instruction “if they could have research to back why they should teach NOS” (I4). It would be fair to say that Ms. Williams could probably handle to read said research as well, but she did not directly state this.

Concerning students as factors in NOS instructional success, Ms. Williams floated both ways. Students who are excited about science and truly understanding science make her excited

to teach NOS, while students who are argumentative and do not want to have to think for themselves make teaching NOS difficult. She also spoke of previous student training as a factor that affects her ability to teach NOS. She noted that many students come to her thinking of science as a collection of facts and desiring for her to maintain this trend. She stated that it would be helpful if they would come to her with some understanding of science as a process and the tentativeness of science, so that her discussion of NOS would be easier. She saw their pre-existing test-driven, step-wise understanding of science thinking as being a negative factor to her ability to teach NOS (and inquiry).

Other mentioned factors included unique student questions that ponder NOS and the training that she received from the university during graduate school.

Conclusions on Ms. Williams. Ms. Williams wants others to think of her in a good light, and she knows how to answer questions to best promote this. On several occasions, however, her answers seemed slightly contradictory when confronted with the realities of first-year teaching. Ms. Williams claimed to not worry much about the evaluation rubric, but when she was expecting an unannounced observation, she admitted to over planning in an effort to impress. She also stated that she asked challenging questions of her students in order to help them gain critical thinking skills, only to craft this into a goal once her school evaluator informed her that her questions tended to be recall focused and lower-order. Similarly, Ms. Williams described NOS as a goal for her classroom that she was excited about and comfortable achieving, only to reveal in the next interview that content impeded her NOS goals and that she should probably be more intentional in her future NOS planning and teaching. This is not to call her a liar or a flip-flop. Ms. Williams likely wants to believe the things that she said. She wants to do what she and others perceive as the correct thing, but she also recognizes that teaching is hard and never ideal.

Despite possessing a goal to teach NOS and the proper motivation to attempt to meet this goal, Ms. Williams did not describe an appropriate understanding of NOS or appropriate NOS instruction. The NOS instruction that Ms. Williams did describe was not congruent with the accepted practice and what she was taught in graduate school. She did not appear to exaggerate her NOS instruction in an effort to positively promote herself. Instead, her descriptions of her NOS teaching suggest that she has honestly forgotten the preferred method altogether. Ms. Williams would likely be the first to admit that she has room to grow concerning NOS, but the hurdles that stand in the way will not naturally be remedied by increased teaching experience.

Analysis of Ms. Shirley

Below is the case study of Ms. Shirley. It is based on two questionnaires, six classroom observations, and four interviews. The case was constructed using InVivo and thematic coding, through the lens of MST.

Biographical Information. Ms. Shirley works too much. She is a second-year science teacher, but she is much more than that. She is the coach of the school's swim team, serves on many school committees, and sings in the faculty choir. She also seems to constantly be on bus duty and bathroom duty. In the fall semester, she also taught two classes that were outside of her biological training and were brand-new to her. Needless to say, Ms. Shirley spoke honestly when she said, "I feel like I don't have enough time to do everything right now… I don't feel like I ever plan" (I1). The second half of this quote is not exactly correct. Though Ms. Shirley's planning period during the school day was often occupied by other school duties, she did stay after school to plan and grade. She rarely left school before 6pm.

In spite of the empty building and setting sun, Ms. Shirley stayed late at Creek Side High almost every day searching for activities and labs that would help her students learn the material

that the curriculum standards for her courses required. Even though one of her classes was an elective that had no standardized test, Ms. Shirley felt an intense urgency to finish the standards. In Ms. Shirley's mind, however, merely covering the standards was not enough. She felt that student understanding and student participation hinged on having lessons that were enjoyable. Never wanting to be the boring lecturer, Ms. Shirley searched endlessly for activities that her students would both enjoy and learn from. I witnessed students counting colored beans for population estimates, measuring pipe-cleaner larvae for forensic entomology, and growing seedlings under weird conditions. Ms. Shirley willingly stuck her neck out on countless occasions for the sake of enjoyable, interactive learning. She was still a novice, so several times the proverbial axe fell on her extended neck. In her words, several of her activities "crashed and burned." I am smiling while I type this, because I loved it. I would take a thousand incorrectly cut larvae and moldy, dead plants over a boring lecture any day. The students still had something to talk about and inquire about, and Ms. Shirley learned how to make things better for year three.

Ms. Shirley wanted very much for her students to enjoy science class and eventually come to appreciate science. She loved science most of her life and wanted her students to come to this conclusion as well. Ms. Shirley established smaller goals to build towards this greater goal before she even met me. She had them written down in a folder, but was able to transfer them to my demographic survey without even looking. Ms. Shirley is a goal-oriented person, who dedicated much of her time to reaching her goals and trying to improve her classroom.

Personal Goals. Ms. Shirley listed both general goals and science specific goals on her demographic survey:

> *Goals in general: 1) create meaningful lessons that connect material (that has to be covered) to real life. 2) improve student mastery and retention.*

Goals in science: they relate to the above goals → Science specific; Creative Labs and projects that are meaningful and get students into science. Rather than pounding info into their heads, I want students to learn and enjoy science at the same time (DS).

The goals that Ms. Shirley listed play into three basic themes that she reiterated when she further described these goals in her first two interviews. These themes are meaningful relevance, mastery and retention, and enjoyment of science.

Ms. Shirley felt that relevance is greatly important to science instruction. She claimed to be constantly trying to figure out how to make the required material relevant and interesting to the students. She felt that relevancy is important because “if it’s relevant and it’s interesting to them then they are going to … pay more attention” and therefore “behavior will hopefully be better” (I1). She also expressed that with increased student attention and interest the students will “hopefully understand it better” and do better on their evaluations and her evaluations. She also said that “if it's cool to them then maybe they'll look into it more” (I2). The concept that students are more likely to think deeply and learn the required material if the lessons are relevant and interesting, is an idea that Ms. Shirley returned to often when discussing her goals for her classroom.

Improving student mastery and retention was another goal that Ms. Shirley described. She planned to do this by utilizing relevant and thought-provoking teaching methods, like higher-order questioning and creative, inquiry driven labs. She explained her interest in mastery and retention as being more about “conceptual understanding as opposed to just [treating the students like a] sponge and then pppth [defecation noise]-ing out on the test” (I1). She expressed that content mastery is more important than test performance, but that “I am just hoping that that will play into higher EOC scores” (I1). She felt that relevant and interesting teaching for conceptual understanding would probably lead to increased EOC scores.

Ms. Shirley also hoped that her relevant and interesting teaching style would encourage students to appreciate science. She expressed that “most kids they don't like science” (I1) and often find science to be boring. She said that she desires for them to like science because she likes science so much. She said, “I like science, so I want them to like science, duh. I just think it's interesting and science plays into everything” (I1). She felt that all students should have a basic understanding of science and should enjoy science enough to continue to be inquisitive on their own. In order to foster an appreciation and enjoyment of science, Ms. Shirley claimed to often tirelessly search for relevant and interesting lesson ideas.

Right before winter break, Ms. Shirley added two more goals to her list of personal goals. Her first new goal concerned classroom management. She claimed that at times her classroom was “pretty chaotic” and often “just crazy” (I2). She desired for this to not happen again. So she made it her new goal to outline and adhere to “clear and finite procedures and expectations that they know to follow” (I2). Ms. Shirley also added an explicit goal to include more inquiry-based labs in her teaching practices. She had previously expressed interest in creative and meaningful labs, but decided to intentionally focus on inquiry as a means to increase student thinking, involvement, and interest. She expressed that learning is “meaningful to them when they figure it out or when they come up with something and they do it” (I2) and that inquiry is the way to achieve this.

Institutional Goals. When asked about institutional goals that affect her science classroom, Ms. Shirley stated that “pretty much everything that we do now is institution run” (I2). She went on to describe a countless supply of goals that are passed down by institutions that are often in response to goals that are set by other institutions. She mentioned that her school, the local government, and the federal government are all involved in goal setting that puts pressure

on her classroom. She briefly mentioned many institutional goals including increased ACT scores (100-90-90-90), increased rigor, pacing guides, and the introduction of Common Core and the Next Generation Science Standards, but she spent most of her time discussing curriculum standards and the new evaluation model.

The first institutional goal that Ms. Shirley mentioned was the state curriculum standards, and she constantly returned to this theme even when describing other things. She claimed that the standards have a tangible effect on her daily classroom practices. She expressed concerns that the standards can be too broad and too detailed, to the point where teachers often feel that they must "lecture them down their throats" (I2) at a crazy pace. She described that "they give us the standards that we go by and if we have time we can put in next her stuff that we think is interesting that we like. But most the time we don't have the time" (I2). Ms. Shirley described this lack of time as spanning across courses and units and not allowing teachers to be creative or try new things. She felt that the standards that were passed down to her from the state supersede the National Science Standards and any goals she may set for herself. She did, however, state that she likes the standards and that "the tests they make [based on the standards] are relevant to the courses" (I2).

Ms. Shirley also discussed the state's new evaluation model as an institutional goal. While stating that "our evaluation process now is pretty demanding on the way we teach," Ms. Shirley acknowledged that "I didn't really alter that very much" (I2). She claimed that she did not have to adjust her teaching habits much in order to fit into the new evaluation model. She said, "Because I feel like what we learned in school in graduate school in undergrad school, we were doing that stuff anyways" (I2). Ms. Shirley felt that the evaluation system was an institutional

goal that affects her, but that her graduate school training helped her to be well prepared for their goal.

Connection of NOS to Personal or Institutional Goals. Ms. Shirley could not remember the last time she consulted the National Science Standards, because they did not directly affect the institutional goals that affected her classroom. Before NOS was mentioned, Ms. Shirley spoke nothing of NOS or any concepts related to NOS. Her goals to be meaningfully relevant and increase student mastery of and interest in science were quite worthwhile and important, but did not include NOS themes.

Is NOS a goal? When asked if NOS was a goal for her classroom, Ms. Shirley said, “I think subconsciously, yes. But it's not like one of those things in the forefront. I feel like the things I do in the forefront all go to that, but I am not just thinking exactly about that” (I3). She described an innate desire for her students to learn NOS that is rarely directly realized in her classroom. She felt that she teaches NOS occasionally, but that it is not included in her deliberate classroom goals. She did, however, mention that her other goals inherently go toward NOS themes, but she never backed up this statement with details. According to Motivational Systems Theory (Ford, 1992), goals must be salient in order to be properly motivating. Specifically, goals must be “conceived of in terms that are sufficiently clear and compelling to be able to direct a person’s behavior in concrete ways,” which requires “specific intentions and a continuing commitment” (Ford, 1992, p. 255). In this sense, Ms. Shirley’s self-reported subconscious goal for NOS instruction cannot be considered a legitimate goal, because she stated no identifiable intentions that could have been committed to or measured.

Emotions about NOS. Ms. Shirley’s emotions ranged considerably concerning NOS. She waffled when discussing its importance, saying, “I don't feel like it's not important, but it's

not like… Now I feel bad, like I should be like ‘rahhhh,’ hehehe, but I don't” (I3). In this quote the ideophone was said enthusiastically, implying that she felt like she should be excited about NOS instruction. On many occasions in Interview 3 and Interview 4, Ms. Shirley expressed regret for not teaching NOS. There is the possibility that her regret was built on the guilt of failing to do something that she believed that I value, but either way she recognized that someone views NOS as important.

Capability Beliefs about NOS. When discussing her current level of NOS teaching, Ms. Shirley expressed no concerns or worries about her capacity. She discussed talking about NOS tenets with her students as if they were regular science conversations that required no additional planning or worries. Her description of her capacity changed when asked how she would feel if she were to teach more NOS. She stated that teaching more NOS would probably make her feel “overwhelmed at the beginning, trying to figure out what are things that we can do” (I3). She claimed to not know enough about NOS or NOS activities to teach it much more often. She also became concerned that appropriately teaching NOS would take a lot of work, because “it would be different for each student, so it would even be more work, because I would have to personalize their learning” (I3). This perception that NOS instruction requires differentiation was rooted in her belief that NOS includes inquiring and critical thinking skills, which will be discussed in the skills portion of this analysis.

In Interview 4, when Ms. Shirley struggled to remember situations when she taught NOS, her perceptions of the challenge of NOS seemed to change. She joked about not wanting me to judge her for her failings and then announced that teaching NOS is hard. She soon changed this to “it’s kinda hard,” but maintained the challenge of teaching NOS within the confines of strict curriculum standards.

Context Beliefs about NOS. Ms. Shirley described her context beliefs concerning NOS with a condition that all other goals would also have to be met. She said, “I feel like most institutions would support it, but they also want the bottom line” (I3). The bottom line that she mentioned here refers mainly to EOC scores and evaluation standards. As long as the teaching of NOS does not interfere with other institutional goals, Ms. Shirley felt that NOS instruction would be supported. She later discussed that NOS instructions could work together with regular standards based teaching, though immediate payback from such may be slow coming.

Ms. Shirley went into more detail about her contexts beliefs concerning her school principal. She said, “I feel that the people at my school would be very supportive because I feel like our principal's definitely for personalized learning and thinking outside the box and developing your own thoughts and stuff” (I3). Her description of NOS in this circumstance is greatly expanded beyond the accepted VNOS tenets, but with this expansion, she still felt that NOS instruction would be supported.

Conclusions on Motivation. Ms. Shirley expressed interest in making NOS a goal and expressed guilt for not teaching enough NOS, but NOS was not a legitimate goal for the duration of this study. Her emotional connection and her capability beliefs were not strong enough to carry her self-proclaimed subconscious goal into reality. Without specific intent to carry out NOS instruction, to call it a goal would be a misnomer. She might have subconsciously wanted to teach more NOS, but this does not succeed in making it a true goal. Ms. Shirley felt that she had a supportive environment for her definition of NOS, but her personal beliefs and emotions kept her from committing to an NOS goal.

Skill. Ms. Shirley expressed an understanding of NOS that does not perfectly match the NOS that she taught or the NOS that she expressed plans to teach in the future. Her

understanding of NOS is described in the next section, which is then followed by a discussion of her actual classroom practices with NOS.

Understanding of NOS. Ms. Shirley described a notion of NOS that is more about questioning and thinking than an understanding of science itself. She expressed an interest in the process and the "wonderment." She was perfectly comfortable discussing science in terms of "trying to understand how and why things function" and with "tak[ing] the steps" to answer questions that one "desire[s] to understand" (VNOS). This casual perspective allowed her to discuss science without emphasizing the empirical or subjective nature. Instead, she wrote, "Although the outcome may not be as expected, experimentation allows for personal feedback (why/what did I do wrong?) and development of thinking" (VNOS), which only hints at both. How is it decided that the results are not as expected? And how is the development of thinking different from inference-based conclusions? Answers to these questions could not be filled by many of Ms. Shirley's responses to the VNOS.

Sticking with her theme of science being about constant questioning, Ms. Shirley expressed firm belief that science is always changing and that science can be done via many avenues. She described theories as tentative stepping stones to future theories by saying, "without the knowledge of theories, they cannot develop into more complex ideas or spin off new understandings." She said that "theories change because our understanding of concepts change" which can be caused by questioning, experimentation, or observations. Untied to a specific scientific method, Ms. Shirley expressed that scientists can "follow set guidelines or come up with [their] own steps" (VNOS).

To answer the deeper questions of NOS that Ms. Shirley avoided directly stating in writing and in oral questioning, some digging and interpretation had to be utilized. She described

science as being “something more finite” (VNOS) than religion and philosophy, which connects with the empirical nature of science and could be interpreted as erring toward empiricism, but she also constantly referred to theories as “ideas that scientists have thought of and developed,” which hints at subjectivity and inference and that the data does not directly lead to conclusions. She similarly discussed the influence of personal beliefs, biases, interpretations, and cultures as unavoidable in science, which can account for a relatively sophisticated understanding of the socially involved tenets.

Ms. Shirley’s only real struggles concerned the tentativeness of scientific laws and the difference between theory and law. Though a little vague, she was correct to say that “laws have been observed to always happen” (VNOS). Conversely, she was not correct when she wrote, “Theories have the ability to change, while laws are finite” (VNOS). These sentences could be interpreted as standing in opposition, because her concept of laws always being observed in the past does not necessarily preclude future changes. Since she clearly understands the role of tentativeness with theories, her confusing statements concerning the tentativeness of laws place her overall understanding of tentativeness as adequate. Her conception of laws as being observationally based and more finite than theories is largely on track and therefore adequate by NOS standards.

Ms. Shirley’s last sentence in her response concerning creativity in science explains her focus on questioning and wonderment in science. She wrote, “My personal opinion is that when anyone wonders, their imagination takes over” (VNOS). To Ms. Shirley, science is more than a collection of facts. Science is more of a journey. She held a fairly sophisticated understanding of many of the NOS tenets, but did not choose to dwell on these in her thinking of science or her teaching of science.

Classroom practices concerning NOS. When asked about her understanding of NOS, Ms. Shirley jumped immediately into describing the tentative nature of science and how she talks about this with her students. She eventually got around to also describing that "there's not one set way" (I3) to do science, the difference between the natural and the supernatural, and the role that beliefs and culture have on bias in science. She discussed teaching all of these things, but her discussion always circled back to tentativeness. In all circumstances, her descriptions of how she taught NOS used narrative words like telling and talking. "We talk about how scientists use science" (I3). "I tell kids that yes, we do things in a certain way and yes we understanding things in a certain way, but 10 years from now they'll be different" (I3). She said that she mainly talks about NOS at the beginning of each semester and then also when she introduces current events. She felt that current events made it easy to "talk about how… this new finding" (I3) builds upon previous understanding and demonstrate the tentative nature of science. In all her descriptions of how she teaches NOS, Ms. Shirley discussed talking and telling about NOS components without ever mentioning activities or in-depth discussions. She described a teacher-centric surface-level mentioning of NOS. On two occasions she noted that "I don't usually say . . . nature of science" (I3). Instead she just mentioned talking about NOS concepts when she feels that they are relevant. She portrayed her teaching of NOS as incidental and infrequent.

After claiming that her instruction of NOS was a subconscious goal and that her conscious goals naturally go toward NOS, Ms. Shirley spent some time trying to connect NOS to inquiry. From there, her oral descriptions of NOS always seemed to include inquiry and critical thinking skills. She expressed that the "new standards" will likely push more NOS because of their emphasis on "thinking and processing and analyzing and connecting" (I3). These ideas are generally respected in science classrooms, but they are not necessarily connected to NOS,

despite Ms. Shirley's conjecture. Later, when discussing factors that affect NOS instruction, Ms. Shirley discussed that students need to try "to figure it out for themselves" and need resources in order to "figure out and tie things together" (I3). When describing her principal's supposed support for NOS, she described his approval of "personalized learning and thinking outside of the box" (I3), which have little to do with NOS and a lot to do with inquiry and critical thinking. She also stated that "they don't test the way NOS would assess things" (I3) which describes NOS not as a specific content, but instead as a specific way of thinking for understanding that has a preferred method of assessment.

In Interview 4, after a couple weeks' time to process NOS, Ms. Shirley jumped back into her description of NOS that includes inquiry and critical thinking. She felt that her Crime Scene Investigations elective class was very applicable to NOS, "because they were hands-on and they were thinking and developing" (I4). She claimed that this was not "like in-your-face this is nature of science," but instead a more indirect way that included questioning and "thinking about how would this be different." The biggest problem with this description of NOS is that it may be so not in-your-face NOS that it is not in fact NOS anymore at all. Soon thereafter, Ms. Shirley started using NOS and inquiry interchangeably. The only activity she ever directly described as NOS was just an inquiry experiment that required justification, but did not highlight any NOS tenets.

Ms. Shirley's fairly sophisticated understanding of NOS never really made it to her science classrooms. Her understanding of a couple of tenets was casually told to her students intermittently throughout the school year. On the other hand, she did intentionally include a fair amount of inquiry and critical thinking in her classroom activities. Her assumption that inquiry and critical thinking are a part of NOS could have led her to the conclusion that she was

moderately successful at teaching NOS in her classes, but even this was not the case. Ms. Shirley had significant trouble thinking of times when she taught NOS and expressed a feeling of guilt for not giving it more time or emphasis.

Responsive Environment. Ms. Shirley's limited teaching of NOS went unnoticed by her environment. She claimed to never have referred to it as NOS, so the likelihood of anyone associating it with NOS was probably very slim. At this point, little can be said of the responsiveness of Ms. Shirley's environment to NOS.

Factors that affect NOS instruction. Ms. Shirley's confusion between NOS, inquiry, and critical thinking may have served to cloud her discussion of factors that affect her ability to teach NOS. Her call for computers to aid with research on inquiry-based assignments was a direct connection to inquiry, but other than tha,t most of her answers were fairly vague. For the most part, the factors Ms. Shirley described make sense in light of the accepted definition of NOS as well as her modified description.

Ms. Shirley's biggest described factor concerned the standards. She felt that the standards greatly affected what she taught and the amount of time that topics get. At times she expressed being overwhelmed by the standards. She said, "I'm down to the wire to get everything done that I have to get done. And I am not trying to put in a lot of extra fluff this semester" (I4). The standards took most of her time, and she felt uncomfortable teaching beyond them, "because if you don't cover this, then they might not know this [other thing]" (I3) and so on. She also claimed to be focused on "differentiation and different learning styles and try[ing] to do different things" (I4), which when paired with the standards did not leave much time to plan for NOS instruction or classroom time for NOS instruction.

Ms. Shirley described that equipment, tools, and resources would be needed in order to do a better job teaching NOS. Stating that “like we don't have any money” (I3), Ms. Shirley made it clear that money would help with the procurement of tools and resources for NOS instruction.

Ms. Shirley also described that she could handle more training concerning NOS. She said, “I guess maybe even my own misconceptions about it. I mean I don't know every single thing about every single thing” before suggesting “maybe more development for me, so that I can like relay it over” (I4).

Related, Ms. Shirley described a couple times that she was never really taught about NOS in any of her science classes. She said, “Maybe also because I was not taught that way. I mean, even through college, science classes did not really talk that way” (I4). She felt that she would probably have a better understanding of NOS and a better ability to teach NOS if she had been taught science that included more NOS.

Ms. Shirley also felt that her ability to teach NOS would be greatly aided if her students came to her already knowing a little about NOS. Concerning student learning and acceptance of NOS, she said that “I feel like if it's taught at a younger age it would be different when they are older” (I3). She felt that NOS would be helped by the “development of student thinking at younger ages” (I4), which she felt is going to be aided by the implementation of Common Core in the coming years. In general, Ms. Shirley expressed belief that Common Core and the NGGS will help her ability to teach NOS in the future. She expressed a feeling, that she admitted was not founded in research, that each of these documents will encourage student thinking and will promote and support NOS instruction.

Conclusions on Ms. Shirley. Ms. Shirley's stated subconscious NOS goal stayed largely in her subconscious. NOS instruction was never noticed during classroom observations and her self-reported teaching events consisted of only telling students about NOS ideas as they related to the content they were already discussing. It is therefore unlikely that any of her instruction was adequately explicit or reflective. She also reported that she never explicitly referred to anything as the nature of science or NOS in her classroom. In this light, Ms. Shirley did not successfully teach NOS this school year. She largely admitted this when discussing her guilt and her desire not to be judged. This does not mean that Ms. Shirley is not a good teacher. She tried very hard to keep her lessons relevant, energetic, and standards-based. She cared about whether her students learned and whether they came to appreciate science. She just did not really teach NOS.

Ms. Shirley's NOS instruction did not succeed because she failed to make it a specific and tangible intention. This was likely exacerbated by an unclear emotional connection to the importance of NOS. She expressed guilt for not teaching it more, but never directly said that it was important and worthwhile. Without an emotional connection and a conscious goal, Ms. Shirley lacked the motivation to properly teach NOS. This was not helped by her confused oral conception of NOS. Intentional NOS was rarely displayed, so her skill at properly teaching NOS remains untested. Ms. Shirley's NOS instruction did not "crash and burn." Instead it lacked the energy to even get started.

Analysis of Mr. Solo

The following is an analysis of Mr. Solo, the only third-year teacher in this project. It is built around two surveys, four interviews, and six classroom observations. The observations took place in a CP biology class and an honors biology class that were taught on a regular schedule

for the entirety of the 2012-2013 school year. The data were coded using InVivo coding and thematic coding in order to create a picture of Mr. Solo and his connection to NOS and his students. The categories below present select quotes that serve to represent grander themes and foci that were evident throughout the data sources.

Biographical information. It would be hard for a person to observe Mr. Solo's classroom and not walk out saying something about how great of a teacher he is. His classroom demeanor is strong and jovial, caring and demanding. The pace is fast, but he repeatedly assesses student comprehension and pushes students to think for themselves. When students are stumped by his constant questioning, he sticks with a student and scaffolds questions to help build that student toward the desired understanding. His PowerPoints are always attention grabbing and full of pictures and models. The students often work in small groups to achieve common tasks. Mr. Solo's classes are energetic and involved. By most modern definitions of quality teaching, Mr. Solo is extraordinary. This is not to say, however, that he does not have his issues. Mr. Solo often uses worksheets to teach and reinforce material, which is not in itself a problem, but on multiple occasions worksheets were noted to contain factual issues to which Mr. Solo admitted to having borrowed the worksheets from a co-worker and not having put adequate time into making sure it was correct or pertinent. So time management and planning may be an issue for Mr. Solo. Also, he admitted to struggling with making the expansive biology content relevant to his students. He understands the importance of relevance to student interest and higher-order thinking, but acknowledges that it does not happen as often in his classroom as he would like it.

Mr. Solo was a scientist before becoming a teacher. This reflects in his love of nature and his appreciation of science. As a field biologist, he studied salamanders, but he always loved birds. He self-reported being "a birder" and even cracked a couple of ornithology jokes during

interviews. (NOS also stands for the National Ornithological Society, which may account for some of his confusion about the nature of science.) Mr. Solo's interest in the outdoors and in the living world reflects in his desire to teach and in his teaching. During Interview 1, he said, "I'm a true naturalist at heart really. I like to know everything about everything around me. And so I sort of just wanted to pass [that] along." Mr. Solo sees all science as important and relevant. Even though he struggles with making his content consistently relevant, Mr. Solo considered relevancy one of his most important classroom goals and actively sought to achieve this in his classroom.

Personal Goals. Mr. Solo expressed five clear goals, in no particular order, on his demographic survey. He listed:

1) Relevance! Reaching uninterested kids.
2) Be a positive role model
3) Positive influence among other teachers.
4) Service
5) Student comprehension/mastery of content (DS)

Mr. Solo expounded on these in Interview 1. His goals and his discussion of those goals revealed the well-rounded nature of Mr. Solo's connection to the teaching profession. Not only did he care about getting students to understand the required content, he also wanted to "hook 'em" and get them "interested in learning about science, rather than thinking it is boring or too hard" (I1). Additionally, beyond cognitive and affective goals with science, Mr. Solo also wanted to be a positive role model for his students and for his school. He viewed teaching altruistically and as a way for him to give back. Mr. Solo summarized his second and fourth goals by saying:

> *I've only got a certain amount of years on the planet, so I don't want to waste it. I want to be doing something that is valuable and I think teaching is a valuable thing because I am interacting with 100 students a day and I might be the only positive thing that goes on that day for that kid (I1).*

Mr. Solo viewed teaching as “fulfilling intrinsically because you really are making a difference every day” (I1). To him teaching is a way to make a difference and serve others. He discussed not only serving his students, but also serving the other teachers in his school. He said that he always seeks to be positive and upbeat with co-workers, but beyond that, Mr. Solo was in the unique position of already being a lead teacher at his school. He claimed to have had successful outcomes in terms of measurement criteria which his administration recognized and said, “Hey, you are doing something right. What is it?” (I2). Mr. Solo was asked to evaluate other teachers in his school using the county evaluation model and help “spread some good things and some advice and some understanding of how the rubric is” (I2). He claimed that his graduate school training helped with his success and his accomplishments within the evaluation process. Even though he was (and is) likely going through significant changes in his own perceptions of teaching and science teaching, Mr. Solo got to help other teachers along the way. He incorporated this into his overall goals and actively sought to help his school community, further proof of his dedication to the school and the students.

In the end, Mr. Solo explained that of all his goals, mastery is the greatest. He felt pressed for time with an extensive curriculum, and so “we need to learn what we’re going to learn every day, so my goal is to get those kids comfortable with constructing what they are going to understand” (I1). His verbiage is key here and holds potential for his teaching capability. He speaks about helping students construct their own understanding and not just content coverage. The content is important, but student effort concerning that content is what Mr. Solo claimed to value in the goals for his classroom.

Institutional Goals. Mr. Solo subdivided the institutional goals that he was aware of by school-level and district-level. As an active part of the leadership team at his school, Mr. Solo

felt that the school's goals were worthwhile and aligned with his own goals. He stated that "our school's goal is to take a holistic approach to the human beings that we are teaching. So we really want to help them be academically successful, but also contributing members to society" (I2). He felt that this was the correct avenue for addressing education and helping students grow.

Concerning district-level goals, Mr. Solo was not so kind. He claimed alignment with the overarching district goal of student success, but that the implementation strategies are often lacking. He said:

> *I guess where maybe things don't align are how we get there and I think it would be more advantageous to have people who have been educators rather than politicians making these decisions or least helping make the decisions for the politicians. You know, because it seems like sometimes we are looking at decisions made, as in who in the world thought of this stuff (I2).*

Mr. Solo spoke about education needing to operate more like a business if it is going to attract new and qualified teachers. This would take time and money that he does not see in play at the moment. He also spoke of veteran teachers needing more time and training to adjust to top-down initiatives. For all his ranting, Mr. Solo recognized that getting through the mandated curriculum was the only real institutional goal that truly has an effect on his classroom. When asked how much he considers the standards in his classroom plans and practices, Mr. Solo answered "completely." This word encapsulates the control that the standards and end of course testing hold over Mr. Solo, but it also portrays acceptance and willingness. In other statements, Mr. Solo went on to describe that he considers standards from the state in every lesson and even has them posted in his room for easy access and to serve as an accomplishment checklist. He said that at the beginning of his career he was unaware of the role that standards would play on his life, but he now works with this institutional goal in order to help his students and his school shine in the eyes of the greater institution.

Connection of NOS to Personal or Institutional Goals. Mr. Solo did not mention anything NOS related in his personal or institutional goals. The emphasis that he placed on content mastery and that the state places on standards-based testing have the potential to include NOS topics, if he considers NOS content to be a part of the standard curriculum. This is not, however, the case. Mr. Solo described his teaching of the imbedded inquiry content as being only "uses of technology and lab equipment and explorations in science" (I4). He claimed that this content is largely untested and is a "feeble attempt to connect inquiry." Mr. Solo claimed to really only teach this content incidentally through regular classroom activities and does not consider it a part of his content mastery goals.

Defining NOS. A slight deviation from the basic case study structure is required at this point, because of Mr. Solo's vocalized perception of NOS. Over the course of the final two interviews, Mr. Solo described an understanding of NOS that is not aligned with the conventional definitions of NOS. Mr. Solo did not dissect the phrase and think about the "nature of" a concept and what that tells about that concept. Instead he discussed nature of science as if it was a compound word from a vocabulary list that he was given in graduate school. With little to no hesitation, Mr. Solo described:

> *My understanding of nature of science is it's more of an inquiry-based level of understanding of science rather than a memorization flip card understanding…. So my understanding is that it is really trying to figure out and trying to explore creatively why things are happening and how they happened in the science world (I3).*

Mr. Solo described NOS as a means to an understanding of scientific content as opposed to content itself. Mr. Solo seemingly confused NOS with the idealized science classroom that focuses on constructivism, inquiry, and higher-order thinking. The concepts he described as NOS are considered appropriate and worthwhile for science learning, but they are not NOS. This incompatible conception of NOS is depicted throughout his interviews and much of the rest of

this analysis. At times, his description of the issues that affect his ability to teach “with” NOS could parallel with factors that could affect traditional understandings of NOS, but the extent of this connection is largely unknown.

Interestingly, Mr. Solo’s description of scientific literacy began with the inclusion of some topics that are traditionally considered part of NOS, but his definition mutated to parallel his description of NOS by the end. He started by describing scientific literacy as “what does a student understand about the process of science and the process of making, developing theories and performing experiments and coming to conclusions and sharing that with other people” (I3). These are ideas that sound like NOS components, but he went on to describe the “deeper” parts of scientific literacy. He felt that in order for students to be scientifically literate, they need to see the interconnectedness of life and connect the big pictures together. This latter half matches his stated goals for relevance and content mastery, but fails to stick with the scientific processes theme that he started with.

Is NOS a goal? When asked if teaching for understanding of nature of science is a goal for his classroom, Mr. Solo responded, “I would like it to be, but no. No, I don't think it is” (I3). He went on to describe that it is a good goal to have, but that the political nature of education keeps him from it. Almost immediately, he cited and blamed the test-based culture for affecting his ability to teach NOS and his desire for more structured standards with less subjectivity. Eventually he circled back to whether NOS was a goal. He bluntly said,

> *So I feel . . . like it would be a good goal to try to teach nature of science more. I feel like I like that more. But I also feel sort of stunted by some of the logistics and political stuff that goes on (I3).*

For Mr. Solo creating a goal concerning NOS instruction was not logical or feasible. He felt that he had too many other things to do than to worry about NOS instruction.

Emotions about NOS. Mr. Solo's emotions concerning NOS were generally positive and were often reflected his regret for not doing it more. "Innately, I want to do that. I would love that. But professionally I don't do it very much" (I3), he said, before explaining hindrances. He said that teaching NOS "would be ideal for teaching" but that "we're set up for a more rigid, standardized way of life, unfortunately" (I3). Later, he said, "But when I think about myself teaching it, I wish I did more" (I3). The regret for not teaching more of his definition of NOS was often quite apparent in Mr. Solo's discussions of NOS. Therefore, it is obvious that to some degree he emotionally valued NOS, even though he did not manage to teach it often. Excuses given when none were asked for validated a level of regret or remorse and a belief in the importance and value of NOS instruction.

Mr. Solo also directly described the value of NOS and inquiry. He said, "The nature of science and scientific inquiry. I mean that's where we should be as a country, and I think that's where we fall behind as a country in education" (I3). This was immediately after a discussion that "there are great powers than the beauty of science." The dichotomy between his descriptions of the ideal and reality was managed by regret and acceptance, but does not deny his understanding of the importance of NOS (and other reform-based concepts).

Capability Beliefs about NOS. Mr. Solo felt that he is capable of teaching NOS, though he admitted that this confidence is largely untested. He said, "I think I could do it. I haven't been in that environment is the thing. So I don't know. But I think I am capable. I think it would be very enjoyable." He went on to describe the revitalization that he may receive by learning alongside his students and helping them explore concepts and come up with their own ideas. He did, however, describe his capability and interest in an inquiry-based classroom and failed to incorporate conceptions of NOS that are aligned with accepted NOS understanding, but this was

his understanding of NOS. He described the NOS training of his graduate school as being “not very effective” (I3). He described learning about NOS and learning “some strategies that would be possibly beneficial, but nothing that changed or revolutionized his world” (I3). He emphasized that his major professor was not to blame for the faults in the training, instead focusing on the daunting power of the realities of the classroom. To revolutionize his classroom actions concerning NOS may have taken a great deal more training and justification. He claimed to be comfortable with what he did know, but that more training would likely be helpful.

Context Beliefs about NOS. Mr. Solo expressed on multiple occasions that support for NOS would necessarily be contingent on how students did on their end of course testing and their value added scores. He felt that support from his principals and staff would be completely dependent on these factors. The support, he claimed, is in whether your value-added score is great, then “keep doing what you're doing” and if the score is not good, “then I would not have support in any of it” (I3). In a later interview, he stated that his school and school district probably has “not much” interest in the teaching of NOS. A discussion of the emphasis placed on test performance led Mr. Solo to conclude that, concerning the teaching of NOS, “I don't think it's a priority with our system” (I4).

Based on his definition of NOS, Mr. Solo also described the importance of student interest. He felt that “it depends a lot on the student” and that he needs the students to “meet me halfway” (I3). On multiple occasions he described his students as not doing that this year. He described this as a barrier to NOS instruction by saying:

> *There were a lot of circumstances where I felt like the students weren't willing to put in their efforts to even be engaged in that kind of thing. So engagement was pretty low this year. And that's unfortunate because it's less fun for me to teach and less fun for them to learn. So it's kind of a nasty cycle when that happens (I4).*

This nasty cycle and the perceived lack of student effort and interest served as a contextual barrier to NOS instruction for Mr. Solo. He felt that his students were not ready for NOS or could not handle NOS, given their regular efforts in class.

Conclusions on Motivation. Motivational Systems Theory (Ford, 1992) describes motivation as the combination of goal setting, emotional connection to that goal, and personal agency beliefs concerning that goal. Mr. Solo valued NOS instruction and felt that he is probably capable of proper NOS instruction. He also felt that his school and school district do not necessarily stand in opposition to NOS, as long as his students still perform well on their standardized tests. All of these could have worked in favor of Mr. Solo being motivated to teach NOS in his classroom, but other aspects stood in his way. First, he felt that often his students lack the motivation and effort to actively participate in NOS. Secondly, and most importantly, Mr. Solo had not accepted NOS as a goal for his classroom. He acknowledged that he would like to teach more NOS in the future, but he had not dedicated himself to the performance of the task. He did not feel ready to do such and he felt that other goals (namely student test performance) are much more important. All this said, Mr. Solo valued his understanding of NOS, but he was not motivated to commit to it as a goal.

Skill for teaching NOS. According to Motivational Systems Theory, goal achievement requires motivation towards a goal, which in turn requires possession of a goal (Ford, 1992). Viewing NOS instruction as a cognitive task that requires intentional attention and therefore teacher instructional motivation (Abd-El-Khalick et al., 1998), Mr. Solo was unlikely to properly teach NOS. In actuality, he was unlikely to teach his definition of NOS or the accepted definition of NOS. Mr. Solo’s confusion about what NOS is should not be construed as a lack of understanding of NOS. He orally misidentified NOS, but cognitively still possessed a fairly solid

understanding of NOS. As a scientist and a science teacher, Mr. Solo understood NOS, it just appears that he did not know to call this understanding by its formal name.

Understanding of NOS. Mr. Solo's interview descriptions of NOS do little to describe his understandings of the consensus definition of NOS. Instead, his verbally articulated description of NOS focused on inquiry, higher-order thinking, and other constructivist techniques for appropriate science instruction. Mr. Solo did occasionally describe his understanding of science and the processes of science. These descriptions were short, but they portrayed an understanding of NOS that is aligned with the currently accepted understanding of NOS. When asked how scientists construct the grander concepts of science, Mr. Solo said, "Scientists are engaged in continual research, continual review of peer's research, continually looking at new theory and new phenomenon and trying to engage in experiments or research that helps explain those phenomenon" (I3). Though simple and to the point, this description of science recognizes the importance of theories, the importance of testing theories, and the social nature of scientific argumentation. It also hints at the roles of observation and inference in attempting to explain phenomenon. Though not a perfectly clear picture of NOS or Mr. Solo's understanding of NOS, this quote does start to give us some insight into Mr. Solo's dealings with science and how he might describe these to his students.

In the more precise and prescribed VNOS questionnaire, Mr. Solo described more fully his understanding of science and NOS. His description of science was quite full and in many respects very similar to the accepted definition of NOS. The greatest eccentricity of Mr. Solo's description of science is his philosophical stance on bias in scientific knowledge. When discussing social and cultural influence on science, Mr. Solo wrote, "Science, itself, simply is. But is not affected by human values, but is rather a direct, and always occurring, entity"

(VNOS). Similarly, he also said that “Science does not judge and is not judged by human experience or values, rather simply is whether understood or misunderstood” (VNOS). He argued that science itself, in its purest form, is objective and unbiased. He argued that our understanding of the science may be clouded by bias, but that the science itself lies underneath and is unbiased. The quest for objectivity in science is undeniable, especially concerning reproducibility and peer-review, and Mr. Solo was quite explicit in his attempt to describe this. Science to him is the ultimate truth that may not be understood as of yet, which is just a modified, future-seeking definition but is not necessarily empiricist. In doing this, he not only recognized that science is tentative, but he also recognized that our current understandings of science may currently be invalid due to error and bias:

> *If you are talking about people's sort of morals or religion or ideals and things like that, they don't affect science in itself as science. Science is the studying and exploration of phenomenon, but unfortunately being human and subjective, human beings with ideas and emotions and beliefs, I think sometimes they are integrated and historically I think that has been the case, but as far as legitimate science I don't think that there is a direct tie of how culture and sociology should affect the actual process of science, but I think it does in a lot of cases (I4).*

The above quote summarizes his philosophy on bias and science pretty well. He recognized the importance of objectivity to scientific endeavors, while acknowledging the underlying subjectivity of much of our science. By taking a unique philosophical stance on this topic, Mr. Solo was better able to describe a difficult NOS concept.

Similarly, Mr. Solo’s descriptions of other NOS tenets were thorough, aligned, and fairly sophisticated. He spoke often of the importance of theory and how theory is developed through observation and idea construction. His description of tentativeness was multi-faceted, while his delineation of theory and law was not only correct but also impressive. His only real struggles dealt with creativity and subjectivity. He failed to describe all levels of science requiring

creativity and imagination, instead only citing preliminary science components as requiring imagination. He said,

> *I believe imagination plays a large role in distinguishing and planning investigations. Many discoveries required scientists to "think outside the box" whether culturally or what was previously known, and may even be unrecognized for their contributions or even (in the case of Darwin) ridiculed for decades (VNOS).*

This description of creativity in science affecting decisions on what and how to start scientific investigations and the planning of said investigations then extended into examples. These examples reiterated his naïve description by highlighting creativity in brainstorming and planning only. They did not extend to creativity in data interpretation.

Concerning dinosaurs, Mr. Solo described gaps in scientific evidence as leaving "room for opposing scientific explanations" (VNOS). He followed this with a parenthetical that said "which is ok." With this, Mr. Solo managed to describe the role of inference in scientific explanations and his acceptance of the implied subjectivity. At other times, however, he described subjectivity and human influence as negatives. He wrote, "Without testable solidification, human disposition or subjectivity can become part of a theory" (VNOS). This partially matches his philosophy about science by nature being separate from bias, but it confuses the role of inference in theory making. Mr. Solo's varied connection with inference and subjectivity can therefore only be classified as emerging.

Mr. Solo's description of science was largely sophisticated, but he did struggle with a couple of tenets. Mr. Solo understood much of the nature of science, even if he did not know to call it such.

Classroom practices concerning NOS. I cannot really say anything of Mr. Solo's skill at teaching NOS concepts to his class. In six separate classroom observations, spread out over a full semester, I never encountered Mr. Solo teaching or discussing NOS tenets. Though I cannot

account for the approximate 84 school days I did not observe, I never heard the words theory, law, or tentative. Instead, science concepts were presented as facts that needed to be memorized and understood. Though questioning often pushed students to make connections between concepts, the concepts were not themselves questioned or discussed as parts of a changing whole. It should be noted that I did not witness the evolution portion of Mr. Solo's biology classes, where discussion of broader science concepts like theories and tentativeness may have been more likely to occur.

I also never saw a lab activity. I saw a preparatory lecture for an organized dissection that was to occur the next day, which led me to believe that little inquiry or theorizing would occur. The lecture prepared the students for basic anatomy identification and outlined specific steps for proper dissection. It was mentioned that amphibians "had to make some evolutionary changes" and that "amphibians once were fish" (O6), but the students did not discuss this nor were they likely to explore this during the next day's unconnected dissection. The students did, however, seem excited about the dissection which met Mr. Solo's affective goals, but did little to directly influence NOS understanding.

Responsive environment. Because of the lack of NOS instruction in Mr. Solo's classes, it is impossible to comment on the actual responsiveness of his environment. His school and school district made no response to Mr. Solo's NOS instruction, because there was no NOS instruction present to respond to. Mr. Solo commented that few groups influence his classroom and that his administration would not care about NOS instruction as long as it does not affect the final scores of his students. I cannot comment on the validity of this context belief, because Mr. Solo chose to not test it.

Factors that affect NOS instruction. Of all the factors that Mr. Solo discussed as affecting his teaching of his definition of NOS, the greatest standout is his uncertainty in whether it could positively affect the EOC and value-added scores of his students. He self-reported that "the main focus of the end of course exam is a hard thing to ignore" and that "that's the most important thing, I would say, that anyone would say, is that the kids score well and do well on their end of course assessment" (I4). He actively considered the state standards every day in his lesson planning and teaching. He felt a significant pull to focus on the standards and the end of course test, to the detriment of other teaching tools and potential content.

Mr. Solo considered NOS, inquiry, and argumentation to be outside of regular science teaching. He once referred to them as revolutionary:

> *[if] I was doing this revolutionary science work, would those kids be engaged in nature science? Would they be developing scientific inquiry and the scientific literacy? Most definitely, but would that increase their test scores? I don't know, and maybe not. And if it didn't, then I would not have support in any of it (I3).*

Mr. Solo considered these reform-minded concepts to be novel and untested. In the above quote he expressed confusion about the potential for NOS and inquiry to affect the outcomes of his students. At another time, he argued that NOS does not "necessarily contradict, but I don't think that it helps" (I4). He described how teachers are afraid to branch out and try new things and that because of the test, he and other teachers are "more teaching scared rather than seeking out ways to try to get the kids to think for themselves and develop their curiosities" (I4). He claimed that because of curriculum concerns, there is not time to try untested things.

Success also played a major factor in Mr. Solo's willingness to try to teach NOS and inquiry. Mr. Solo is the most experienced participant in this study, and his two years of prior teaching experience were also met with two years' worth of successful EOC and value-added scores. With this success comes a degree of confidence that Mr. Solo recognizes:

Especially if you score well and your kids have scored well on tests before and you know what you did, it's more likely that you are going to say, no I need to keep doing what I'm doing, because they did well (I4).

Though he placed the above quote in the second person, it truly speaks to his reality. He was successful. His scores and his principal said so, so he had no real reason to change his ways. He commented multiple times about starting unprepared for the politics of education and the emphasis on testing, but once he was a part of it, he willingly played his part. Doing so does not require drawing outside of the lines or doing “revolutionary science work.”

Mr. Solo also felt that student motivation also played a role in his ability to teach NOS. He referred to this year’s students as being of lower ability and possessing lower engagement than he is used to. Mr. Solo felt that this directly affected his ability to connect the lessons of his classroom to bigger picture ideas and to engage in teaching strategies that are outside of his normal routine. Perceived student ability and motivation affected Mr. Solo’s motivation to teach NOS and inquiry. On the positive side, Mr. Solo stated that he felt the year-long biology classes allowed for more flexibility and exploration, concepts that he felt relate to NOS.

Other factors that Mr. Solo felt would positively affect his teaching of NOS included observation, training, and resources. Mr. Solo felt that he and other teachers need to see what real NOS instruction looks like in order to successfully teach it. He felt that this would not only require the loosening of curriculum standards, but also extensive training. Beyond just an in-service workshop, Mr. Solo thought it would require “some pretty intensive changes of educational thought processes, because education has been the way it is for so long” (I3). Beyond training, he also stated that materials and facilities will probably be needed to facilitate laboratory-based instruction and that the students will need increased access to technology for

independent learning. And all of those things cost money, “so money could possibly be an issue there” (I4).

Conclusions on Mr. Solo. Mr. Solo is an interesting case. He is still a novice science teacher, but he is also considered to be experienced. He is heralded as an excellent teacher by his administrators and the performance of his students, yet he does not perform the reform-based practices that were emphasized in his graduate training. He performs the requirements of the evaluation model, but he can’t even recall an appropriate definition for the nature of science.

Not wanting to change the semi-structured interview protocol too much or the constructivist nature of this study, I spoke to Mr. Solo in much detail about his teaching practices that reflect the accepted definition of NOS and its tenets. I do, however, now know a great deal about his efforts to teach using inquiry and big-picture, higher-order thinking. This was his attempt at defining NOS and he did admit to failing to adequately teach in these ways as often as he would like or should. In this sense, Mr. Solo was not successful at teaching his definition of NOS or the accepted definition of NOS.

Analysis of Ms. Heffernan

Ms. Heffernan was a first-year ecology and biology teacher at Dougie High School. The following is an analysis of her motivation and goal achievement concerning NOS instruction in her science classrooms. This analysis is based on 2 surveys, 4 interviews, and 6 classroom observations. The qualitative analysis utilized InVivo and thematic coding over the extensive data set on Ms. Heffernan in order to paint a picture of the relevant information. Ideas and quotes presented in this analysis are representative of a greater body of data, which can be read in the appendix if wanted.

Biographical Information. For two years after graduating from undergraduate school with a degree in ecology and evolutionary biology, Ms. Heffernan worked as a zookeeper. She found the job rewarding but the career ladder lacking. She knew that she enjoyed doing “keeper chats” with the zoo patrons and was even told by zoo volunteers, who were retired teachers, that she should consider teaching. Ms. Heffernan did and has not looked back. She never once compared her students to zoo creatures, but she did claim to enjoy teaching as much as she did zookeeping.

During this study, Ms. Heffernan taught freshman science classes in a school that has a “freshman academy,” a concept that partially isolates freshman for their introduction to high school and further separates the student by gender for their science, math, and English courses. In the fall semester, Ms. Heffernan taught one section of CP ecology to boys and two sections of CP ecology to girls. In the spring semester, she taught two sections of CP Ecology to girls and one section of honors biology to girls. During her internship, Ms. Heffernan taught biology and physical science, but based on her major, she knew that she would prefer ecology. Though she is certified to teach biology, Ms. Heffernan was formally trained in only about 1/3 of the high school biology curriculum. She described ecology as a division of the life sciences and then colorfully announced, “None of my college courses were about photosynthesis. They were about ‘can you identify this fish’” (I1).

On multiple occasions Ms. Heffernan described herself as some variant of “extremely OCD and organized” (I1). Not qualified to comment on her supposed psychological disorders, it would be hard to ignore her statement about being organized. Papers were always in neat stacks, daily topics and assignments were written on a dry erase board and always stayed up for one week, and each lab table had its own little pouch containing scissors, a glue stick, and colored

pencils. Each student had a lab notebook and a notes notebook, both of which were required to have a current table of contents and be organized in a specific way. Their notes notebooks were so organized that Ms. Heffernan was able to treat them like a textbook in order to tell the students where to look for specific information they may have forgotten. Ms. Heffernan was so organized that it spilled over into her personal goals.

Personal Goals. Ms. Heffernan listed six goals on her demographic survey. Keeping the abbreviation, capitalization, and emphasis intact, these goals were:

· *Help S transition from mid → high sch.*
· *Enforce the goal of "rigor" in sci. class*
· *Gain understanding of nat. world and how organisms interact with each other and abiotic factors.*
· *Scores on EOC = high*
· *Teach organization and responsibility*
· *SURVIVE!!*

Many of Ms. Heffernan's goals overlap. When describing her goal to help students transition from middle school into high school, she wrote:

> *I found that they don't know how to do a lot of things like take notes, stay organized, do your homework, study. They don't know any of that stuff, so I am trying to help scaffold them if you will for how to do all that stuff (I1).*

Included in this description of what is needed for a successful transition is developing organizational skills. Likewise, when describing her goal to teach organization and responsibility, she considered it part of the transition. She described their bags as being "ridiculous" with "their papers everywhere" and that students who were absent "want you to hand them everything that they missed on a silver platter" (I1). To counter these issues, Ms. Heffernan worked hard to establish a classroom and protocols that force students to keep organized notebooks and seek out specific missed items. Schedules and class tables of contents

posted in large fonts on the walls allowed easy access for students to stay organized and responsible.

Ms. Heffernan also commented that her goal to teach them responsibility is reinforced by her need to counter the conception that has likely carried over from middle school wherein students tend to “think that their grade is just going to appear somehow” (I2). Instead she actively showed them spreadsheets of their grades and discussed the math behind their missing grades.

Her goal of rigor was also rooted in the transition from middle school. Ms. Heffernan is under the impression that ecology is perceived as an easy class, but she does not feel that having an easy science class will help them in the long run. She said, “I don't want them to come [out of] this class and think that's how their next class is going to be, so I tried to make this challenging” (I1).

Concerning the goal to have her students receive high scores on the end of course tests, Ms. Heffernan said, “That's a personal goal. I don't think it's going to happen this semester, but hopefully one day” (I1). Whether this is pessimism or realism, it is not for lack of trying. Ms. Heffernan’s efforts in the classroom were relentless. She kept the students involved in an ever rotating cast of activities and avoided extensive lecturing, not because this is what the evaluation model recommends, but because this is what she felt is necessary for success with students of this age.

Not to be entirely lost in the notion of “learning how to do school” (I1), Ms. Heffernan was intentional to include a goal concerning her content area. Claiming that “that’s why I’m teaching this class” (I1), Ms. Heffernan wanted for her students to learn about the interactions of organisms and to get a sense of the fascination that she feels concerning the natural world. Her

excitement was real and she shared it with her students often, but after announcing that a video or project is going to be fun, she was aware that her students often asked, “Is it teacher fun or kid fun?” (I2). That said, passing on her fascination with science, like high EOC scores, may take a little bit of time.

Ms. Heffernan realized that perceiving success with most of her student based goals was basically impossible to prove in the short run. She did not expect “immediate gratification” but she said that she would enjoy hearing from other teachers in the future “that so-and-so is doing really well” due to skills that were learned in her class (I1). Despite this, Ms. Heffernan did describe enjoying the rapport she has built with many of her students, citing that “they’re pretty cool little people and it's fun to see some of them most days” (I1).

Ms. Heffernan’s last goal was written in all caps with two exclamation points. She later jokingly described survival as “my ultimate goal for this year” (I1). Her plight as a first-year teacher was unknowingly summarized in the following way: “Hopefully all this other stuff will happen but I just need to make it, cause I'm still figuring it out” (I1). To her, survival was wading through all of the extra duties and expectations that teachers have to deal with that could not be explicitly taught. Survival was dealing with discipline issues while dealing with tardy entries into the computer system. Ms. Heffernan saw survival as an achievable goal, but she knew there would be significant challenges to it often.

Institutional Goals. When it comes to institutional goals that affect her classroom, Ms. Heffernan did not share many opinions on them. She merely presented them as facts that she had to address. She did not portray stress or dismissal. She just described what they are and how they affect her class.

In Interview 2, Ms. Heffernan revealed that her personal goal of rigor was handed down to her as an institutional goal. She could not remember whether it was a county-wide goal or if it just came from her administration, but it was brought up at the beginning of the year during a staff meeting. It then became a recurring theme with the administration, because "they keep talking about enforcing rigor in your classroom" (I2). She stated that she was trying to meet this goal by keeping her students busy with productive work and by giving pretty rigorous tests. She felt she was being successful at accomplishing their goal.

Another institutional goal that Ms. Heffernan discussed was the curricular goal being passed to her by the county. She said, "The Hart County science department … has some kind of agenda for what I should be teaching… They are telling me what I should be teaching" (I2). She then referenced the pacing guide, the standards, the EOC review, and the county-wide EOC test. She mentioned that these affect much of her planning for her classroom. Additionally, she mentioned that she does not have an ecology specific textbook, so she has to "use the standards to direct me as to what is important and where I need to go and in what detail." As a first-year teacher, this strategy did fail her a little, because at times she found herself unable to predict the depth that the county expected of her and her students. At the end of the first semester, Hart County distributed a review guide for the ecology EOC and allowed the teachers to preview the test a couple weeks early in order to check for errors. Both of these enlightened Ms. Heffernan of concepts that the county felt important enough to put on the test, but that she had not interpreted from the standards. Concerning survivorship curves, Ms. Heffernan said, "That's not in the standards. So either I'm not reading into it enough or they just picked something random. I don't know" (I2). The amount of time between the review and the test did allow her time to address these issues, but it may take some time before her curricular goals match those of the state.

Ms. Heffernan discussed not being bothered by the curriculum. She said, “it's nice to have an outline of what you're supposed to do, because I've never taught it before and I don't mind people saying here's what you need to do. That's kind of helpful” (I2). She also stated that she likes how few standards ecology has (even though the simple nature may have led to her under-analyzing what would be on the EOC).

Concerning all institutions that directly affect her, Ms. Heffernan admitted to being a team player and a follower. She said:

> *I just do what anyone important tells me to do when they tell me to do it. And I figure that way I'm doing what I am supposed to be doing, and if they want me to do something else they'll tell me. And then I'll do it then (I2).*

Similarly, when asked about the role that the National Science Education Standards (National Research Council, 1996) play in her practices, Ms. Heffernan expressed that she does not remember looking at them, but that she does remember studying the Next Generation Science Standards in graduate school. She then admitted that she uses neither of these to currently inform her teaching decisions. She bluntly said, “Nobody's told us to start using them, so I'm not using them. I use what I'm told to use, which is the state standards” (I2). For Ms. Heffernan, perceived institutional goals take precedence.

Is NOS a goal? When asked whether teaching for student understanding of NOS and scientific literacy is a goal for the classroom, Ms. Heffernan was rather blunt and honest. She said:

> *Really, I would say no. I mean, I want my kids to understand the nature of science, and I don't know what scientific literacy is, but I am sure it is good, but I mean really the most important thing for them is to make a good score on the test that is 25% of their grade. That's really what's most important for them at that point (I3).*

She went on to explain that the EOC does not include NOS questions, so therefore it cannot be a priority for her class. This reinforced her earlier statements that she does what is

asked of her and does not do what is not asked of her. Ms. Heffernan may have appreciated NOS, but she was not willing to prioritize it when so many other things were asked of her.

Emotions about NOS. During her explanation of why NOS was not a goal for her classroom, Ms. Heffernan made it clear that she does value NOS. She said, “I want them to understand [NOS], and I do hope that they come away from my class with it” (I3). She recognized the value of student NOS understanding, but what was missing from her descriptions of NOS is an emotional investment in its need. She felt it was important, but does not feel it is important enough to justify extra effort.

Capability Beliefs about NOS. In Interview 3, Ms. Heffernan described ambivalence towards her teaching of NOS. She commented on the issues that students have understanding the tentative nature of science and the concepts of theories, but said that this did not give her any bad feelings towards it. Likewise, she said, “I am not like super excited talking about the nature of science, but it does make for a good intro type of thing, where I can get them used to how we do things” (I3). She presented NOS as a needed part of the curriculum that she willing teaches. She did not seem particularly focused on understanding of NOS, but did feel capable of teaching it.

In Interview 4, she was more candid in her assessment of her own abilities. She declared, “I would say that I have some good like activities and stuff,” but then recognized that they may not be as effective as they could be. She said:

> *But then we talk about it later in the year or I reference it sometimes and they don't always remember what we were talking about, but that happens with anything. It's not just NOS. Without repetition they forget things. So. I don't know. Probably average NOS teaching abilities (I4).*

She was correct that students do not necessarily master a concept on the first go-round and do often forget concepts as time goes on. In this case, she recognized that her students struggle with remembering NOS, but she was quick to say that this happens often with other

content as well. She assessed her ability to teach NOS as average, which did not seem to discourage her from further NOS teaching.

Context Beliefs about NOS. Early in the interview process, before NOS was ever discussed, Ms. Heffernan said the following concerning her administration:

> *Like I can't tell you a time when an administrator has walked into my room besides an evaluation. I think as long as … you are not doing something you're not supposed to be doing, they are like okay. I guess (I2).*

Early in her first year of teaching, Ms. Heffernan came to an awareness that her principals are unlikely to be involved in her classroom unless she does something wrong. She claimed to “like it this way” and discussed that since she does not teach or act in ways that are not specifically denied, that she in turn feels “pretty free to do whatever” (I2).

In this sense, Ms. Heffernan would likely have felt free to teach NOS, since she had not been instructed not to. More so than that, Ms. Heffernan expressed that NOS is in the state science standards, and therefore expressed this as direct approval by the state and county for NOS instruction. She said:

> *They put it in the standards for like every single science course…stuff about students will be able to defend their conclusions from an experiment…So if it's in the standards, it must be important to them. Because they put in every year that I know of (I4).*

Ms. Heffernan's interpretation of the standards included NOS concepts, so she felt that this correlates to intent and interest in NOS instruction from the state and county systems.

Conclusions on Motivation. Ms. Heffernan did not prioritize NOS instruction enough to consider it a viable goal for her science classroom. She expressed appropriate personal agency beliefs of herself and her context in order to be able to successfully teach NOS, but this is not enough to actively make it happen. She expressed an interest in having her students understand NOS, but failed to express an emotional connection to NOS strong enough to make it a true goal.

Therefore, Ms. Heffernan was not motivated to teach NOS beyond the minimum that she perceived to be expected of her by the curriculum standards.

Skill. Despite lacking a goal to teach NOS, Ms. Heffernan demonstrated a clearly defined skill for teaching NOS. She did not teach it often or with much pomp, but she did teach NOS explicitly and with repeated emphasis. The contents of her skill will be broken down in the next two sections.

Understanding of NOS. Ms. Heffernan described science as a way of understanding the natural world. She further described it as being factual and focused on the tangible. She described it as being built on understanding and not beliefs. Ms. Heffernan clearly identified the importance of and the difference between observation and inference in science. She understood and valued the role of creativity in inference and conclusion making, while she simultaneously acknowledged the role of social and cultural values. She succinctly wrote that “Human interpretation/point of view/bias/creativity/etc. influences observations/conclusions drawn from hard facts” (VNOS). Further concerning creativity, Ms. Heffernan went on to say of analysis and interpretation of data that “probably the most imaginative and creative part is figuring out why” (VNOS).

Most of Ms. Heffernan’s answers to the VNOS were succinct and clearly constructivist. However, her initial description of theories and laws was confusing and would have merited a clarifying question after analysis, but she offered her own clarification before this was known. While clarifying a statement that some things in science may not always be 100% true, Ms. Heffernan discussed the difference between observations and inferences as well as the difference between laws and theories. She stuck by her use of the words fact and proven, but still acknowledged tentativeness. She described Newton’s Laws as “proven laws that we haven't

found any evidence against and are true in this universe for now," which provides a caveat for the laws to possibly have been different in the unobservable past and for our understanding to potentially change. Her description of the importance of experimentation was similarly clarified in interviews, when she stated that experiments and/or observations were required for science.

Interestingly, Ms. Heffernan repeatedly described bias removal as a part of NOS, which is not explicitly mentioned in the accepted definition of NOS. Once, she said:

> *That's part of the nature of science is that it is not supposed to be bias, but unfortunately bias is still going to exist, which is why it is important to have other people doing your studies and stuff to make sure it is a reliable outcome and not influenced by your personal feelings or opinions or what you want to happen (I4).*

She offered argumentation via peer review as the counter to implicit bias in science. She described peer review as a means to check work, validate results, remove bias, and add to the evidence and support. She felt that this is a part of what makes science science.

Ms. Heffernan demonstrated a clear understanding of NOS that was largely aligned with the accepted definition. Any potential issues were clarified in later interviews to reveal a dynamic and thoughtful understanding of NOS. She described a largely sophisticated understanding of NOS that was capable of serving her classroom and her NOS instruction well.

Classroom practices concerning NOS. When describing her teaching of NOS, Ms. Heffernan referenced several of the major NOS tenets, but not all. She mentioned the tentative nature of science, the importance of theories, the role of bias (via social and cultural values and creativity/inference), and argumentation. She acknowledged that "there's a bunch of other stuff in the nature of science" (I3), but that those are the ones she tends to think of. She claimed to focus on the tentative nature of science and on helping the students come to an understanding of what a theory is. She seemed very concerned that students think that a theory is "just a theory." She further explained that students "put the word 'just' in there and think it's some kind of wild

guess. And that's not what a scientific theory is" (I3). She went on to say that "you can explain that to them til you're blue in the face, and they still don't get it" (I3). She used this blue-in-the-face description on three occasions to highlight her frustrations with teaching about theories, especially concerning evolutionary theory. Explaining something until you are blue in the face sounds like direct instruction lecture and the teacher telling the students what they need to know, but this is not the full extent of how Ms. Heffernan claimed to teach theories and other components of NOS.

Ms. Heffernan mentioned that NOS must be taught explicitly and claimed to do this at the beginning of every school year. I saw her beginning of the semester presentation where she defined science as being the study of the natural world that is separate from religion and society, seeks to eliminate bias, includes peer-review, and develops theories. This lecture and PowerPoint went on to review the metric system, describe ethics, define theories, and describe the scientific method as a non-mandatory scaffold. On the next day, when I was not present, Ms. Heffernan claimed to have had the students participate in an activity that she called the "checks lab" in which they were given limited evidence (in the form of cashed bank checks) and tasked with creating stories to describe a unified storyline. Eventually the students were given more checks and asked to amend their "tentative explanations." Ms. Heffernan felt this activity taught the students about the tentative nature of science and the role of hypotheses and theories. She stressed that she explicitly discussed these concepts with the students after they completed the task.

Ms. Heffernan claimed to mainly teach NOS at the beginning of the year when she was teaching the metric system and (her correctly modified version of) the scientific method. She then emphasized that she returned to its major themes throughout the year, just as she does with

all of her content. She felt that laboratory activities were the perfect time to reference back to NOS and she also described having her students flip back in their notes notebooks to the definition of theory when they challenged her on evolutionary theory being “just a theory.” She expressed that having experiences at the beginning of the year, like the checks lab, eased future conversations about NOS. She said that when you were referencing topics and their associated activity, “you are not just referencing the word hypothesis, you are referencing an experience that they had, so they can remember it” (I3).

Ms. Heffernan demonstrated a thoughtful skill for NOS instruction that included interactions and explicit teaching. She also claimed that her NOS instruction showcased many of her sophisticated NOS tenet understandings. The extent to which students were given time to reflect on their NOS gains is unknown, as reflection was never observed or mentioned.

Responsive Environment. Ms. Heffernan’s context beliefs concerning NOS were confirmed in her last interview which took place about one week before the spring semester ended. She reiterated her assumption that since NOS was included in the curriculum standards this meant that the state and county approve of its teaching. In mentioning this and not mentioning other impositions, it can be assumed that Ms. Heffernan’s NOS instruction met no resistance other than student acceptance and effort.

Factors that affect NOS instruction. Ms. Heffernan expressed little concern about factors that affect her ability to teach NOS. She felt she gave it appropriate time and that this time appropriately served the needs of her students and her curriculum. She said:

> *I think that NOS gets as much time as any other unit does, because you come back to it. I teach it like the first week or week and a half…. And then we reference it throughout the rest of the semester, but I teach it the way I do everything else. I'm not going to give special thought to NOS. Just like I don't give special thought to meiosis over any other unit (I4).*

When asked about factors that negatively affect her ability to teach NOS, Ms. Heffernan started to discuss time as an impedance, but quickly recanted this. She realized that if she had more time, she would likely not teach more NOS and instead would spend more time on the interdependence and biodiversity unit, because “that's the unit that got the shaft” (I4) in her end of the year time crunch.

One of the biggest reasons Ms. Heffernan gave for not teaching more NOS is that it is not emphasized on the EOC tests that count as 25% of her students’ final grades. She claimed that “They don't ask questions about the nature of science really on the EOC. I don't think there was one on the EOC that I previewed” (I3). She also said that “It's in the standards, but it's not tested” (I3). Since Ms. Heffernan was a rule follower and taught only what she felt she needed to teach, the lack of NOS on her EOC tests was certainly a factor that affected her desire to teach more NOS.

Ms. Heffernan also mentioned a couple of positive factors that concerned NOS. She talked about how she liked starting the year with NOS, because it gives her a good platform for the rest of her science discussions. She also felt that doing lots of laboratory experiments in her class helped her teach more NOS, because the labs provided avenues to discuss NOS that lectures could not. In this vein, she also commented that her large amount of lab money, which was provided by the district based on the poverty of her students, allowed her the freedom to do more labs and therefore teach more NOS.

Conclusions on Ms. Heffernan. Ms. Heffernan taught NOS to her students. She taught many of the correct NOS tenets explicitly at the start of the semester and reiterated them when relevant throughout the rest of each course. She discussed teaching NOS tenets through a couple of activities, one of which she described in great detail. She sought out NOS activities on the

internet on her own and selected the “checks lab” for potential to be educational, enjoyable, and relatable. Ms. Heffernan has a firm understanding of NOS and NOS teaching strategies. Ms. Heffernan commented that many of her students struggled with the difference between layman’s theories and scientific theories, which may mean that more NOS teaching and more reflective teaching may be a benefit, but Ms. Heffernan is not convinced of the importance of NOS in order to justify any changes. Ms. Heffernan does not appreciate NOS enough to make it a priority in her classroom. She believes that many of the NOS tenets are covered by the curriculum standards of the courses that she teaches, and she feels that she gives it as much attention as is called for. Ms. Heffernan directly stated that NOS is not a goal for her classroom and that its status will not likely change unless it receives more emphasis in the county standards, the EOC tests, or the expectations of her superiors.

Analysis of Ms. Platypus

The following is an analysis of Ms. Platypus, a second-year biology teacher at Poison Claw High School in Hart County. It is based on 2 surveys, 6 classroom observations, and 4 interviews. Several of the interviews were quite lengthy because Ms. Platypus likes to talk. Because of this, the following analysis features select quotes on broader themes that were selected via InVivo and thematic coding.

Biographical information. Ms. Platypus is a second-year biology teacher who is much more comfortable in her second year than she was in her first. Concerning her first year, she spoke of struggling to stay afloat and of stress-induced hives that did not go away until summer. Ms. Platypus claimed that this school year was much better and no obvious skin blemishes were noticed. It is almost hard to imagine Ms. Platypus stressed out and struggling. She is organized and relaxed, as a person and as a teacher. Even when her students are loud and obnoxious, she

keeps an even keel and tells them what is up, why it is not appropriate, and what they need to be doing.

Ms. Platypus is a science teacher, but science is not always her primary focus. She seems equally driven to help her freshman biology students figure out how to be learners and be better citizens. Biology is the context, but she spends a lot of time training them to take more efficient notes, stay organized and on top of their studies, and ready to recall what is needed of them. Ms. Platypus spends a lot of time creating and reiterating visuals and memorization strategies for specific content in order to help her students with retention and understanding. Many science teachers do this, but she probably does it more than most. Ms. Platypus claims that she herself was “not that great of a student” (I1) and creates strategies that are similar to the ones she had to invent for herself when she was in high school. Ms. Platypus feels that her struggles as a student prepared her for successful teaching and give her an avenue to connect with her struggling students. Ms. Platypus readily admits her struggle in schooling to her students and uses this as a platform to explain the strategies that she implements in order to help them. This is a new strategy to me, but it does seem to have its benefits. Importantly, though praise is often distributed for all successes, her strategy placed greater emphasis on effort than natural ability. Once, after a student recalled an obscure fact that he himself referred to as an overachiever answer, Ms. Platypus said, “I wish my brain worked like that. I have to study” (O1). This deprecated her a bit, but provided an excuse and an incentive for the students who may not have known it themselves.

Similar to her relaxed and cool nature, one of Ms. Platypus’ strengths is her ability to accept the constraints within which she works and be happy with what they have to offer. She values the goals of her principal and the school model/evaluation system. She understands their

intentions and worth, and she seeks to work with them in order to improve herself, her students, and the whole school. Though she does not love every aspect of the state biology curriculum, she willingly works with it, not for fear of the EOC, but out of respect for the ideas of its creators and the unifying power of a cohesive state-wide curriculum and student understanding.

Personal Goals. When describing herself and her reasoning for being a teacher in Interview 1, Ms. Platypus spoke first about her love of ecology and her initial desire to study trees professionally. From this spawned a personal goal to educate "kids about their environmental impact and what they can do to reduce their… trash production …and to help stabilize our environments" (I1). This became intertwined with her reasoning for becoming a teacher, because she recognized that she could have a larger impact on the world as a teacher than as a biological researcher.

Her environmental education goal did not, however, make it on her demographic survey. Instead she listed six separate goals, none of which directly referenced science or NOS. She listed:

1. *Caring for all students.*
2. *Teaching each and every student.*
3. *Treating all students with respect (and I expect respect in return)*
4. *Hands on activities at least once a week.*
5. *Obtainable goals/objective each day.*
6. *Visuals on a daily basis (help students remember)*

When asked to describe her listed goals, Ms. Platypus started by saying, "a lot of my goals are student oriented rather than curriculum oriented, because I, while I care a lot about teaching the students the curriculum, I care more about the students than the curriculum" (I1). She expressed desires to care for and show respect to each and every student, to the extent that she sought out troublesome students and let them know that she still cares about them and that each day is a new day. Because of this respect and caring, Ms. Platypus claimed to have students

who get in trouble all the time in their other classes, but will do “Punnett squares for two weeks straight” (I1) for her because she asked.

Ms. Platypus took on her second goal, to teach each and every student, as a challenge to herself. She recognized that it can be hard to pay attention and help every student every day, especially the outliers. The students who struggle require extra attention, but for Ms. Platypus much of the struggle is also with the “few that, you know, are successful on a general basis” (I2). She claimed that it can be hard to attend to them and properly access their understanding and needs, because of all of the other distractions. Ms. Platypus created this goal to actively remind herself to give the successful students the attention that they too deserve.

Her goals to include hands-on activities and visuals came from Ms. Platypus’s own educational past. She placed educational value on visuals as an alternate means to successful learning and hands-on activities as a way to mix up the structure and attention of the class. She recognized that her students “get bored with the monotony of the classroom” (I1), similar to how she probably did, and saw activities as a way to alleviate some of this monotony. To Ms. Platypus, hands-on activities could be labs, group projects, posters, etc. She admitted to having trouble coming up with labs for every unit and that she fell back to posters and projects often. She said, “the hands-on activities, I'm still doing it, it's just it's not the way I want it to be. But it's still my goal” (I2). Ms. Platypus was intentional with her goal setting and did not pick only goals that she knew she could easily accomplish. Instead she picked goals that she knew would benefit her classroom and her students.

One personal goal that Ms. Platypus felt that she could accomplish was her desire to create and post obtainable goals and objectives every day. In her first year, she was informed by an evaluator that her objectives were too broad and were not attainable in only one day. Ms.

Platypus took this to heart and claimed to understand the value of having attainable goals in order to give “the students a sense of accomplishment each day” (I2). This goal was passed down to her by her school model and administration, but Ms. Platypus adopted it and welcomed it into her classroom. During every classroom observation, Ms. Platypus had simple objectives written on the board that were always assessed for mastery at the end of class.

Institutional Goals. Ms. Platypus’s personal goal to include obtainable goals and objectives daily came down to her from her school’s educational model. Her school adopted a program that was designed to improve teacher and student performance that affected Ms. Platypus’s routine daily. She embraced this model, because she valued its potential for positive change in her school. Her goal to utilize obtainable goals and objectives daily derived directly from an institutional goal of the educational model. She mentioned that her school’s educational model requires several other components, like Kagan strategies, group work, and specific formative assessment strategies, that have to be done and have to be done in a certain way. She claimed that it is strict, but that she is grateful for the training she is receiving. She also stated that she is glad that she is a “newer teacher rather than already being very experienced and trying to go back and change all my ways to make it work this way” (I2). She felt that it is worthwhile and holds all of the teachers accountable.

Ms. Platypus also recognized that her principal and her father have goals for her, but that these goals don’t actively affect her daily life. She said that her principal desires to raise the school up, not let anyone talk bad about it, and not let their test scores be the lowest in the county. She said that her father challenged her to be prepared and be knowledgeable. She said that her principal and her father want to see her succeed and want for her to do the best that she can. She agreed with all of these goals, but knew that they are mainly inspirational.

An institutional goal that did affect Ms. Platypus is the curriculum standards. She recognized that the "state curriculum is part of our lives and the state end of course exam is a big part of our lives" (I1). This does not mean that she loved everything about the standards or testing. She claimed to "hate that we spend over half of the year on a nonvisual scale" (I2) in biology, but still recognized that it is "really important for them to understand that you are made of like a billion little tiny entities that are functioning on their own" (I2). She accepted that it is different from her personal preference and gladly played along. She once said, "I follow the standards. That's what they tell me to do, so that's what I'll do" (I2). Sometimes, that is the way institutional goals work.

Connection of NOS to Personal or Institutional Goals. Ms. Platypus's personal goals contain almost no mention of science and her institutional goals only mention science in terms of required content. When asked about the National Science Standards, which highlight NOS as content, Ms. Platypus could not remember ever having read them. Similarly, when directly asked about institutional goals that her university might have for her science classroom, Ms. Platypus said, "There's not like a specific goal that is stuck in the back of my head, like chirping at me" (I2). She claimed that they would likely want her to give them a good name and that differentiation and scaffolding were ingrained in her teaching habits, but that none of these are really goals that she seeks or feels any pressure from currently. NOS is not hidden within any of Ms. Platypus's goals nor did it ever naturally surface on its own. Considering her claim to have never read the National Science Standards and her failure to connect NOS with the goals of her graduate school training, NOS instruction was not perceived as a likely goal prior to Interview 3 when it was directly brought up.

Is NOS a goal? In Interview 3, after much confusion with creating a personal definition of NOS, Ms. Platypus said that NOS is a goal for the science classroom. She said that "that's part of being a good science teacher." She then went on to describe the parts of NOS that she felt should be taught in order to facilitate good science teaching.

Emotions about NOS. Ms. Platypus claimed to have come to her understanding of the importance of NOS through participating in challenging college science courses. She liked the way that one particular ecology professor affected her by constantly challenging her with "but why" (I3) questions, even if her initial response was correct. She felt that this forced her to consider where her ideas were coming from and better connected her to NOS. She felt that the ideas of NOS have been so ingrained in her, that she can't help but embrace them and teach them.

Ms. Platypus also described the need for students to understand NOS because of the way that the world is changing and the fast progression of communication and technologies. She talked a lot about sharing and learning and students needing to be a part of this and understand it. She also described greatly valuing reasoning skills and helping students learn how to figure things out for themselves. Since Ms. Platypus considered reasoning skills to be a part of NOS, I can use deductive reasoning and the transitive property to conclude that she also values NOS and NOS instruction.

Capability Beliefs about NOS. Ms. Platypus claimed that her ecology training and the challenges presented to her by her favorite ecology professor and her science education professor have so affected her that NOS and the regular content "kind of all flows together when I teach it" (I3). She described feeling comfortable teaching it in response to student questions. She said that she prefers to teach NOS concepts one-on-one as opposed to whole-class, but in general she felt

confident in her ability to teach NOS. In fact, she said, “I am always confident in my ability to teach something. And I am not trying to sound cocky. I just am” (I4). She said this to explain how she could take on NOS or any other teaching task that was asked of her. Additionally, Ms. Platypus said that NOS is not very daunting, because “it's not something that I think about on a daily basis” (I3).

Context Beliefs about NOS. In Interview 3, Ms. Platypus commented on her context beliefs concerning her principal, the school model, and other teachers. Concerning her principal’s ideas on the teaching of NOS she said, “My principal was a science teacher, so he loves it. He loves making people think” (I3). Ms. Platypus felt that his appreciation of thinking and his praise of her encouraging her students to think justified her assumption that he likes NOS instruction. On the thinking theme, Ms. Platypus felt that her school’s educational model would likely support NOS, because NOS “pulls a little bit at each of” the different types of thinking that the model encourages: “problem solving, and curiosity, and then research” (I3). She also stated that the other science teachers in her school probably support NOS instruction. She said, “I don't know they necessarily call it the nature of science, and I'm not really even sure how thye teach in their classrooms, but when we discuss certain items it seems that they are on board” (I3). They may not call “it” NOS, because what she was describing may not be NOS, but this did not stop her from feeling support to carry out her definition, whatever that may be.

In Interview 4, Ms. Platypus added a caveat to her claim that others would love NOS inclusion. Discussing her school and the school district, Ms. Platypus said, “I think both would love to integrate it more as long as we're still covering the curriculum” (I4). She then began to backpedal even more, only to return to the same spot:

> *And right now with all the different standards and things to follow, I don't know if now would be the time. But I mean education is constantly changing and it's never stagnant.*

That is for sure. I mean, I think they'd both be open to it, just so long as it stays with the curriculum and with the evaluation system… Cause it all plays into every lesson (I4).

At that moment, it seemed that Ms. Platypus was starting to realize the extent of the influence of the curriculum and evaluation system on her statements about adding new content and goals into her instruction. She waivered, but in the end decided to stay as positive as she could within the obvious confines.

Conclusions on Motivation. Ms. Platypus claimed that teaching NOS is a goal for her classroom and she stated no contextual, capability, or emotional opposition to that goal. She felt that she was more than capable to incorporate it into her teaching and that her principal, fellow teachers, school, and school district would openly support its inclusion. She did state that that support would be present only if the inclusion of NOS did not adversely affect the curriculum and evaluation system, but she never directly indicated that her NOS goal achievement could potentially cross this line. With that said, Ms. Platypus possessed all the markers necessary to be motivated to teach her understanding of NOS.

Skill. The goal of teaching for student understanding of NOS is complex. Achieving this goal requires content knowledge of NOS and pedagogical knowledge of best teaching practices for NOS. Possession of both of these is required for a person to have the skill needed to successfully accomplish this goal. Ms. Platypus struggled in both of these realms, which are described in the next two sections.

Understanding of NOS. The first time I directly mentioned NOS to Ms. Platypus was when I asked, "What is your understanding of NOS? Or nature of science?" The following was her initial response:

Nature science. Okay. huhhehehe. um. Aww man. The nature science, I mean, it's constantly changing. It's constantly evolving and that's a good way to explain evolution to students as well. Is that I mean it's never the exact same. And you can also always talk

> *about how there's exceptions to every rule. So the nature of science in general, I guess in biology and ecology, evolution and stuff like that, it's still changing. I don't know… But the nature of science is still based on scientific evidence, scientific facts. It's been a while since I've heard that. And I'm trying so hard to remember (I3).*

Her attempt at defining NOS was a struggle that extended way beyond this initial response. She started by hinting at two key NOS tenets: that science is tentative and empirically based. She also mentioned a non-conventional concept that there are exceptions to every rule. When asked to clarify what she meant by science as "constantly changing," Ms. Platypus cycled back to a discussion of exceptions being ever present in science, but this never continued to conclude that these exceptions might eventually lead to modified theories or anything related to change. Instead she stated that she just wants to help students accept that "there's little exceptions to everything" (I3). When she got back to addressing the tentativeness in science, she said, "And then I can think about ecology and ecology is even changing. Evolution is changing. Chemistry, not really changing. Physics, not really changing. I mean they do. Well, just not in the same sense" (I3). This trend continued as she attempted to describe that evolution and populations were constantly changing, so therefore the science about them would also have to change. For most of Interview 3, this was all of the change in science that she could account for. Although she eventually added that changes in communication systems and scientific equipment can add to changes in science, it was as if she knew that the concept of science as ever changing was important to NOS because of something she had been taught a couple years ago, but that she did not understand what was meant by this change.

Ms. Platypus's definition of NOS continued to evolve throughout Interview 3, eventually to include ideas of how scientists work with a particular emphasis on the sharing of ideas after work is completed. This did not continue into peer review and argumentation; it just stopped at sharing. Her definition changed even more, perhaps based off the concept of how scientists

work, to include concepts of questioning, explanation, inquiry, and deep thinking. These last conceptions of NOS are the ones she was mainly talking about when she was discussing her idea that her principal and school district would likely love the inclusion of NOS in her classroom. This conception of NOS as inquiry and critical thinking continued into Interview 4 and never wavered.

When discussing how she naturally teaches NOS during the regular flow of course content, Ms. Platypus claimed that it must be because the concepts of NOS are so ingrained in her teacher mind. A little more bluntly, she said, “I think I have been doing it, I just don't use that term, nature of science, probably because it was shoved in my throat for a couple of years” (I3). The concepts of NOS were certainly discussed in her science education courses, but the vigor of their emphasis cannot empirically be discussed beyond Ms. Platypus’s perception. It is, however, apparent that the tenets of NOS did not make their way into Ms. Platypus’s working vocabulary. This could prove detrimental to any attempt to explicitly teach the tenets, but what is also important is whether she understands the tenets of NOS, even if she could not explicitly state them.

An analysis of Ms. Platypus’s VNOS and her answers to oral clarification questions portrays an understanding of NOS that is conflicted and naïve. When asked “What, in your view, is science?,” Ms. Platypus wrote, “Science is an academic discipline that aims to prove or disprove a theory” (VNOS). Though short and failing to mention anything about the natural world, the biggest issue of this statement is the use of the words “prove” and “disprove.” These words were recurring themes both written and oral. She believed that experiments “may prove or disprove a given hypothesis” (VNOS) and that experiments must be conducted in order to properly prove an idea. In this same vein she wrote, “In order for it to be classified as fact, a

theory must be proven or disproven" (VNOS). This and similar statements portray an understanding of science that is finite and empiricist. She discussed views of scientific laws as proven and unchanging, while "theories have evidence to support them... however they are not accepted as 'facts' and could be subject to change" (VNOS). This describes a possibility for theories to be tentative, but her descriptions of the tentative nature of science focused largely on changes in species and populations. In her written description of changes in science, Ms. Platypus wrote, "Species that may have been able to breed before may become un-compatible based on geographic isolation. Therefore, 'we' proved they were the same species before because they could reproduce, but that may no longer be valid" (VNOS). This statement further confuses laws and theories as well as portrays actual changes in the nature that the science is describing and not the science itself.

Similar to her statements about the tentative nature of science, the statements of Ms. Platypus concerning the socially and culturally embedded nature of science and the role of creativity and subjectivity in science strongly suggest that Ms. Platypus either knew the essence of the desired answers or could infer them based on the questions. She partially answered each of these in a manner that leans towards the desired answer, but does not adequately demonstrate belief or understanding. Concerning social and cultural influence on science, she discussed that it is in some way universal and influenced, but her description of social and cultural influence focused people's opinions of established science and the development of a research agenda, but not on the science itself. She started her answer to the question on creativity and imagination with an affirmative "absolutely," but then went on to describe (and re-iterate orally) that creativity and imagination do not affect the conclusion but definitely affect the "whole first half of the scientific method" (VNOS). Concerning the dinosaur question and the role of subjectivity

and inference, Ms. Platypus stated the obvious that we were not there and therefore have to work with the evidence that we have, but she then skirted the issue of different interpretations by saying they may both be right. Ms. Platypus started to answer each question on the right foot, but managed to step off the accepted path before she had concluded.

Considering her obsession with proving and disproving concepts, the empiricist understanding of NOS that Ms. Platypus possessed was quite clear. Though she never focused on numbers, she did focus on right and wrong without regard for human influence on scientific results. One quote from her discussion of her troubles with teaching evolution to her inquisitive honors students sums up this idea well. She started off well, but then she presented the science as a fact that cannot be argued with:

> *But I had to completely disconnect evolution from their beliefs. I'm like, "First of all, it's not a belief. It's just something that I am teaching you." I was like, "So just, that is what it is. Also, we did not come from monkeys, because otherwise monkeys would not still exist"(I3).*

Classroom practices involving NOS. No direct observations were ever recorded of the accepted tenets of NOS. Most class periods consisted of a bellringer, a short lecture that included visuals, and a short worksheet or activity. In all circumstances, science content was discussed as a collection of facts that needed to be memorized and connected. At times, Ms. Platypus did circulate the room to ask individual students probing questions. These questions were never noticed for being NOS based in the accepted sense, but some of them may have been interpreted by Ms. Platypus as NOS. Since Ms. Platypus's stated definition of NOS included inquiry and deep thought, it is conceivable that Ms. Platypus would consider her challenging questions to be NOS-driven.

In this vein, Ms. Platypus claimed in Interview 3 to teach NOS with her students. She admitted that "it's not like a planned thing," but when the opportunity arises she "definitely

take[s] it" (I3). She claimed to plan it into some articles that they read. She said, "We'll read together as a class and then discuss. I kind of plan it into that on a classroom level, but most of the time it's just one-on-one" (I3). She returned to this one-on-one concept of NOS instruction often. Generally in response to a student question, she felt that she could "sit down at a desk and really help teach it to that student" (I3). In one-on-one situations, she felt that she could help them think on their own and reach their own logical conclusions, much like scientists. She claimed to teach the tentativeness of science like this as well. She said that they "liked the curiosity of it" when they came to understand that "not everything is set in stone" (I4) and that their thoughtful, but malleable consideration of scientific ideas was similar to those of scientists. She claims to be trying to help them individually to think for themselves like scientists do.

In Interview 4, Ms. Platypus was unable to think of any times when she specifically taught NOS content to her students, even though she claimed to have thought about it since the same question was asked in Interview 3. She maintained that she only really mentioned NOS concepts when they made sense to individual student questions. This technique fails on two accounts. It fails to be explicit or reflective, unless the line of questioning happens to be very direct and extended. This technique also fails because it requires the teacher to have a very sophisticated NOS understanding that is easily accessed on a moment's notice. Both of these issues would be challenging for any science teacher, but are currently insurmountably daunting for Ms. Platypus considering her current understanding of NOS and undeveloped understanding of "explicit and reflective" NOS instruction.

Responsive Environment. Ms. Platypus's casual commitment to NOS instruction was never met with any objection or praise from anyone who could affect her standing as a teacher. Her principal did praise her encouragement of her students to think for themselves, which may fit

under her personal definition of NOS, but does not fit under the accepted definitions. This may have led Ms. Platypus to feel more empowered to teach NOS, but it did nothing to encourage the accepted understanding of NOS. Without thoroughly testing the waters of accepted NOS, it is hard to comment on the responsiveness of Ms. Platypus's environment. That said, the responsive environment was likely not the contributing factor toward the accomplishment of this NOS goal.

Factors that affect NOS instruction. Under her definition of NOS, Ms. Platypus felt the biggest factor that affected NOS in her classroom was student "mental capacity." She felt that her honors students were much better prepared to learn and think about NOS, while her CP students struggled to just comprehend the required material. She also commented that many students are "not at a point yet where they want to learn" (I4) and only care about what is necessary for the EOC. She implied that NOS would not be a concern for these students.

Ms. Platypus also felt that having more educational resources related to NOS would be helpful and may even increase her confidence. She said, "I think just resources and lesson plans or ideas or articles. Something for me to read up on just to refresh my memory of how to integrate more and plan to integrate more on a daily or weekly basis" (I4). She spoke of a theoretical binder that included lesson plans that linked NOS topics to specific content topics. Conversely, she said, "I don't think I'd need more training" (I4) though it is unclear if this came from confidence in her understanding or from dislike of training.

Another factor Ms. Platypus discussed concerned her paycheck. She said:

> *You have to think about everything that is affecting your paycheck or your job stability every day. And if the nature science is not affecting my pay or my job stability, that is not something that is going to be in my head every day (I4).*

By saying it this way, she comments on the curriculum, the EOC, her school's educational model, and the evaluation system. In this light, she said that NOS would be easier to teach more

often if it were specifically integrated with the standards and cleanly fit into the expectations of the evaluation system.

Ms. Platypus offered a couple more factors that affect NOS that are sort of one-offs, but are worth mentioning. She felt that her undergraduate major, biology, helped instill a curiosity in her that physics with all of its “formulas and facts or laws” can’t. She also felt that her openness to let students see her thought process and encourage students to share their thoughts is a positive factor for NOS teaching. Lastly, Ms. Platypus felt that some geographic regions are more likely to accept curiosity, inquiry, and science, while others accept their education as a fact without challenge.

Conclusions on Ms. Platypus. Ms. Platypus is a strong-willed teacher who has a lot of confidence in herself and her teaching. Much of this confidence is well deserved. She covers the required content, ensures student understanding, and has students who enjoy her class. Her confidence toward NOS, however, is largely unfounded. Her understanding of NOS is naïve and her perception of her understanding of NOS is unclear and incorrectly linked to inquiry and critical thinking. Largely because of this link to inquiry and thought, Ms. Platypus felt that she did a satisfactory job teaching NOS and felt confident in her ability to teach NOS.

Analysis of Mr. Stevenson

The following case study is of Mr. Stevenson. Data was collected over both semesters of the 2012-2013 school year. Two different physical science courses were observed a total of six times. Additionally, data was collected through two questionnaires and four interviews. Data was analyzed according to MST using thematic and InVivo coding. Select quotes are used to reinforce concepts that were demonstrated through a variety of sources and conversations.

Biographical information. Mr. Stevenson was a first-year teacher in a different county than the other participants. Though his school and county participated in the pilot state chemistry EOC toward the end of the spring semester, none of his chemistry or physical science courses had an official EOC that was created or graded by an outside source. This means that the school, the students, and Mr. Stevenson were not directly judged based on performance in Mr. Stevenson's courses. This allowed Mr. Stevenson a great amount of freedom, which he openly utilized. He kept his physical science course in the spring semester at a lower level but in almost perfect alignment with his chemistry courses. He also extended the chemistry half of the physical science curriculum well beyond the halfway point of the semester. Both of these decisions helped Mr. Stevenson with planning and allowed him to focus his time on other concerns. One of these concerns was the robotics club. Mr. Stevenson was asked to be the second sponsor of the robotics club at his school and quickly found himself immersed in electronics that he had never considered in his life. For approximately one fourth of the school year, Mr. Stevenson was constantly working with the robotics club students on their robot that they were designing for a competition. He worked with them late into the night five days a week and came to work many Saturdays. For this he received no extra pay, but I did hear that the students greatly appreciated his help and commitment.

Mr. Stevenson's other time consuming concern was labs. He wanted greatly for students of all levels in both his chemistry and physical science courses to experience labs and benefit educationally from them. He regularly expounded on the ability of labs to foster critical thinking and independence in students. Via labs, Mr. Stevenson constantly challenged students to back up their assumptions with evidence. Mr. Stevenson appreciated the benefits of laboratory experiences so much that he announced that his summer plan is to attempt to structure his

chemistry course to be almost entirely lab based. He recognized that this will be a challenging task, but he explained that it would be worth it. He also announced that he plans to become teacher of the year as soon as he is eligible, which is now in four years. He does not plan to do this by maintaining the status quo.

Mr. Stevenson is probably incapable of maintaining the status quo. He is just not that guy. He is too funny and too weird to become boring and predictable. Not only is he young, but he is also genuinely interested in many of the same things that his students are: video games, comics, internet memes, explosions, etc. Mr. Stevenson enjoys South Park, a cartoon television show, so much that he often reprimands students in the voices of characters from the show, to which the students laugh and correct their behavior. He also arrives at school early several days a week to play Magic: the Gathering, a card game that is universally considered nerdy, with several of his former students. Mr. Stevenson naturally connects with his students and uses this to his advantage in order to connect their interests with the science content. Mr. Stevenson related Call of Duty, a video game, to gravity and Red Bull to photon emissions. Mr. Stevenson admits to telling “nerdy jokes” and takes pride when his students can do the same. He allows tangential conversations as long as they relate to the content at hand and do not last too long. Mr. Stevenson relates to his students and values them as people. He values his classroom environment almost as much as he does his science content.

Personal Goals. Mr. Stevenson listed several goals that spoke to the heart of scientific literacy, even though he never used those words. Mr. Stevenson expressed an interest in helping prepare his students to be active participants in society via logical thinking, curiosity, and people skills. He wrote:

- *Educate my students in a way that allows them to make intelligent and logical decisions. This is primarily because my students are all part of a democracy and should therefore be capable of making an educated vote where necessary.*
- *Inspire my students to become scientists by generating curiosity and removing the stereotype that "I'm not good at science."*
- *Create a safe environment where students can express both their interests and shortcomings in a way that benefits their learning.*
- *Create community of scientists that work together both through problem-solving and constructive criticism (DS).*

He later said that his biggest goal is "to educate my students so they can make intelligent decisions" (I1). He went on to say that he hopes to "teach [his] students to think for themselves" and inspire them to "investigate the world around them" (I1). He felt that one of the biggest barriers to this is the perception of students that "science is hard, it's not for me, I am not a scientist" (I1). He, therefore, expressed a desire to change this and convince his students that they are scientists. Mr. Stevenson recognized that "the percentage of individuals going into science is extremely low" (I1) and that a vast majority of his students will not become professional scientists. He did, however, express a desire for his students to become "intelligent individuals and make educated decisions" (I1). He said that he hopes to help them become "a little more open-minded and more analytical about all sides to give them a full-on perspective of the situation before they make an absolute decision" (I1). He wanted them all to become amateur scientists in everything that they do. He hoped to do this by "emphasizing the why" and requiring his students to think through their understanding and explain their evidence and reasoning for all of their conclusions (I1). He often challenged his students to explain themselves, even if they answered a question correctly. He wanted them to not only know but to also think. He challenged his students to think through their science issues as well as their life issues and seek to back all claims that they make.

Mr. Stevenson also expressed a desire for his students to work together as a community of scientists. He not only desired for his students to explain their thinking, he also wanted to challenge them to defend their statements in front of their peers and reach consensus. He claimed that this is "how science is based a lot of times" (I1) and connected this idea to the peer review in which scientists participate. He claimed that "all the truth really is a consensus of scientists and their analysis of evidence" and hoped to "parallel how scientists in the field actually generate knowledge" with how his students learn science (I1).

Having a safe environment was portrayed as being integral to all of Mr. Stevenson's other goals and classroom ideas. He claimed that "you have to have [the] environmental factor of them feeling safe to where they can get up in front of the class and present that" (I1). Students have to feel comfortable with explaining themselves without fear of persecution from the teacher in order for Mr. Stevenson's involved participation goals to succeed. Mr. Stevenson felt that encouraging his students to act cooperatively while reasoning through their science content was gravely important for science classroom success and for the future of democratic society. Without training his students to think for themselves and stand up for themselves, Mr. Stevenson expressed concern that "if we're a nation that's run by the people, if we don't have an educated community then we're not going to have a very good nation. It's just going to be built on a lot of …ignorance" (I2).

Institutional Goals. When asked about institutional goals, Mr. Stevenson mentioned the influence of state curriculum standards and then immediately proceeded to narrate his frustration with the chemistry standards. Mr. Stevenson expressed frustration that the chemistry standards were officially changed three weeks into the second semester of the school year. He stated that this "entire performance …is based around the standards" (I2), which only made the changes that

much more frustrating. Mr. Stevenson sarcastically referred to the changes as "convenient" and later used them to mirror a feeling that the structure of education is in a constant state of flux and does not adequately give teachers time to adjust. When talking about the state standards as an institutional goal, Mr. Stevenson inherently connected them to the new evaluation model, because in it he is required to display the standards with which his classes are working on a daily basis. He expressed that evaluations cause him great stress, especially when he considers "the sixty-four points… in the instructional evaluation" that he is expected to hit (I2).

Mr. Stevenson considered much of the state standards and the evaluation system to be overly stressful. He also considered that the state-wide chemistry EOC that was pilot tested this spring and will likely be official in the fall would only add pace and stress to his teaching load. Despite the stress, Mr. Stevenson did make it clear that he accepted these things as part of the job. He said, "this is what I have to do, [so I] do it" (I2). He also claimed that his graduate training made him more prepared for the evaluation model than most teachers and that despite the stress, "if you practice it every single day, when you get your evaluation you just ignore the principal being there and you go with it" (I2). Mr. Stevenson expressed a view of the institutional goals that was very pragmatic, but he was also very blunt about their affect:

> *They dictate what I teach, they dictate how I teach it, they dictate how I structure as far as my environment, they dictate how I handle discipline, everything. They dictate the time I have to do it, the tools I have to do it with to some extent. I mean they have full influence over everything that I do…. So I feel like they have the majority control. The only thing that I control is how I present the material to some degree, but they put their hands in that too (I2).*

Mr. Stevenson also discussed some institutional goals that do not have much of an effect on him. The first of these was reading standards. He described standards that are "pushed in the school, but not emphasized" (I2). He explained that his principals and probably the county "want reading and writing in every single class period" (I2). He claimed to understand the importance

of this, but acknowledged that he only has an hour and a half and has several chemistry standards to cover as well. Needless to say, Mr. Stevenson admitted that reading and writing were not always realized in his class.

Another largely ineffectual institutional goal that Mr. Stevenson described came from his graduate school. He felt that the university expects him to implement inquiry in his science classroom, “because that's been shown to work” (I2). He said that they “kind of push[ed] me more towards the whole inquiry-based stuff. I think that was really emphasized” (I2). He described this institutional goal as “not like some overhanging force,” but instead referred to it as an institutional goal that he had accepted into his research-based repertoire. When referring to his plans to include more inquiry, he said, “it just makes a ton of sense how well it lines up with the way actual science is and scientific knowledge is generated” (I2).

Mr. Stevenson was aware of several institutional goals that affected his classroom. Some, like the standards and the evaluation model, have significantly more effect on Mr. Stevenson’s classroom and therefore receive significantly more attention from Mr. Stevenson.

Is NOS a goal? I asked Mr. Stevenson “Is teaching for student understanding of nature of science a goal in your classroom?” His first response was, “Currently not as much” (I3). He did not specify what it was currently less than, but in the context of his later statements, he effectively meant no. He claimed to have too much else on his plate to be worrying with NOS right now. He said, “It's more like I'm trying to get the students to just think more and not have everything just so defined for them. I feel like once I've mastered that I'll move on to deeper, more in-depth things” (I3). He also described that he needs to focus on producing numbers, “increas[ing] these kids’ test scores,” and “reduc[ing] the achievement gap” (I3). He felt that he needed to focus on these things, “Because I need to make sure I can teach before I teach what I

think needs to be taught" (I3). Getting rehired for a second year was a concern for Mr. Stevenson, to the extent that he tailored his goals and classroom plans specifically to help ensure that. NOS, therefore, did not become a goal.

Emotions about NOS. When stating that NOS was not a goal for his classroom, Mr. Stevenson referred to NOS as part of his phrase "what I think needs to be taught" (I3). Later, when discussing NOS instruction, he also said, "I think that is something that needs to be done" (I3). His emphasis on the word need when describing NOS continued when he said, "if I'm going to actually inspire these kids to be scientists, then they need to understand what science is to truly realize that that is something they want to pursue" (I3).

On multiple occasions he described NOS instruction as a need for students and science courses, but when asked to explain the importance of NOS, Mr. Stevenson waivered. He said, "I have a little bit of why I feel it's important, though I don't feel that I have enough of why I feel it's important yet" (I3). He did not feel that he understood its importance enough to take NOS to the next step. He was not emotionally invested in NOS enough to make it a goal or be motivated to actively attempt it.

Capability Beliefs about NOS. Mr. Stevenson expressed that he does not feel confident enough in his own understanding of NOS in order to properly teach it. He said:

> *It's something for one that I need to personally better define for myself before I ever attempt to teach it. Because I feel like my definition is very fuzzy. I don't feel like I have a very concrete definition or opinion of the nature of science as of yet. I kind of feel like I have all these ideas of what it is, but I don't know what it is entirely (I3).*

At this point in the interview he had not clearly constructed a definition of NOS, but he had discussed many key points of NOS and had explained that it dealt with "what makes science science" (I3). In response, I told him that he had been hinting all around a definition of NOS and that "It is personal to each person, so you … have something." Mr. Stevenson did not feel that

this was good enough. He wanted a clear understanding for himself, or he feared that his students would not accept it:

> *But it's a matter of constructing it in a uniform fashion, because if you are not sure yourself, then it's kind of hard to teach it, because again you are just going to be dancing around it and students are going to sense that uncertainty in you and they're going to be like, "This is crap. This teacher doesn't know what he's doing." So, that's something I need to do first (I3).*

Mr. Stevenson was very adamant that he needs to solidify his understanding of NOS before he puts forth any more effort into teaching it. He stood by this belief in the next interview as well. When asked about his confidence in his ability to successfully teach NOS, Mr. Stevenson said, “On a scale of 1 to 10, I give myself about a 3” (I4). He later claimed that he may be selling himself short, but either way, it is safe to say that he is not confident in his capacity to teach NOS.

Context Beliefs about NOS. When talking about support for NOS instruction, he said, “on a political level I wonder if they care” (I3), referring to the state. He felt that the state standards and the emphases of the state tests do not promote NOS instruction. Instead, speaking from the point-of-view of the state, he said, “We don't care about if they know how science works, they just need to be able to answer these questions and know these facts” (I3). He felt that the state only cares about improving our standing against those of the other states and other countries and that those standings do not include NOS instruction.

Mr. Stevenson described the position of his administrators toward any extra goals as similarly being largely ambivalent. He said, “I think they could care less about my goals as long as I'm getting them the results that they want” (I1). He said the same thing about administrative support of NOS when he said, “as long as I give them their numbers, my principal wouldn't care. That's all he cares about, is numbers” (I4). Giving them their numbers was a recurring theme in

all four of Mr. Stevenson's interviews. He claimed that that is all they care about and that as long as those are produced, he can largely do what he wants in his classroom. This could be construed as free reign, but when describing why NOS was not a goal, Mr. Stevenson said that he needs to focus on the goals of his administrators. As a first-year teacher he felt that he was not confident enough in his ability to achieve the "needed numbers" so he personally decided to put some of his own desires on the backburner. In this sense, his administrators were not officially being unsupportive of NOS, but the context did affect Mr. Stevenson's perceptions of his ability to fulfill an NOS goal alongside context goals.

Conclusions on Motivation. Mr. Stevenson clearly did not possess motivation toward NOS instruction. He did not have the self-efficacy to believe that he could do a good job teaching NOS. He did not possess an understanding of the importance of NOS to connect with it on an emotional level. He believed that his administrators would not be against NOS, but also felt that their other expectations were too burdensome to add NOS to his teaching repertoire. With all of these considerations, it is no surprise that Mr. Stevenson did not possess a goal related to NOS. Without a goal or the other components, Mr. Stevenson was not motivated to teach NOS. Without motivation, it was unlikely that he would teach much NOS.

Skill. Because Mr. Stevenson lacked the confidence, goal, and motivation to teach NOS, demonstration of his skill was not expected. One partial instance of NOS instruction was, however, noticed during one of his classroom observations, and he also spoke a little about how he teaches it. Mr. Stevenson's understanding of NOS was revealed in the VNOS survey and during two interviews. His understanding of NOS greatly contrasted his perceptions of his understanding. The next section will detail his understanding and will be followed by a discussion of his NOS instructional practices.

Understanding of NOS. Mr. Stevenson possessed a fairly strong, sophisticated understanding of the nature of science. His answers to the VNOS survey required no additional clarification, but his oral answers to other NOS related questions backed up this conclusion. The first time he talked about NOS, Mr. Stevenson told a story that reveals how his view of science has changed over the years:

> *[I] had a misconception in high school that science was pretty well defined and everything was clean cut and everything was- "these are items. We know this. This is the way light works. We know this. This is how everything works. We know this. For a fact. You can't contradict it." And that was all crap. And I didn't realize that until I was in college and everything that I thought I knew was torn apart (I3).*

His understanding of science was “torn apart” and replaced by an understanding that clearly included ideas of tentativeness, interpretation, creativity, and social influence. He described theories as being based on evidence and ideas. He wrote, “Theories are often defined and redefined in order to accommodate for newly observed evidence” (VNOS). When asked about creativity and imagination in science, his first statement was, “They definitely use it when drawing conclusions that explain their data. In a lot of cases things (like the atom) cannot be directly observed, so a degree of imagination is required” (VNOS). He described bias on all fronts of science, from the direction that science goes to the scientific results themselves. While acknowledging the role that interpretation has on science, Mr. Stevenson regularly reinforced the ideas of empirically based evidence, replicability, peer-review, and the test of time as measures to “transcend or minimize” the effects of personal, social, and cultural bias.

Mr. Stevenson described science as not needing a scientific method. He lifted up the concept of observational science while at the same time recognizing the ability of controlled experimentation to provide clearer explanations of phenomena. Mr. Stevenson’s understanding of NOS was clearly constructivist and sophisticated. The only tenet where he struggled

concerned the difference between scientific theories and laws. He described an understanding of the importance of each and that each is tentative, but he struggled with defining a difference and settled with a hierarchical view. He claimed to not be happy with this view, citing the contradiction of Newton's laws in extreme scales, but admitted to knowing no other explainable difference. Mr. Stevenson admitted on his VNOS questionnaire that he has "always struggled with explaining the difference between theories and laws." The difference between theories and laws was the only part of the VNOS that Mr. Stevenson claimed to struggle with, and it was the only NOS tenet that he truly did struggle with. Compared with depth of his fairly sophisticated understanding of the rest of NOS, his issue concerning theories and laws does little to explain his negative self-efficacy concerning his understanding of NOS.

Classroom practices concerning NOS. When asked to define NOS, Mr. Stevenson did not describe many of the NOS tenets. Instead he talked loosely about what science aims to do and how science works. He talked about testing assumptions by manipulating variables and said that "science itself is generally constructed of human discussion and observation" (I3). During later discussion of his NOS teaching, Mr. Stevenson described the importance of bountiful evidence, tentativeness, and the importance of peer review and replicability as being part of NOS. Each of these areas is important to the accepted definition of NOS, but his discussion of how he taught them revealed a lack of appropriate skill.

Mr. Stevenson discussed all of his NOS instruction as being "not directly, not like 'this is the nature of science'" (I3). Instead of referring to things as NOS, most of his claims to NOS instruction involved passive transfer of ideas. He described having them share the results of their labs so that they can learn from others and so that they can practice defending their interpretations of evidence. He said, "So if they can come to different conclusions and defend

their conclusions, then maybe together they come to a final conclusion that is the truth itself about what is happening" (I3). He described wanting the students to form their own tentative explanations and work through them with their peers in order to better understand NOS. When asked about future NOS teaching, he said that if he had the funds to buy better equipment, then "they could replicate those [famous] experiments and come to their own conclusions, then I think that would be ideal" (I3). He claimed that experiencing science would be ideal for teaching the nature of science, which leans toward implicit assumptions about NOS learning.

At other times, Mr. Stevenson described "mentioning" and "emphasizing" concepts to his students that he considered a part of NOS. He said, "I've mentioned it, that if you make a claim and you don't have evidence to support it than that claim isn't worth crap" (I3). He later discussed the tentativeness of science by saying "Science isn't as clear-cut as society makes it appear. So things that we might think are absolutely certain and correct are in fact not. I emphasize that a lot, too, when we learn about Aristotle and Democritus" (I3). In both of these circumstances Mr. Stevenson claimed to tell his students about NOS type concepts. He claimed to talk about both of these concepts frequently. His emphasis on the importance of evidence and explanation was noted in several classroom observations, but the direct tie of this to the accepted understanding of NOS is questionable. He also claimed to emphasize student discussion of data to "ensure that they are seeing different perspectives of the data" (I3). In all of these cases, Mr. Stevenson directly talks to his students about NOS type concepts, but evidence of their interaction or reflection is not given or observed.

Mr. Stevenson was observed teaching a little NOS content on one occasion. During his sixth classroom observation, a student question during a laboratory experiment led to an impromptu discussion of replication and the empirical nature of science. A student asked if they

needed to take and record precise measurements for the lab, since his directions were not specific. Mr. Stevenson then decided to pose this to the whole class and discussed why experiments needed to be able to be replicated. The students mentioned validity and he discussed how science required precision and lots of data. The discussion did not extend to describe that other scientists would need to be able to reproduce the same experiment in regards to peer review, but Mr. Stevenson did actively talk about the nature of science with his students.

The NOS and NOS teaching that was observed of and described by Mr. Stevenson focused largely on the tentative nature of science and on the importance of evidence and peer-review. This is all that he either cognitively associated with NOS or felt comfortable enough to talk about/teach. This brings to light an important concept to studies of teacher NOS understanding. The ability of a teacher to answer VNOS and other NOS test questions in a fashion that leads researchers to believe that participants hold a sophisticated understanding of NOS does not necessarily equate to teacher ability to express this understanding. Demonstrated understanding of NOS may not even necessarily equate to belief in one's understanding. Mr. Stevenson seemed completely unaware that he possessed a fairly sophisticated understanding of NOS, and this appeared to present a significant challenge to his ability to teach NOS.

Responsive Environment. Mr. Stevenson repeatedly commented that "as long as I give them their numbers, my principal wouldn't care. That's all he cares about is numbers" (I4). Mr. Stevenson may have tested this assumption with his over-inclusion of chemistry in his physical science class, but he did not test it concerning NOS. Mr. Stevenson rarely taught NOS, and when he did, it was self-described as either being passive through labs or mentioned in activities with other direct aims. Mr. Stevenson reported that principals were rarely in his classroom, so the likelihood of them being present for any NOS discussion is slim. The only time a principal

discussed Mr. Stevenson's teaching with me, the assistant principal praised his ability to relate with the students and get them involved with science. Her approval of Mr. Stevenson was solidified when she commented that she hoped that he would stay with their school for another year.

Factors that affect NOS instruction. Mr. Stevenson strongly felt that the biggest factor that affected his ability to teach NOS was his own clarity on the subject. He said, "I need to personally better define [NOS] for myself before I ever attempt to teach it." The subtext of this quote suggests that Mr. Stevenson believes that he has never taught NOS. It may be more appropriate to interpret this as he thinks that he has never taught NOS with explicit intention or that he feels he has never taught it well. More importantly, Mr. Stevenson expressed that he feels that he must clarify his understanding of NOS for himself before he attempts to teach it to his students. He expressed that it is largely his fault that he does not possess a clear definition of NOS. He said that "I did not acquire it because I was surviving grad school," and that it was taught well, but that he was too overwhelmed with all of his other duties to fully absorb and reflect on NOS while he was in grad school. He explained that he doesn't need more NOS training or access to NOS lessons, because "I feel like I could Google most of that, honestly." Instead he felt that he just needs to reflect and clarify his understanding for himself.

For Mr. Stevenson, time and the content standards blend together as a cohesive factor that affects his ability to teach NOS. He said, "Time is the primary. You have a limited time to teach and master the amount of material that covers a massive array of material." He describes the content standards for chemistry as being numerous and incredibly broad. He said that the content standards fail to take into account required background information and can only be achieved

during ideal circumstances with an ideal class. He felt that this was not the case at his school and therefore felt that this impeded his ability to teach NOS. He said:

> *I kind of feel like I am limited as to how much I can dive into [NOS] because the emphasis of my job is on content, so we have a lot to go through and we're already two chapters behind. Do we have time to discuss those things?*

To Mr. Stevenson, NOS is one of “those things” that is extraneous and does not directly help him finish the content standards or improve the numbers that his principal wants to see. To be able to properly attend to NOS, Mr. Stevenson said that he “would need lots of time.” Mr. Stevenson feels that he would need more time to plan NOS into his lesson plans and more classroom time so that precious content time would not be lost to NOS time.

Another factor that Mr. Stevenson discussed as affecting his NOS teaching was technology and funding. He felt that technology would help his ability to teach NOS, but that his school has very little. In fact he said, “We are dealing with like nothing in a lot of cases.” He did not have the laboratory equipment that he felt would help and he claimed to not have the ability to purchase it either. He expressed dismay that “they don't allow teachers to save up to buy those technologies either, because they give you a set amount of money you have to spend by this date, which results in a lot of waste.” He described teachers spending their entire surplus on staplers, because their money could not roll-over for bigger, more worthwhile purchases.

Conclusions on Mr. Stevenson. Mr. Stevenson possesses a very clear understanding of NOS that stands in stark contrast to his perception of his understanding of NOS. Mr. Stevenson does not feel that he possesses an adequate understanding of NOS and is therefore very reluctant to explicitly teach NOS in his classroom. This, paired with his perception of the pressures of the content standards, keeps Mr. Stevenson from becoming emotionally invested in NOS or from making it an explicit goal. Mr. Stevenson therefore does not teach much NOS in his classroom.

Much of the NOS he does teach is either implicit or teacher-focused. When Mr. Stevenson emphasized concepts to his students that he considers NOS, they were often fringe to the accepted NOS standards.

The topic that Mr. Stevenson felt is related to NOS that he emphasized the most deals with the need for significant evidence to back up claims. This supposed NOS topic is a great topic of conversation for science classes, but in isolation it hyper-focuses on the empirical nature of science. It is interesting that Mr. Stevenson focused on this tenet, when his descriptions of NOS that are not linked to teaching greatly focused on the influence of interpretation, creativity, and bias on science. He acknowledged the social side of science, but never seemed to talk about this with his students. Instead his focus on evidence appeared to steer away from social influence. This all makes Mr. Stevenson very interesting.

Beyond Individual Case Studies

The preceding chapter presented individual case studies for each of the seven participants in this study. Each case is unique and complex. That said, keeping the details separate can be confusing. Appendix H is provided to categorize some of the characteristics of each case study.

The next chapter, Chapter 5, begins to combine the data and stories of each of the case studies into an accessible and comprehensive format. This cross-case analysis will discuss commonalities between the cases and showcase outliers and interesting highlights. It is organized in the familiar MST structure.

Chapter 5: Cross-Case Analysis

Each of my seven case studies presents its own unique story of a novice science teacher's interaction with NOS instruction. Each case was analyzed through the lens of Motivation System's Theory (MST), which served as a medium to dissect each teacher's situation and construct an individualized understanding of that teacher. MST helped to organize the large amount of qualitative data and differentiate each case from the others via a similar construct. MST provided a means to describe the factors behind and facets of goal creation, goal motivation, and goal achievement for each novice science teacher.

This chapter will present a cross-case analysis of all seven novice teacher participants. The results of their individual case studies will be compared for commonalities and interesting features. This analysis will also be analyzed through the lens of MST and organized similarly to each of the case studies.

Goal Development

None of the novice teacher participants listed or discussed any personal goals concerning NOS without prompting. NOS was similarly not described as an institutional goal being pushed on them by any groups, such as their school, their school district, their state, or their graduate school university. In fact, for the demographic survey and the first two interviews, NOS was never mentioned by any of the seven participants. Though not directly related to NOS, only one teacher stated a goal that hinted toward scientific literacy. Mr. Stevenson stated a goal concerning educating youth towards thoughtful decision making and eventual voting, but did not include NOS instruction as a means to this end, as the literature often suggests (American Association for the Advancement of Science, 1993; Lederman & O'Malley, 1990; National Research Council, 1996; Schwartz & Lederman, 2002).

Instead of stating goals related to NOS, the participants listed a variety of goals that showcased their classroom personalities and their perspectives on education and science education. Each goal was special and valuable on its own, but two recurring themes occurred in the participants' personal goals. The first commonality concerned an interest in facilitating an appreciation of science in their students. Six of the seven explicitly discussed a desire for students to like science. These teachers discussed science as a whole as being fascinating and expressed a desire to pass this on. Several expressed a desire to overcome stereotypes like "I'm not good at science" (Stevenson, DS) and science class "is boring or too hard" (Solo, I1). Similarly, this affective goal for science enjoyment was repeatedly stated in conjunction with statements concerning the idea that "most kids…don't like science" (Shirley, I1). These teachers felt it necessary to combat this notion in their everyday practices and in their goals.

The second common theme in the personal goals of my participants was relevance. According to Mr. Solo, "Relevance is one of my biggest things" (Solo I1). This sentiment was echoed by four of the other participants. These teachers listed direct goals or spoke at great length about a desire to make science content relevant to the lives of their students. They felt that relevance could serve as a medium for maintaining and developing student interest in activities and content. Ms. Mangrove said it well when she said, "this semester I really want to start seeing connections between what we talk about in class and what they see and experience in everyday life" (Mangrove, I1). Mr. Solo and Ms. Williams expressed interest in helping students see the "big picture," so that their content was not isolated and minute. Ms. Shirley took relevancy a step farther and expressed hope that it would lead to interest which in turn would help students "pay more attention so behavior will hopefully be better" (Shirley, I1).

Relevancy and appreciation of science were common goals expressed by a majority of the teacher participants. Ms. Platypus was the only dissenter from both commonalities. Her personal goals had little to do with science and instead focused on the students and the expectations of her school's evaluation model. She admitted that "a lot of my goals are student oriented rather than curriculum oriented, because I, while I care a lot about teaching the students the curriculum, I care more about the students than the curriculum" (Platypus, I1). Instead of talking about content, her goals mainly focused on caring and respect. Not only did she not outwardly promote relevancy or appreciation, Ms. Platypus openly contradicted appreciation of science when discussing her need for respect in the classroom. During a semi-fictitious dialogue concerning a student who claimed to not like science in which Ms. Platypus served as author and actor of both parts, Ms. Platypus's caricature of herself said, "you don't have to love science, but you've got to love my class" (Platypus, I1). Ms. Platypus demanded respect and personal appreciation from her students with or without content, while the others seem to focus on relevance and appreciation as a means to increase interest and then possibly respect/personal appreciation.

The institutional goals described by the novice teachers likewise did not mention NOS. The institutional goals most commonly discussed included completion of state curriculum standards, high student success rates on end of course (EOC) examinations, and high personal scores on teacher evaluations. In most cases, these institutional goals were never described as including NOS, and eventually these institutional goals were used to describe factors that adversely affect NOS instruction. From this standpoint, these institutional goals came to affect the context beliefs concerning NOS of many of the participants. As such, these will be discussed in the coming context beliefs section.

Without explicit mention, NOS never surfaced as a personal or institutional goal for any of the participants. After completing the VNOS questionnaire and discussing scientific literacy and NOS in an interview setting, two dichotomous scenarios arose among the novice teachers when asked if NOS instruction was a goal for their classrooms. Most of the teachers announced that teaching for NOS understanding was not a goal for their science classrooms. All of the teachers in this group, which we will hence forth call the No Goal Group, expressed either some appreciation for the importance of NOS or regret for not making it more of a priority, but none of them considered NOS to be a viable goal for their classrooms. After stating that NOS was not a goal, members of the No Goal Group always immediately stated basic reasons for why NOS was not a priority, which were largely based on context beliefs.

Based on MST interpretation, Ms. Shirley is a member of the No Goal Group, though this was probably not her intention. Ms. Shirley attempted to describe her attention to NOS as a subconscious goal that her training and her conscious goals naturally leaned her toward. Ms. Shirley's subconscious may have helped her to occasionally include NOS topics in her class discussions, but MST requires goals to be conscious and deliberate in order for motivation to be outward and measureable (Ford, 1992). Therefore, Ms. Shirley is considered to be a part of the No Goal Group. It should be noted that she too shared the commonality with the rest of the No Goal Group concerning almost immediate apology and excuses for the lack of NOS instruction.

The other obvious group of teachers is the two who claimed that NOS instruction is a goal of their classroom. When asked if teaching for student understanding of NOS is a goal, Ms. Platypus said, "Yeah. Because, I mean, that's part of being a good science teacher" (Platypus, I3), while Ms. Williams said, "Yes. I would say so. I definitely want my kids to kind of understand the thought process behind why scientists think what they think" (Williams, I3). Both

of these teachers went on to extoll the virtues of NOS instruction and did not make excuses for their NOS teaching, like their counterparts in the No Goal Group. Standing alone from the pack, Ms. Platypus and Ms. Williams therefore compose what I will call the NOS Goal Group from here on out to ease discussion. Though the groups have many similarities, they also have several differences which will be highlighted in the coming sections.

Emotions Concerning NOS

The emotional connection of the novice teacher toward NOS instruction varied. Though no one stated purely negative emotions, some negative elements led to composite emotional descriptions that ranged from mixed to strongly positive. The negative emotional elements largely focused on capability beliefs, context beliefs, and fear of effort required for further NOS inclusion, while positive emotional elements focused on the value of NOS to science classrooms. Three teachers stated almost entirely positive emotional connections to NOS. Both members of the NOS Goal Group and Mr. Solo kept their emotional connection to NOS positive, while the other four members of the No Goal Group stated mixed emotions toward NOS.

Capability Beliefs

The capability beliefs held by the novice science teachers stretched the full spectrum. Mr. Stevenson whole-heartedly doubted his ability to teach NOS, calling his personal definition of NOS “very fuzzy” (Stevenson, I4) and scoring his own confidence toward teaching NOS as 3 out of 10. On the opposite end, the NOS Goal Group plus Ms. Heffernan expressed full confidence in their ability to successfully teach NOS. The other three fell somewhere in the middle; not comfortable, but not uncomfortable. Ms. Mangrove said, “I always tried to teach it, but I never

felt like I reached as many students as I wanted to… so I'm fairly confident. But trying to, you know, develop myself always."

Capability beliefs are the first place where Ms. Heffernan starts to stand alone, a trend that will continue. She is not a member of the NOS Goal Group and she did not have particularly strong emotional connections to NOS, but she did believe in her ability to successfully teach NOS. Her confidence was rooted in recounted memories of specific lessons that she had taught and recognized as NOS. This alone serves to classify Ms. Heffernan as an outlier, but this status will only grow in the coming sections.

Context Beliefs

Context beliefs consist of a person's understanding of their environment and the understanding of whether this environment supports the success of the stated goal. For the goal of NOS instruction in a science classroom, contextual factors could be any number of players, both living and nonliving. School-level administrators and *higher ups* at the county and state level are the most easily identifiable potential contextual players. As such, questions were directly asked of the participants about support for NOS instruction from these institutions. The members of the NOS Goal Group were the only participants to state largely positive support from their administrators and the county/state concerning NOS. Ms. Platypus felt that her principal, as a former science teacher would be excited by NOS (and critical thinking) and Ms. Williams described a belief that the county not only supports NOS but plans to include more of it (and inquiry) in the future. The others felt varying degrees of support directly for NOS, but all agreed that other conditions would have to be met before NOS would be supported. Ms. Shirley kept it positive when she said, "I feel like most institutions would support it, but they also want the bottom line" (Shirley, I3). Mr. Stevenson was more blunt when he said, "As long as I give

them their numbers, my principal wouldn't care.” The numbers and the bottom line that Mr. Stevenson and Ms. Shirley mentioned refer to the EOC scores and value-added scores of students as well as the evaluation scores of teachers. This sentiment that the support for NOS instruction is contingent on performance in other areas was mirrored by the rest of the No Goal Group, with the exception of Ms. Mangrove, who felt that the tasks required of the bottom line were too great to allow for support.

The contextual factors that my participants felt most greatly affected their ability to teach NOS content were non-living constructs. The ability of these factors to affect the teachers was built largely on the individual teacher’s perception of that factor. These factors never explicitly opposed NOS. Instead, the assumed power of the factor contributed to each teacher’s ability to additionally include NOS.

One of the big contextual factors that was consistently discussed by all participants was the curriculum standards. Each course taught by each teacher had curriculum standards that were constructed by the state, added to by the county, and expected to be followed and completed by the teacher. In all cases, my participants expressed concern about the standards and on many occasions an overwhelming feeling of stress was discussed. The pressure caused by the standards was discussed by every teacher before NOS instruction was ever brought up. Referring to the curriculum standards, Mr. Solo said, “Long story short, we are very tied to it and I check off everything I cover on our standards” (Solo, I1). In Interview 2, Ms. Mangrove said that you “have to get through all of this insane content, that's just massive, it's just too too much. Something has to give” (Mangrove, I2). In this instance, the thing that had to give was her school’s emphasis on literacy, but her stress concerning the content standards echoed into her discussion of NOS and was also echoed by the other participants. Ms. Williams similarly made

excuses for her lack of attention in other areas, because of the standards. She said, “I really think first-year teachers are just trying to make it through the content” (Williams, I2). Ms. Williams’s comment suggests added curricular stresses for novice teachers. Novice teachers are inexperienced by definition, so they are always teaching classes and therefore curriculum standards that they have either never taught before or have limited experience with. This could have only added to the stress caused by the curriculum standards that were described as strict (Solo, I2), broad (Heffernan, I1; Shirley, I2), vague (Solo, I1, I3), ambiguous (Mangrove, I2), and numerous (Heffernan, I2).

Another contextual factor that was almost entirely synonymous with discussion of the curriculum standards was the EOC’s that are administered at the end of each semester by either the county or the state. All of the teacher participants had an EOC for at least one of the courses they taught and a vast majority of these teacher’s courses had EOC’s.

All of my teacher participants discussed and described EOC’s in great detail in many of their interviews. They most often described their interactions with their EOC’s in terms of pressure and stress:

> *Just the pressure of having that standardized test at the end and them having 25% of their grade depended on what they score on the test and you know, my grade as a teacher depending on how they score and is that going to affect my job and that kind of thing (Mangrove, I1).*
>
> *The pressure of the end of course exams is upon me (Solo, I3).*
>
> *It adds pace and it adds stress (Stevenson, I2).*
>
> *I'm super freaked out about when the EOC runs around (Stevenson, I1).*
>
> *It's a big push. They need to pass the EOC. The state test (Williams, I4).*
>
> *But also I am teaching so these kids can get this test, and that test measures their understanding and it also measures my ability to teach them, I suppose. So that's a lot of pressure (Solo, I3).*

The teachers worried about completing their curriculum in a timely manner before the EOC's. They worried whether students mastered and retained information from lessons. They stressed about whether their exam review sessions were sufficient and whether their students would be successful on the test. To this extent, all seven teachers stressed the importance of the standards and EOC's on their everyday classroom practices. Ms. Platypus clearly laid this out when she said:

> *I would like to teach about things that I am more passionate about all the time, but the state curriculum is part of our lives and the state end of course exam is a big part of our lives. . . . And now with the new system, the new evaluation system too, we can receive compensation based on our evaluation scores and our students' performance scores on that end of course exam (Platypus, I1).*

Ms. Platypus described a reality where the curriculum standards and EOC's dictate much of their lives as teachers. This idea was shared by all of the participants and carried over into discussion of NOS:

> *I want my kids to understand the nature of science,… but I mean, really, the most important thing for them is to make a good score on the test that is 25% of their grade. That's really what's most important for them at that point. And they don't ask questions about the nature of science really on the EOC (Heffernan, I3).*

Almost every teacher mentioned at some point that the EOC's for their courses are worth 25% of a student's grade. This was often presented as a justification for why NOS was infrequently taught. Discussions of NOS instruction, in general, often turned toward context beliefs concerning curriculum standards and EOC's. Mr. Solo mentioned that he does not see NOS often, because "we have a test and that test is the goal" (Solo, I3). Ms. Mangrove said, "You lose the nature of science when you start to get more into the focus on the EOC and the scores and getting kids to pass and that whole stuff" (Mangrove, I4). Referring to her self-assessed lack on NOS teaching, Ms. Shirley said, "I'm down to the wire to get everything done

that I have to get done. And I am not trying to put in a lot of extra fluff this semester" (Shirley, I4).

When discussing how her students did not learn as much NOS as she would like, Ms. Mangrove blamed the EOC, saying, "Again that just nasty EOC at the end of the semester." She claimed that she needed to focus what would be on the test, which was not NOS. She even described her favorite unit for teaching NOS as not being worded as such in the standards nor being supported by the question types of the EOC. Instead, she talked about NOS as being separate from the EOC:

> *So just like the specific goals of the content standards, you know what you are expecting, what your students are expected to know, that kind of limits or kind of like guides how you teach it because you want them to be successful on that major - gosh, I keep talking about that test, but I mean it really just puts a little dark cloud over the whole way you teach things… It's kind of like the content standards and the EOC pigeonhole you into teaching certain content certain ways (Mangrove, I4).*

Ms. Mangrove described the content standards and the EOC as a dark cloud that controls what and how she teaches. She did not consider NOS to be a part of the EOC content or teaching style. Similar to Ms. Shirley's discussion of NOS as "extra fluff", Ms. Mangrove did not consider NOS to be a part of her content and her regular teaching plans. The biggest takeaway from the depictions of NOS and the EOC of most of the teacher participants is that NOS was perceived as being outside of the curriculum and not tested for on the EOC. Even Ms. Platypus, who expressed fairly positive context beliefs, discussed NOS as being separate from the standards and the EOC. She said:

> *It's just difficult to throw another thing into the mass, you know? When there's specific things they are asking us to do every day, every week, every lesson, every class… You have to think about everything that is affecting your paycheck or your job stability every day. And if the nature of science is not affecting my pay or my job stability, that is not something that is going to be in my head every day (Platypus, I4).*

Since Ms. Platypus believed that student performance on the EOC did reflect in her pay and job stability, while NOS did not, she was able to justify giving NOS less priority in her instruction. Ms. Platypus even claimed that her students perceived that NOS was a separate content, when she discussed student questions about, "why do I have to do this? How is this going to help me on the EOC?" (Platypus, I4).

Despite her goal to teach for NOS understanding, Ms. Williams similarly bent to the contextual factor of the EOC. It was not strong enough of a factor to cognitively stop her NOS instructional goal, but she did feel that its power was strong enough to shape her plans for her goal to fit within the parameters of the EOC's needs. Referring to NOS, she said:

> *Whenever it does come up in a lecture or in a question, I enjoy teaching it, but it's just not something I plan for, because they're not going to be tested on it and their scores reflect our scores and all that (Williams, I4).*

Ms. Williams shaped her NOS teaching behavior and her perception of her NOS goal around the parameters of her perceptions of the EOC's effect on her students and herself. Like their peers, Ms. Williams and Ms. Platypus acknowledged a rift between NOS and the EOC's, but unlike their peers, they claimed willingness to work with and around the issue.

Six of the seven novice science teachers discussed NOS as being separate from the regular curriculum. Mr. Solo went as far to question whether NOS hurts student preparedness for standardized testing, when he said, "It's hard to say that it necessarily contradicts, but I don't think that it helps" (Solo, I4). The other five who felt NOS was separate from the curriculum, instead stated that they just needed more time to teach NOS. They felt that their regularly allotted time was barely enough to cover the required standards, so therefore extra time would be needed if NOS were to get proper inclusion. Ms. Shirley said, "If we had more time I feel like you could spend more time building up to thinking about [NOS] more" (Shirley, I4). Ms. Mangrove and

Mr. Stevenson echoed this same sentiment during both of their last interviews when discussing factors that affect NOS teaching. Mr. Stevenson said that “time is the primary [factor]” (Stevenson, I3) and that in order to teach more NOS, “I would need lots of time” (Stevenson, I4). Ms. Mangrove cited time again and again as her primary obstacle to NOS instruction. She blamed timing so often that she tired herself of it, saying, “But time again. huhuhuhh. I don't always feel that I have time to do it. Which is not so good. But, I think I have the skills to help myself develop activities if I had the time” (Mangrove, 3). Ms. Mangrove accidentally revealed the dual meaning of time concerning NOS in this one quote. This quote directly referred to additional time required for NOS planning, but her laughing referred to her previous statements that there was not enough classroom time to cover the required content and include NOS. Ms. Mangrove, and several of the other participants, felt that preparing NOS lessons and teaching NOS both required extra time that did not properly exist. Several teachers suggested that changes made to the curriculum standards could free up time for NOS instruction.

Ms. Heffernan continued her trend of being an outlier concerning most of the aforementioned context beliefs. Though she felt that the EOC dictated much of her teaching schedule and that the EOC failed to include many NOS related questions, Ms. Heffernan stood alone in her feeling that the curriculum standards include NOS and that she felt that she had time enough to appropriately teach the required NOS expectations. Concerning the placement of NOS in the standards, Ms. Heffernan said:

> *They put it in the standards for like every single science course. Like the technology and engineering and like stuff about students will be able to defend their conclusions from an experiment and stuff like that. . . . So if it's in all the standards, it must be important to them. Because they put in every year that I know of (Heffernan, I4).*

Ms. Heffernan described the Embedded Inquiry and Embedded Technology & Engineering sections of every science course curriculum in our state. She felt that the

requirements of these sections included NOS topics and that she was therefore expected to teach them in her classroom. She claimed to teach much of these sections during the first week and a half of the semester "along with the metric system and stuff like that. Intro science stuff" (Heffernan, I4). Ms. Heffernan also felt that she gave NOS an appropriate amount of time in her classes. In her mind, NOS was part of a unit and she felt that she did justice by this unit and would not give it extra attention even if she had extra time in the semester. Instead, Ms. Heffernan honestly said that if she were given extra time, she would use it on the units that she had to rush through at the end of the semester. Ms. Heffernan had very positive context beliefs concerning NOS, because she felt that they were in the standards and she felt that she utilized her time wisely to accommodate successful teaching of the NOS standards.

Conclusions on Motivation

Motivational Systems Theory requires a goal, emotions, and personal agency beliefs in order to motivation to occur. In the seven cases in this study, only two participants expressed explicit NOS related goals, which means that only two of them could have been properly motivated to achieve an NOS related goal. The two participants not only stated the goal required for motivation, but also stated positive connections to the other requirements of MST. Ms. Williams and Ms. Platypus both expressed positive emotions, positive capability beliefs, and positive context beliefs. They described a personal and environmental scenario that was conducive to goal achievement and therefore attained proper motivation toward their NOS goals.

Not only were Ms. Williams and Ms. Platypus the only participants to express explicit NOS related goals, they were also the only participants to describe positive connections to all three of the other MST requirements for motivation. Emotions, capacity beliefs, and context beliefs proved more troublesome for the members to the No Goal Group. These participants each

expressed negative or mixed connections in at least one of these categories. Ms. Heffernan expressed a mixed connection in only the emotions category, while the others expressed mixed or negative connections in at least two categories. Among the No Goal Group, Mr. Solo was the only participant to express an overly positive emotional connection, Mr. Solo was the only participant to express strongly negative capability beliefs, and Ms. Mangrove was the only participant to express strongly negative context beliefs.

Additionally, Ms. Heffernan was the only No Goal Group member to express strongly positive beliefs towards either context or capability. But, because she expressed mixed emotions towards NOS and failed to recognize NOS instruction as a goal, according to MST, she was not motivated to accomplish an NOS goal. This does not, however, mean that Ms. Heffernan was not motivated to teach NOS. This will be discussed in the following sections.

Skill for teaching NOS

In the individual case studies, I divided the MST category of skill into understanding of NOS and classroom practices concerning NOS. This distinction was considered important because the findings of research in NOS instruction have demonstrated that science teachers must possess understanding of NOS in order to appropriately teach it (Schwartz & Lederman, 2002). This distinction will be maintained for this section as well, but the understanding of NOS will be further divided into performance on the VNOS and verbalized NOS understanding, in order to appropriately showcase an observed differentiation.

Understanding of NOS. Six of the seven participants filled out the VNOS questionnaire after their fourth classroom observation and before their third interview. Mr. Stevenson's VNOS questionnaire was started under similar circumstances, but due to time constraints, the survey was paused 2/3 in to complete Interview 3. The questionnaire was completed immediately after

the interview without pause or internet consultation. All of the participants completed the questionnaire in between 30 and 60 minutes. The results of the VNOS questionnaire are interesting and noteworthy in their own right, but the distinction between the VNOS results and the verbalized understandings of NOS that the participants provided during the third and fourth interviews proved even more noteworthy. In order to draw attention to this distinction, the following two sections will present them separately.

Performance on the VNOS. Of all the NOS tenets described by Lederman, et al. (2002) and tested for in the VNOS questionnaire, the participants of this study struggled the most with differentiating between scientific laws and scientific theories. Though everyone expressed an understanding of the importance of theories and laws, six of the seven wrote unsophisticated answers on the VNOS questionnaire. Though some of this confusion was clarified in the subsequent interviews, in total four participants presented a naïve understanding of theory/law, two presented an adequate understanding, and one presented a sophisticated understanding. The confusion with the difference between theories and laws stemmed largely from establishing a hierarchy between the two. Mr. Stevenson openly admitted his confusion before he gave an answer that matched the common misconception:

> *I've always struggled with explaining the difference between theories and laws. The major difference is the degree of evidence for each. Theories have significantly less evidence supporting them and have a greater degree of uncertainty, whereas a law has a multitude of evidence and greater certainty. The point at which a theory becomes a law is unknown to me (Stevenson, VNOS).*

Ms. Mangrove gave a fairly comparable answer, but additionally suggested that laws need not be readily tested:

> *Scientific theory is supported by current evidence, but it's still not considered fact and is therefore still subject to investigation. Scientific law has such an overwhelming amount of supportive evidence that is considered fact and it's [not] as readily investigated (Mangrove, VNOS).*

Ms. Williams and Ms. Platypus extended the hierarchy even further by calling scientific laws facts and argued that they “cannot be proven wrong” (Williams, VNOS) and “will not change” (Platypus, VNOS). Doing this not only displayed a lack of understanding concerning laws and theories, but also expressed a naïve understanding of the tentative nature of science. Ms. Platypus went as far to say that “scientific laws are proven” (Platypus, VNOS), which definitively used a word that most NOS researchers and philosophers of science are not comfortable using.

The trouble differentiating between theories and laws can partially be explained by the fact that many of the participants explained that they do not often use the words theory and law in their classrooms. In interviews, atomic theory and the theory of evolution were commonly mentioned, but other theories and laws were few and far between. Gas laws were mentioned by only one teacher and cell theory by another. On the VNOS, when examples of theories and laws were asked for, the law of gravity and Newton’s laws were the only two examples of laws given. These two laws were not even taught in courses by most of the teachers who cited them, which may confirm how little they use the term law in their science classes. In the 41 classroom observations of this study, specific laws or theories were mentioned on only five ocassions. In every case the teacher named the law or theory, but did not describe it as a law or theory. Ms. Mangrove reviewed the different gas laws as relationships to be memorized, Ms. Heffernan taught natural selection without referring to it as a theory until the end of the lesson, and Ms. Williams reviewed VSEPR theory as rules follow. In Interview 4, when Ms. Heffernan expressed that her students struggled with the concept of theory as it relates to evolution, I asked if she teaches any other concepts as theories in hopes that that would help their definitional problems. Matching the theme of the theory/law struggle, Ms. Heffernan could think of only one other

theory, cell theory, that she teaches and immediately began to incorrectly contemplate whether it should be considered a law instead of a theory.

Further discussion of VNOS based participant NOS understandings necessitates separating the participants by groups. The No Goal Group all faired comparably in their answers to the VNOS questionnaire. All five members of this group scored sophisticated on at least five of the eight consensus tenets. Ms. Mangrove and Ms. Shirley demonstrated a sophisticated understanding of five, and the others mastered six each. Other than the distinction between theories and laws, members of this group individually expressed adequate understandings of the role of creativity and imagination in science, the lack of a universal recipe-like scientific method, the theory-laden nature of science, and the tentative nature of science.

The NOS Goal Group had limited success with describing an understanding of NOS that matched the consensus definition. As was previously noted, Ms. Williams and Ms. Platypus both identified scientific laws as being facts that are permanent and therefore not tentative. On top of this, they placed significant emphasis on experimentation and deemphasized social involvement. Concerning the importance of experiments, Ms. Williams offered a confusing example of how scientific knowledge can be developed “simply by observing,” but that confirmation of those observations still requires experimentation. She wrote, “We can say that the sky is blue by observation. This can help us develop scientific knowledge but can't confirm that the sky is in fact blue” (Williams, VNOS). Concerning social influence, Ms. Platypus discussed social and cultural values affecting only the direction of scientific research and the acceptance of scientific ideas. Ms. Platypus did not manage to appropriately display understanding of the roles of inference, subjectivity, or creativity in science, but Ms. Williams did manage to express vague but emerging conceptions of all three. These are the largest reasons why Ms. Williams’s overall

understanding of NOS was classified as borderline adequate and Ms. Platypus's understanding was classified as naïve. Despite their differences, both members of the NOS Goal Group presented understandings of NOS via the VNOS questionnaire that are not aligned with the accepted NOS definition.

Verbalized NOS understanding. All of the teacher participants verbalized an understanding of NOS that was different from the NOS understanding that was derived from their VNOS answers. These differences are highlighted in Table 3 and described in detail in this section.

Table 3

Participant NOS Understandings

	Mangrove		Williams		Shirley		Solo		Heffernan		Platypus		Stevenson	
	VNOS	Verbal	VNOS	Verbal	VNOS	Verbal	VNOS	Verbal	VNOS	Verbal	VNOS	Verbal	VNOS	Verbal
Tentative	A	+	N	+	A	+	A	-	S	+	N	+	S	-
Empirical	S	-	A	-	S	-	S	-	S	-	N	+	S	+
Theory-Laden	S	-	N	-	S	+	S	-	A	+	N	+	A	-
Interference, Imagination, Creativity	S	-	A	-	A	-	N	-	S	-	N	-	S	-
Socially and Culturally Embedded	S	-	S	-	S	-	S	-	S	-	A	-	S	+
Observation/Inference	S	-	A	-	S	-	S	-	S	-	N	-	S	+
Lack of Universal Scientific Method	N	-	A	-	S	+	S	-	S	-	N	-	S	-
Theories/Laws	N	-	N	-	N	-	S	-	A	-	N	-	A	-
Argumentation	-	+	-	+	-	-	-	+	-	+	-	+	-	+
Exceptions to Every Rule	-	+	-	+	-	-	-	-	-	-	-	+	-	-
Bias Removal	-	+	-	-	-	-	-	+	-	+	-	-	-	+
Inquiry	-	+	-	+	-	+	-	+	-	-	-	+	-	-
Critical Thinking	-	-	-	+	-	+	-	+	-	-	-	+	-	-
Scientific Processes	-	+	-	+	-	-	-	-	-	-	-	+	-	+

Note. N = naïve, A = adequate, S = sophisticated, - = not measured or described, + = included

Verbally, many of the participants struggled to define NOS and could name only a couple of the tenets. Others described NOS in unique ways that included many other aspects of science teaching. These differences and changes mainly occurred during Interview 3, which took place immediately after the completion of the VNOS questionnaire (with the exception of Mr. Stevenson, who was 2/3 done). Interview 4 was largely used to validate responses from Interview 3. I was able to confirm that none of their verbalized conceptions changed significantly between the third and fourth interviews, despite access to the internet and other NOS resources. The following section details some of the interesting trends in the participants' verbalized descriptions of NOS.

During Interview 3, all of the teacher participants were directly asked, "What is your understanding of NOS?" The answers to this question varied greatly, but for the most part followed two trends. Several of the teachers focused on describing science as a quest to understand nature or the universe and described the basic process of scientific knowledge creation. Others immediately jumped to discussing the tentative nature of science as the primary tenet NOS and then further described basic science. Ms. Platypus's first response was, "the nature science, I mean, it's constantly changing" (Platypus, I3). Ms. Shirley similarly said, "The nature of science. That science is always changing and it is not finite" (Shirley, I3). Six of the seven participants' responses fell within these two trends, and five of these six came to mention the tentative nature of science within five lines of dialogue. Tentativeness was very important to the vocalized understandings of NOS of five of the participants, but interestingly, none of them referred to it by name. All of them referred to science as changing over time, but none said tentative. Ms. Heffernan struggled for a bit on a summative word and decided to call science "dynamic" (Heffernan, I3). As noted earlier, Ms. Shirley called it "not finite" (Shirley, I3).

Though none naturally called it by name, the teachers made a case that the concept of science changing over time was important to science and to student understanding of science. Ms. Shirley described its importance when she said:

> *Yes, we do things in a certain way and yes, we understand things in a certain way, but 10 years from now they'll be different. So it's okay that what we know now is going to be changing. And how we go about finding that out is going to be changing, too (Shirley, I3).*

Ms. Shirley's interest in the tentativeness of science was shared by a majority of other participants with varying levels of sophistication, but this was the only NOS tenet from the VNOS definition of NOS that the majority of the participants vocally described as being a part of NOS. They did, however, reach consensus on two other topic that are not included on the VNOS: argumentation and bias-removal.

The role of argumentation in science was verbally described by six of the participants within the context of NOS. Though not explicitly a part of the VNOS tenets, these teachers described argumentation as a part of NOS. Ms. Mangrove stated that science is "a continual process where you reevaluate previous findings and you retest" (Mangrove, I3). Mr. Stevenson described science as being improved "through discussing with others" (Stevenson, I3). Repetition of experimentation and argumentation with other scientists were recurring themes throughout this study. Mr. Solo described peer review as a behavior of scientists equal to experimentation and theorizing. He said, "Scientists are engaged in continual research, continual review of peers' research, continually looking at new theory and new phenomenon, and trying to engage in experiments or research that helps explain those phenomenon" (Solo, I3). Peer review was explicitly discussed as a vital part of science by three of the participants, and the essence of peer review was described by three of the others.

Along the same lines, bias removal was described in the context of NOS by four of the participants. Ms. Heffernan directly stated, “That's part of the nature of science, is that it is not supposed to be bias” (Heffernan, I4). Mr. Solo argued that it is the job of scientists to “seek out the best explanations based on unbiased research and repetition” (Solo, VNOS). All of the bias-concerned participants recognized that bias exists in science, but felt it was equally important to understand that science seeks to remove bias whenever possible. Ms. Mangrove summarized this when she wrote, “Even though science/scientists have bias, the journal writing process serves as a means of checks and balances to overcome the biases” (Mangrove, VNOS). She felt that bias removal was important enough in science to include it in her description of bias on the VNOS survey. Mr. Stevenson expressed much the same when he wrote, “As scientists we do attempt to overcome this dilemma by adding a peer-review system. . . . I feel that only time and continual testing/experimenting are the only way things will transcend or minimize such opposition” (Stevenson, VNOS). Not only did these four participants feel that bias removal was an important part of NOS, they also felt it was important to talk about bias removal with their students.

An additional non-consensus NOS tenet was separately discussed by three of the research participants. Ms. Mangrove, Ms. Platypus, and Ms. Williams felt that an understanding that there are exceptions to every rule in science was a part of NOS itself. Ms. Mangrove said, “this is science and there are exceptions to every rule” (Mangrove, I4) when describing the two aspects of NOS that she felt her students learned best. Ms. Platypus mentioned the idea that there are exceptions to every rule in her first monologue about NOS in Interview 3 and affirmed this with a story about students questioning whether carnivorous plants are autotrophs or heterotrophs. Talking about how she prepared students for exceptions, Ms. Platypus said, “I feel that's teaching the nature of science, because that’s showing them that there's little exceptions to everything I

guess" (Platypus, I3). Ms. Williams also felt that students needed to accept that there are exceptions to every rule in science and mentioned transition metal bonding as an example of this lesson. When pressed, however, she could not explain why exceptions are an understood/tolerated part of science. None of these three who felt that exceptions to rules are a distinct part of science connected the exceptions to failures in the current theory and instead described it as a separate tenet of NOS that needs to be taught to and accepted by students.

The next areas where participants' vocalized understandings of NOS differed from my interpretation of their VNOS understandings are much more holistic. Vocalized descriptions of NOS often extended well beyond the accepted NOS tenets and encompassed very different science teaching perspectives. NOS was frequently connected to and described as including inquiry, critical thinking, and "thinking like a scientist."

Four of the participants in this study discussed inquiry as a part of NOS. For Ms. Mangrove, her discussion of inquiry started as a part of her feelings about NOS. She felt that the state would need to loosen its expectations so that she could "teach more inquiry and nature of science and things like that" (Mangrove, I3). This presented inquiry as another science teaching practice parallel to NOS that she would like to include in her classroom practices, but her description of inquiry and NOS soon collapsed into one common entity. She later said, "I don't know if I necessarily always understand the content well enough to create nature of science inquiry-type projects" (Mangrove, I3). She also described the evaluation model as giving a nod to NOS because it pushes towards inquiry and described her teaching of NOS during the gas laws unit as being based on investigation. Over the course of two interviews, Ms. Mangrove's description of her interactions evolved to include inquiry as a part of NOS. Ms. Shirley and Ms. Williams similarly answered NOS specific questions with inquiry influenced answers. Ms.

Shirley answered a question about whether she has an NOS unit in her courses with, “No. We kind of, we talk about inquiry, but I tried to do inquiry like things throughout the semester.” Ms. Williams answered a question about whether her NOS goal was personal or institutional by saying, “I would probably say both. I think the school currently is maybe pushing towards more inquiry and more thinking in science.” In all cases, inquiry-type teaching was presented as a part of NOS.

Several of the teacher participants also described NOS as including the teaching and use of critical thinking skills as well as helping students to think like scientists. This trend was observed in five of the participants. In all cases, they extended their definition of NOS beyond just a content to include a way of teaching. Ms. Shirley described NOS as including “thinking outside of the box and developing your own thoughts” (Shirley, I3). Ms. Platypus felt that NOS included “but why” questions and challenging students to explain their thinking. Ms. Williams said that her future plans to teach NOS would include more hands-on things in order to “get them thinking on their own” (Williams, I4). Mr. Stevenson described his insistence on supportive evidence as being the aspect of NOS that his students learned the best and claimed to teach NOS by making his students think and act like scientists in the lab. Six of the seven participants discussed teaching practices that promote inquiry, critical thinking, and/or scientific behaviors as being a part of NOS. Most flowed effortlessly between accepted NOS tenets and these extraneous skills and practices. The benefits of teaching with inquiry and building student critical thinking skills are not being challenged, but the perception of NOS held by these six teachers that includes them is noteworthy.

Mr. Solo’s vocalized definition of NOS stands alone for its inclusion of extraneous aspects as a part of NOS. During Interview 3, Mr. Solo responded to the question about his

understanding of NOS by saying, “My understanding of nature of science is it's more of an inquiry-based level of understanding of science rather than a memorization flip card understanding” (Solo, I3). He went on to say, “So my understanding is that it is really trying to figure out and trying to explore creatively why things are happening and how they happened in the science world” (Solo, I3). Mr. Solo described NOS as a way of teaching science for deeper understanding. He basically described NOS as being inquiry and critical thinking. During Interview 4, Mr. Solo mirrored his earlier definition of NOS when he said:

> *Teaching the nature science is sort of letting the students build their own understanding of scientific phenomenon through inquiry and experimentation and things like that. So less memorization and flip-card learning and more hands-on exploration and coming to conclusions on their own and then connecting ideas, I guess, based on scientific phenomenon (Solo, I4).*

Mr. Solo explicitly confirmed the connection between his vocalized understanding of NOS and inquiry and critical thinking when he used those exact words to answer a question about factors that affect his ability to teach NOS. Mr. Solo faulted the EOC for making the focus of his class “more test-based and performance-based on a formal assessment rather than fostering inquiry and critical thinking and things like that” (Solo, I4). In every situation, I continued to ask about only NOS and Mr. Solo instead turned every answer toward inquiry and critical thinking. To him, they were the same thing. Despite having a fairly sophisticated understanding of NOS according to the VNOS questionnaire, Mr. Solo did not verbalize a congruent understanding. In lesser degrees, this was mirrored in several of the other teacher participants and was demonstrated in their beliefs about their NOS teaching practices.

Classroom practices concerning NOS. In total, 41 classroom sessions were observed for this study. During each observation, I took detailed notes of what I saw and heard. Most teacher actions were written down, but specific attention was placed on hearing and recording

vocalizations of references to the 9 tenets of NOS (the 8 from VNOS plus argumentation) and words like science, scientists, theory, and change. After each observation, a personal reflection was composed and the notes were then typed for later analysis.

During most observations, course specific content was presented as pure facts that needed to be learned. Most facts required little to no manipulation and only memorization. Not everything was lecture, however. Some group work and laboratory activities forced students to think for themselves and reason through their conceptions of material. This is all an overgeneralization of what was observed, but the major conclusion should be that very little NOS was observed. Conceptions of the broad sense of science and the practices of actual scientists were rarely discussed. Topics related to NOS were observed in only two classroom sessions. Only Mr. Stevenson and Ms. Heffernan attempted to teach NOS-related topics on one occasion each.

During Mr. Stevenson's 6^{th} classroom observation, a seemingly impromptu discussion of an NOS-related topic was observed. This did occur after Interview 3, the interview where NOS was first mentioned and discussed, but the inclusion of NOS in this lesson did not appear forced. It came about in response to a student question. The students were doing a lab where they dissolved zinc chloride in water and attempted to isolate the gaseous byproduct. They had done the lab the previous class period and were repeating it for an unknown reason. During the introduction, Mr. Stevenson asked the students how they knew that the byproduct was hydrogen. A student shouted that they lit it on fire. Mr. Stevenson agreed, stating, "because we know chemically that hydrogen is flammable" (Stevenson, O6) and the potential NOS conversation came to a halt. No mention of inference was made concerning the presence of hydrogen in the accepted understanding of zinc chloride. No mention was made of other possible flammable

gasses. An NOS moment was lost, but another soon surfaced. A student asked if they needed to take measurements of their chemicals. This led Mr. Stevenson to explain why measurements are needed for replication. He asked the students why replication was needed in science, and the word validity was offered. Mr. Stevenson quickly discussed how replication was needed for publication and telling the world about your findings. Though he did not specifically discuss the need for others to replicate your experiments as a part of peer review, he did describe the importance of repetition for producing valid, worthwhile results. This may have been NOS-light, but it was still NOS. (Fun side note: instead of capturing released hydrogen from the chemical reaction, one of Mr. Stevenson's students partially filled his balloon with natural gas straight from the nozzle. When he lit it to test for flammability, the explosion was obviously too loud and fiery to have come from the actual lab activity. Instead of kicking the student out of lab, Mr. Stevenson did not even accuse the student of a misdeed. Instead, he made the student attempt to explain how it could have been physically and chemically possible for his results to be that good.)

On another occasion, I observed Ms. Heffernan teach a very explicitly NOS lesson. This occurred at the beginning of the second semester in a CP ecology class. Since it was early in the semester, I happened to come on her *What is Science?* day. The class started with a tricky mind puzzle, which Ms. Heffernan used to describe how scientists use problem solving and described that the students were in essence "simulating the scientific method" (Heffernan, O2). To connect the critical thinking required for the puzzle to the scientific method was a bit of a stretch, but this was not the real NOS of the lesson. Instead, Ms. Heffernan's extremely detailed PowerPoint and accompanying direct instruction lecture highlighted NOS regularly. She had a slide dedicated to defining science that included how science studies the natural world and is therefore separate

from religion and society, how science aims to eliminate bias, and how peer-review serves to check the work of other scientists. She also defined a scientific theory as “an explanation of nature supported by many observations and experiments over time” (Heffernan, O2) and specifically mentioned that theories are not “wild guesses”. The lecture also included a description of the basic scientific method, but she very intentionally said, “When I say the scientific method, I do not mean everyone does step one, step two, etc. but I do mean that scientists use it as a template” (Heffernan, O2). Though she gave no examples that were counter to the basic scientific method, she did mention that it is not the only way that science is done. She also explicitly talked about the role of interpretation and explanation in the conclusion step of the scientific method as well as the role of variables and control groups. It was a lot of information for one class period, but she was very explicit concerning the aspects of NOS that she chose to highlight.

These two instances represent the only times that NOS was observed in the classroom of a participant in this study. Some additional instances of NOS instruction were narrated by several of the participants during interviews 3 and 4, but these cannot be independently validated. The descriptions were, however, generally presented as infrequent and meager, which loosely triangulates with the observed lessons.

Two content topics were most commonly associated with NOS by the participants of this study. All three of the chemistry teachers reported teaching the tentativeness of science during their lessons on the atomic theory. And three of the four biology/ecology teachers reported teaching the importance and explanatory power of theories during their lessons on evolution.

Concerning atomic theory, the chemistry teacher s felt that the evolving history of atomic understanding allowed for a poignant discussion of the tentativeness of science. Ms. Mangrove

described that it is easy to teach NOS during the atomic theory unit because “it's very easy to see how the model has changed. You can see how the scientific process has worked, because we have like six models you can talk about” (Mangrove, I3). To her, the history of the atomic model allowed students to see scientific progress in a clear, linear fashion. Ms. Williams echoed this sentiment, when she described why NOS is easier to teach during the atomic theory unit than during any other unit. She said:

> *I just find it a little bit easier to teach that non-permanence in atomic theory versus a lot of other subjects, because like everything else is so intense I think for them in their understanding, that it is kind of hard to push, to tell you all, this is not permanent, but we're learning it. Some units I don't really bother, but when I think, really, units that encourage it, like atomic theory, I'll put it in there (Williams, I3).*

Ms. Williams found NOS to be harder to teach during other units. She felt that teaching the tentativeness of science through the history of a scientific theory was easier than teaching that other scientific content is also tentative. She described that some knowledge in her class just needed to be learned and not viewed as temporary. Ms. Williams and Ms. Mangrove described their atomic theory NOS lessons as including PowerPoints with lots of pictures of the historical models and teacher-centered discussions. They both described also teaching the role of inference in atomic theory, since many of the components of atoms could not be seen at the time of their “discovery.” Ms. Williams described having to discuss how scientists have to “think differently” because they can always see and touch everything, and Ms. Mangrove talked about “mak[ing] the theory kind of fit the evidence” (Mangrove, I3). Mr. Stevenson did not specifically detail how he teaches his atomic theory unit, but he did connect it to NOS. He said, “Science isn't as clear-cut as society makes it appear. So things that we might think are absolutely certain and correct are in fact not. I emphasize that a lot, too, when we learn about Aristotle and Democritus” (Stevenson, I3).

Evolution proved to be a useful NOS topic for three of the biology/ecology teacher participants. Though their described NOS instruction during discussions of ecology was less organized than that of the chemistry teachers during atomic theory, the biology/ecology teachers claimed to successfully discuss NOS topics with their students. Ms. Shirley said that she used evolution to describe how much the science behind evolution has changed since Darwin's day. Ms. Platypus described emphasizing the difference between science and beliefs during this unit. Lastly, Ms. Heffernan described having to emphasize the definition of a theory during the evolution unit when her students exclaimed that evolution is "just a theory" (Heffernan, I3). In all of these cases, evolution allowed the science teachers with opportunities to discuss NOS with their students.

Beyond these two units that lent themselves to NOS instruction, the novice science teachers struggled to think of other content that they ever used to teach NOS. Instead of citing specific instances, most mentioned that they "just throw it in here and there" (Williams, I4). NOS was not something that they planned for, "but when the opportunity arises, I definitely [teach it]" (Platypus, I3). NOS instruction was described as sporadic (Williams, I4) and unintentional (Solo, I3). This unplanned NOS instruction was most often linked to student questions and laboratory experiences. Five of the seven participants mentioned teaching NOS through these unplanned means and four described this as the only way that they taught NOS outside of the atomic theory and evolution units. Additionally, four participants described their approach to NOS instruction as subtle and specifically mentioned that they do not ever refer to it as NOS or the nature of science.

Subtle and unplanned are not words generally used to describe appropriate NOS instruction. Instead researchers look for explicit and reflective instruction (Khishfe & Abd-El-

Khalick, 2002; Lederman, 2007), which by nature require a certain amount of emphasis and planning. Participant discussions of NOS instruction never included the word reflective, but one teacher did mention explicit. In her first description of NOS, Ms. Heffernan said:

> *When I think of nature of science I think of the stuff that I teach at the beginning of any science course before you get into it. Then you're supposed to apply it throughout as well, but they have to have the basis explicitly taught at some point (Heffernan, I3).*

I then asked her to describe what she meant by explicit, and she said, “They got a chance to figure it out, and then after they had that experience, we talked about it” (Heffernan, I3). The experience she described as leading to her explicit discussion of NOS is another reason that Ms. Heffernan’s classroom practices concerning NOS set her apart from the others. She was the only teacher participant to describe teaching NOS with a specific decontextualized NOS activity. Her Checks Lab activity, which she easily found on the internet, allowed the students to reflect on the role of inference in science and the concept of hypotheses and theories. It also provided that class with a common experience related to NOS that they could reference back to all year.

Responsive Environment

As with each of the individual case studies, reflecting on the actual responsiveness of their environments is very hard to do. Since NOS instruction was extremely limited and principals very rarely visited the classrooms of these novice science teachers, administrators were unlikely to have seen any NOS instruction. Similarly, the EOC scores of students in these teachers’ classes are unlikely to have been affected in either direction by NOS instruction. The limited NOS instruction likely had no influence on the environment and therefore likely received no response from the environment. This cannot however be proven without significant administrator interviews and EOC score analysis, which are not going to happen at this time.

Conclusions on Goal Achievement and NOS Instruction

According to MST, goal achievement requires motivation, skill, and a responsive environment. Since appropriate motivation was observed in two of the participants, analysis of goal achievement is that much easier. Ms. Platypus and Ms. Williams both demonstrated motivation for NOS instruction, but their demonstrated skill set concerning NOS instruction was not adequate. Both demonstrated an understanding NOS that was not sophisticated. Both verbally discussed an understanding of NOS that nontraditionally included exceptions to rules and either inquiry or critical thinking as major tenets of NOS. Their descriptions of NOS instruction depended on sporadic, unplanned moments that could only be as good as their limited vocalized understandings could react to. Knowing that NOS requires explicit and reflective instruction for change to occur in student understanding, Ms. Williams and Ms. Platypus were not successful at achieving their NOS goals.

Though she did not have an NOS goal and therefore lacked motivation to achieve an NOS goal, Ms. Heffernan did achieve moderate success at appropriately teaching NOS. She saw NOS as a part of her required content and therefore as a contextually supported task. She sought to utilize her sophisticated understanding of NOS and her learned understanding of how NOS should be taught to positively affect the NOS understandings of her students. She used contextualized and decontextualized situations to explicitly teach NOS content to her students. At the beginning of the semester and then periodically thereafter, Ms. Heffernan highlighted and reiterated many of the major NOS tenets to her students. Though nothing is known about changes in the NOS understanding of Ms. Heffernan's students, the situation was appropriate for potential NOS learning.

Chapter 6: Conclusions

This study was designed to study the interactions between novice science teachers and the nature of science (NOS). Motivational Systems Theory (Ford, 1992) served as a theoretical lens through which to discuss the goals, motivations, skills, and achievements concerning NOS of seven participant teachers. The questions that guided this study were:

1. What are the factors that facilitate or impede novice science teachers' ability to promote student NOS understanding?
    a. What are the personal factors?
    b. What are the contextual factors?
2. How do personal and institutional goals concerning NOS affect classroom practice related to NOS?
3. Considering all factors, do novice science teachers teach for NOS understanding? If so, how?

For this group of participants, the answer to question number three was largely no. As was noted in the previous two chapters, NOS instruction was observed only two times in 41 classroom visits. NOS instruction was described by all of the teachers, but this was rarely described as occurring outside of atomic theory and evolution units and was most often described as unplanned and sporadic. Many of the teachers struggled to think of situations and content where they had included NOS instruction, but they did not struggle to name factors that affected their ability to teach NOS.

I will now attempt to answer the other two questions, though their answers are complex. This will then be followed by implications and recommendations for future study.

Teacher Stated Factors That Affect NOS Instruction

During Interview 3 and Interview 4, the seven novice science teacher participants of this study were tasked with naming and describing factors that affect their ability to teach NOS in their classrooms. Some teachers were quicker than others to start naming factors, but all of the teachers contributed their thoughts and ideas. When conversation waned, I made an effort to emphasize that factors could be negative or positive. In most cases, even more factors were therefore discussed. Few of the factors that the participants stated were surprising. They often overlapped the colloquial complaints of many teachers concerning any teaching goal (Srikantaiah, Zhang, Swayhoover, & Center on Education Policy, 2008). Factors like the end of course test (EOC), student preparedness, and a lack of time and resources could affect teachers in all grade levels and all subject areas. In this case, the teacher participants claimed that these factors and others affected their ability to teach NOS in their science classrooms. In an effort to not demean the stated concerns of the teacher participants, I will discuss their named factors in greater detail, utilizing the capability and context sections of MST to provide a familiar structure.

Stated factors related to capability beliefs. Though the majority of factors that were stated by the participants concerned context beliefs, several shared factors that related to capability beliefs. None of these stated factors were ever shared by a majority of the participants, but they still merit discussion. Two of the participants, both members of the No Goal Group, directly stated that their current understanding of NOS potentially stood in the way of their NOS instruction. These teachers, Ms. Mangrove and Mr. Stevenson, felt that clarifying their personal understanding of NOS would help their ability to teach more NOS in the future. Both also claimed to have received appropriate NOS training during graduate school, but that it may not have been enough. Ms. Mangrove especially felt that since she never experienced science

coursework through an NOS perspective, she therefore struggles with understanding the concepts and how to include it in her practices. Mr. Stevenson admitted that he was very distracted and overwhelmed in graduate school as an explanation for why his personal understanding of NOS was not better developed. He claimed to be in a better place right now and could soon be ready introspectively consider his understanding of NOS and then prepare himself to better address NOS in his classroom.

Also related to capability beliefs, Ms. Mangrove and Mr. Solo expressed interest in further training concerning NOS instruction. They expressed that their current limited exposure to and inexperience with NOS was a factor in their teaching and that additional training would be helpful. Mr. Solo expressed that "extensive" training would be beneficial, implying that his current level of training was definitely a factor. Conversely, Mr. Stevenson and Ms. Platypus were pretty adamant that they did not need further training; Ms. Platypus, because she was confident in her ability to teach anything and Mr. Stevenson, because he felt he could "Google it."

Three teachers felt that additional resources like lesson plans and correlated articles would be helpful toward their ability to successfully teach NOS. Mr. Solo directly linked NOS teaching resources with additional training, while Ms. Platypus asked for resources instead of training. Ms. Shirley failed to express an opinion about training in either direction, but did express interest in getting lesson plan suggestions that successfully integrate NOS concepts with her curriculum.

Lastly, in capability-related factors, Ms. Platypus offered her openness as a positive factor. She felt that her openness to student questions and her willingness to talk through her lines of reasoning with students helped to promote NOS in her classroom. This stated belief

affirms her belief that NOS can casually be taught without specific intentions during regular classroom conversations.

Stated factors related to context beliefs. None of the participants described any administrators or larger educational institutions as being explicitly against NOS instruction. Instead, they spoke of roadblocks that were caused by institutions that had the potential to stand in the way of NOS instruction without being specifically built for such a purpose.

The state curriculum standards for each specific course and the corresponding EOC's were the most discussed factors affecting NOS instruction. These were often paired with a discussion of the time constraints that they created, which were described as leaving little time for NOS teaching. Six of the participants described the pressures of finishing the required curriculum before the EOC test as a limiting factor for NOS instruction. All of the teachers discussed how NOS had little to no presence on the EOC's of any of their classes. Based on this and possibly their interpretations of the standards, six of the seven described NOS as being extraneous to the curriculum and therefore outside of the regular expectations of their courses. The curriculum and EOC's were presented by these participants as working against NOS instruction. Suggestions were made to lessen the demands of the curriculum in order to allow more time for NOS instruction. It was also suggested by one teacher that NOS be included on the EOC so as to encourage more NOS instruction.

Four teachers also considered the scientific equipment and technology available at their schools to be limiting factors to their NOS instruction. They felt that more money and more equipment could better prepare them to teach NOS and allow for more involved NOS experiences. The confusion between inquiry and NOS could, however, be fueling the emphasis on equipment and technology. Equipment was described as being needed to foster hands-on

experiences with science that would challenge students to think for themselves. Ms. Shirley and Mr. Solo described the usefulness of computers based around the ability of students to do outside research. Though equipment and computers could be useful to NOS instruction, it was not clear from participant descriptions that they intended the equipment and computers for the accepted tenets of NOS.

Lastly, five of the participants considered student prior training to be a factor that affects NOS instruction. They described NOS (as well as inquiry and critical thinking) as being a foreign concept to most of their students. Several described the mental capacity of some of their students as being unready for NOS (Platypus, I4) and many described their honors students as being more accepting and ready for NOS than their normally tracked students. Low student engagement and ability were cited for their effect on NOS instruction (Solo, I4), especially with respect to NOS being viewed as external to the curriculum. Most of the teachers described the benefits that could be gained from having students introduced to NOS at a younger age, so that they could better teach it in their own courses.

Conclusions on teacher stated factors. The factors that were cited by the participants as affecting their NOS instruction likely had a profound impact on their NOS instruction. Ms. Mangrove's belief that there was not enough time to appropriately teach the regular content and teach NOS likely served to keep her from additionally planning for and implementing NOS instruction. Mr. Stevenson's lack of confidence in his own understanding of NOS probably did affect his enthusiasm and motivation to bring NOS into his classroom. Mr. Solo's belief that his lower-level students were not ready for higher-order thinking and NOS likely did influence his willingness to teach more NOS. The beliefs of each participant concerning capability and contextual issues affected his/her reaction to and interaction with NOS in the classroom.

The teacher stated factors from this study closely resemble the factors described by Abd-El-Khalick et al. (1998) and Lederman et al. (2001) in their studies of factors that affect the NOS teaching of pre-service science teachers. The biggest differences between the factors named by the pre-service teachers of the previous studies and the novice science teachers of this study are directly linked to the difference in titles of the groups. Pre-service teachers reported having to operate within the constraints of the mentor teachers (Abd-El-Khalick et al., 1998) and their master's degree programs (Lederman et al., 2001) as impeding factors, both of which are factors that novice science teachers who already have master's degrees by nature do not have to deal with. The pre-service teachers featured in Abd-El-Khalick et al. (1998) additionally reported a preoccupation with classroom management as affecting their NOS instruction. Though some of the novice science teachers reported issues with student behavior, none named classroom management as a factor that detracted from NOS instruction. Most other factors cited by Abd-El-Khalick et al. (1998) and Lederman et al. (2001) correlate to the findings of this study. Overlapping teacher stated factors include content, testing, time, and understanding of NOS.

One factor described by the pre-service science teacher participants in Abd-El-Khalick et al. (1998) that could have affected my participants, but was not reported, was an insistence that NOS can be learned implicitly. Though my participants did not consistently report an understanding that NOS needs to be taught explicitly, they did consistently describe efforts to teach NOS that included direct instruction (especially concerning atomic theory and evolution) and direct responses to student questions. The link described by a majority of the participants between NOS and either inquiry or critical thinking could, however, be used to make the reverse argument. If they truly believed that inquiry was a part of NOS and they taught their students science through inquiry, then the supposed NOS gains of students would likely be implicit,

unless they were explicitly taught about inquiry. Therefore, speaking to the implicit assumptions of my participants who clearly possessed confused vocalized understandings of NOS is not practical.

Of all the factors that affect NOS instruction that were named by this study's teacher participants, the majority related to curricula, testing, and student readiness. There was a noted lack of participant stated factors that directly addressed their skill at teaching NOS or their understanding of NOS. These missing factors demonstrate the incomplete picture that is revealed by relying on participant ideas only. Though the factors and concerns that they voiced are valid and did affect their NOS instruction, other factors had a greater impact on their NOS instruction. These factors and their impact will be discussed in the coming sections.

Role of Motivation Systems Theory in NOS Instruction

Ms. Heffernan was an outlier in many aspects of this study. She was the only participant to describe her NOS instruction as explicit. She was the only participant to describe seeking out NOS resources on the internet. She was the only participant to describe planning and teaching a decontextualized NOS lesson. She was the only participant who was able to recall two or more specific instances where she specifically taught NOS. Ms. Heffernan presented a pretty strong case for herself as the most qualified NOS teacher in this study, but she refused to consider NOS a personal goal. In fact, Ms. Heffernan described a fairly weak emotional connection to NOS.

According to MST, since Ms. Heffernan possessed no NOS goal, she would accordingly lack motivation to reach that goal, which would in turn lead to failure to accomplish that goal (Ford, 1992). Since Ms. Heffernan was the only participant in this study to demonstrate any level of concrete NOS instruction, this would potentially call into question the role of MST in discussions of NOS instruction. The argument for keeping MST as a useful construct partially

lies in the semantics. MST relies on the creation of a conscious and explicit goal. Ms. Heffernan, however, did not feel the need to create a goal for NOS instruction. To her, NOS was a part of the curriculum and therefore a part of her job expectations. Just as she did not feel the need to create an explicit goal concerning organelle instruction or keeping the pencils in the pencil cup sharp, Ms. Heffernan saw no need for an NOS goal. To her, NOS was a responsibility of her job that she would accomplish. Ms. Heffernan stood alone, because she was the only participant who perceived NOS to be a part of the curriculum standards and therefore a part of the expectations that were passed down to her by the state, her county, and her administrators.

Ms. Heffernan's outlier status allows us to isolate her from the discussion of MST and discuss the differences between viewing NOS as a part of the curriculum and viewing NOS as an extraneous task.

NOS as a part of the curriculum standards. Ms. Heffernan was the only participant in this study who expressed an understanding that the curriculum standards for her courses included NOS. In Interview 3 she argued that the standards are not really a factor that affect her NOS instruction, because "they are in the standards." She argued the same thing in Interview 4, saying, "They put it in the standards for like every single science course." In both interviews, she explained that NOS is in the Embedded Inquiry and Embedded Technology & Engineering sections of the state curriculums of every high school science course.

Examination of the Embedded Inquiry section can validate Ms. Heffernan's claim, as long as you look at it through an NOS lens (see Table 4). Without using the same words as the VNOS definition of NOS, the state standards can be interpreted to include descriptions of science as tentative, theory-laden, socially & culturally embedded, influenced by creativity & imagination, and built on argumentation. The standards discuss competing theories, bias, and

reevalutation/extension. The standards also suggest tracing “the historical development of a scientific principal or theory,” which sounds a lot like the atomic theory and theory of evolution lessons that several of this study’s participants described. The only statement that is obviously contrary to the consensus NOS definition is the concept of “free of bias.” The standards ask students to “draw conclusions that are free of bias” and “determine why a conclusion is free of bias.” Aiming for limited bias is one thing, but assuming that it is possible for something to be completely free of bias is not aligned with the accepted definition of NOS. Also notably problematic is the implication by the standards that these NOS-type concepts should be taught implicitly. The standards call for students to design, collect, verify, analyze, compare, etc. (See Table 4). These action verbs are not subsequently followed by requests for students to understand the concepts or even reflect upon them. The focus on “doing” promotes inquiry, but appropriate NOS learning would likely be lost without specific intervention. Therefore, seeing NOS concepts as being in the state standards is very plausible, but extending those standards to include explicit and reflective NOS instruction may require additional teacher effort, skill, and foresight.

Table 4
Standards from the State Science Curriculum and their associated NOS tenets

Designation	Description	Possible Related NOS Tenets
CLE.Inq.1	Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.	Tentative
CLE.Inq.2	Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.	Theory-laden, Socially & Culturally Embedded, Creativity
CLE.Inq.3	Use appropriate tools and technology to collect precise and accurate data.	Empirically Based
CLE.Inq.4	Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.	Empirically Based, Socially & Culturally Embedded
CLE.Inq.5	Compare experimental evidence and conclusions with those drawn by others about the same testable question.	Argumentation

Note . Only Course Level Expectations are listed. Similar comparisons of NOS to Checks for Understanding and State Performance Indicators could be made, but would be largely redundant. Listed NOS tenets are not provided by the state. Instead possible links to accepted tenets are suggested by the study's author.

This raises the question, why did Ms. Heffernan come to believe that the standards include NOS, while the other six participants did not come to this same conclusion? Via the VNOS, Ms. Heffernan did express one of the most sophisticated understandings of NOS, but several others were quite sophisticated themselves. Ms. Heffernan did not even express much of an emotional attachment to NOS. She said, “I want my kids to understand the nature of science” (I3), but immediately downplayed it compared to the EOC and other class concerns. To Ms. Heffernan, NOS did not deserve special attention in her teaching. Just like with the other

participants, NOS did not naturally surface in her personal goals or conversations about her teaching. Ms. Heffernan was a first-year teacher during this study, so perhaps the NOS training of her graduate school courses was fresher in her mind than some of the participants, but the other two first-year participants did not express any indication that the standards include NOS.

Whatever the cause, Ms. Heffernan believed that the standards included NOS. Because of her belief, Ms. Heffernan argued that the state and the county must support NOS. She said, “So if it's in all the standards, it must be important to them” (I4). Within the MST framework, her understanding of NOS as a part of the curriculum standards provided the appropriate context beliefs for motivation and goal achievement. In Ms. Heffernan’s case, however, NOS instruction was not a personal goal. Ms. Heffernan did not feel that NOS was important enough to justify an individual goal. Instead, her context belief concerning NOS instruction raised NOS only to the point of viewing it as a professional obligation equivalent to any other classroom content. She said, “I'm not going to give special thought to NOS. Just like I don't give special thought to meiosis over any other unit” (I4). Though not elevated over content, Ms. Heffernan did view NOS as a part of the content, and therefore viewed its inclusion as a professional obligation. This appears to be all the motivation that Ms. Heffernan needed to attempt to teach NOS content.

Ms. Heffernan was the only member of the No Goal Group to state largely positive capability and context beliefs concerning NOS. The other members of that group waivered on at least one of those categories. Both members of the NOS Goal Group did express positive beliefs in both of these categories, but without Ms. Heffernan’s belief that the standards include NOS, positive capability beliefs and context beliefs alone did not appear enough to support instructional success for Ms. Platypus and Ms. Williams.

For Ms. Heffernan, NOS was just a part of the regular curriculum. As a part of “intro science stuff” (I4), Ms. Heffernan described NOS as a unit. She said, “I think that NOS gets as much time as any other unit does.” Because she viewed it as a unit like any other, Ms. Heffernan claimed to teach NOS just like any other unit. She said, “I teach it the way I do everything else” (I4) after she claimed to focus on it for a set period of time and then “reference it throughout the rest of the semester” (I4). Ms. Heffernan also described NOS as operating comparably to other classroom content. She described that when referencing NOS content at times after the original unit that “they don't always remember what we were talking about, but that happens with anything. It's not just NOS. Without repetition they forget things” (I4). To her NOS was regular content that operated like regular content in the eyes of her students. She managed student confusion with NOS just as she did every other content area.

Because Ms. Heffernan was able to view NOS content as regular class content, NOS instruction did not require a special goal. Just as meiosis, evolution, or any other content required no extraordinary goal, nor did NOS. To her, NOS could be appropriately taught without emphasis. This allowed Ms. Heffernan to attempt to teach NOS outside of the regular restrictions of MST. Her plans and efforts to teach NOS operated without an external goal, and her personal skill and the lack of environmental restrictions carried her plans forward.

Greater than the fact that Ms. Heffernan successfully skirted traditional MST discussion of motivation, is a discussion of the value of perceiving NOS to be a part of the regular curriculum. Six of the seven participants discussed an understanding of NOS that placed it outside of the curriculum standards. Presented as an external entity, NOS therefore required special attention and intentional inclusion. This distinction established a scenario where intentional goal creation and motivation must occur for proper NOS instruction to occur. In

contrast, by viewing NOS as internal to the curriculum and expected, Ms. Heffernan created a fast track to NOS instruction that may have eased the challenges she encountered. Just as the professional obligation to EOC success trumped NOS inclusion for many of the other participants, inclusion of NOS instruction trumped non-inclusion for Ms. Heffernan. By her understanding of NOS and the curriculum of her courses, Ms. Heffernan was just as likely to not teach NOS as she was to not teach the parts of a cell.

Ms. Heffernan's understanding of NOS as a part of the curriculum standards for her courses set her up for a different experience with motivation and NOS instruction than the other participants. Their understanding of NOS as external to the curriculum made MST much more relevant, which will be addressed in the next section.

NOS as external to the curriculum standards. Most of the novice science teachers in this study viewed NOS as separate from their regular course curricula. Even the teachers who conflated NOS and inquiry failed to describe NOS in inclusive terms. Instead, these six teachers presented NOS as a content and/or teaching style that is external to the required curriculum. They described NOS as requiring extra work and extra time. Some put it on par with differentiation and literacy expectations. Mr. Solo even pondered whether NOS would run counter to the regular curriculum and possibly adversely affect student scores. All of these teachers described multiple contextual factors that hindered their ability to teach NOS. These factors provided explanations and excuses for their limited NOS instruction. Most of the teachers in this category expressed some degree of guilt for not teaching more NOS, but described the deficiency as having no bearing on their student scores or job security.

To the six teachers who did not view NOS as a part of the state curriculum standards and therefore as outside of their regular professional obligations, inclusion of appropriate NOS

instruction would have required a goal, motivation to achieve that goal, and all the other parts of MST. Specific intention toward NOS instruction would be needed. This was not, however, the case with many of the participants.

Ms. Mangrove, Mr. Solo, Ms. Shirley, and Mr. Stevenson all failed to acknowledge NOS as a legitimate goal for their science classrooms. All cited contextual and capability factors that impeded the creation of an NOS instructional goal. When discussing why NOS was not a goal for her classroom, Ms. Mangrove said, “You have to pick and choose and prioritize what goals you achieve each day” (Mangrove, I3). To her, NOS did not make the cut. An NOS goal was not just not prioritized, it was not even created. Ms. Mangrove and the other members of the No Goal Group were not willing to create or state a goal that they knew that they could not accomplish. You cannot fail at a goal that you never establish.

Ms. Platypus and Ms. Williams did express an NOS teaching goal. They also expressed overall positive context beliefs, capability beliefs, and emotions about NOS instruction. These components of motivation appear to be prerequisites for goal setting, when NOS is perceived as external to the curriculum.

Motivation and NOS instruction. Motivational Systems Theory provided an excellent framework to investigate the factors that affect NOS classroom instruction, but NOS does not actually cleanly fit into the confines of MST.

For Ms. Heffernan, NOS instruction was a professional obligation that she described as a natural part of her curriculum and classroom practices. To her, the state and her county expected her to teach NOS. Though she did not initially describe it as such, NOS could be considered to be an institutional goal (or part of an institutional goal) that Ms. Heffernan felt that she is expected to achieve. For her, the success of this institutional goal did not require Ms. Heffernan

to create a personal goal. MST was created for personal goals, so in its traditional sense MST is not appropriate to discuss Ms. Heffernan's case. Instead the understanding of an institutional goal paired with Ms. Heffernan's desire to fulfill her professional duties may have served as motivation enough for her to attempt to teach NOS.

For the other teachers, goal creation operated slightly differently than the expectations of MST as well. For these teachers, when NOS was viewed as external to the state science curriculum standards, creation of a personal goal would be needed for successful NOS instructional implementation. NOS was not, however, an insular goal. Other goals and potential goals, both personal and institutional competed with NOS for classroom attention. Though few of these were described as opposing NOS, many did vie for classroom time. Choice therefore created much of the dilemma as opposed to contextual support. In light of the competing goals and potential goals, for these six participants, creation of an NOS goal hinged on emotional connection to NOS as well as positive capability and context beliefs. Potential personal goals that are extraneous to expected job requirements are not accepted lightly and may require excessive interest and beliefs (Cho & Shim, 2013). Without strong emotion, capability beliefs, and context beliefs, the four members of the No Goal Group (excluding Ms. Heffernan) expressed a reluctance to accept an NOS based goal. Conversely, the members of the NOS Goal Group expressed a strong emotional connection to NOS and strongly positive capability and context beliefs and were subsequently willing to accept an NOS based instructional goal. For the six participants who expressed belief that NOS was external to the curriculum standards, acceptance of NOS as a goal paralleled motivation toward achievement of that goal. In this sense, emotions, capability beliefs, and context beliefs appear be prerequisites for teacher goal creation, when potential personal goals are perceived as being in competition with other goals.

Both Ms. Heffernan's experience and the experience of the other six participants suggest an alteration of MST for educational goal setting. Teachers are resistant to change (Koballa, Glynn, & Upson, 2005; Schweikert, 2011) and do not appear to accept new goals lightly. Acceptance of a goal, be it personal or institutional, appears to directly correlate to motivation toward goal achievement. When teachers discuss a goal that they possess for their classroom, they additionally appear to be acknowledging motivation toward achieving that goal. Doing so also appears to reduce the risk of goal failure.

Goal achievement and NOS instruction. Possessing proper motivation for NOS instruction does not necessitate NOS instructional success (Abd-El-Khalick et al., 1998; Brickhouse, 1990; Lederman et al., 2001). Skill and a responsive environment also play a part. For this study, however, responsive environment was not a focus and/or a major factor. So little NOS was observed or reported, that reaction from the environment was even less likely to occur or be observed. In Interview 4, which for most participants occurred after all official school evaluations, no active resistance to or support of NOS by administrators or evaluators was reported, confirming the assumed minimal impact of the environment on their NOS instruction.

Skill did play a major part in goal achievement for the participants of this study. Whether a goal was expressed or not, skill was probably the biggest limiting factor for most of the participants. All seven described teaching NOS at some point during their science courses, but only one participant described any NOS instruction that was congruent with the accepted standards of NOS instruction. Six of the novice science teachers did not describe their NOS instruction as explicit or reflective (Abd-El-Khalick & Lederman, 2000a), even though they had all participated in discussions, lectures, and activities dealing with NOS instruction during their recent graduate school courses. None of the participants connected NOS to conceptual change

(Cepni & Cil, 2010; Clough, 2006). Even Ms. Platypus, who claimed that NOS was "shoved in my throat for a couple of years" (I3), described her NOS teaching as occasional and unplanned, which are not commonly discussed NOS teaching strategies.

Except for Ms. Heffernan, the participants described largely inappropriate NOS instructional practices. These same participants also verbally described NOS without recall of many of the expected tenets and in ways that included inquiry, critical thinking, and scientific processes. To expect teachers to remember how to appropriately teach a content that they cannot properly verbalize and possibly don't properly understand, could be asking too much. Thus, much of the issue concerning the NOS-related skills of the participants in this study lies within the education and understanding of the participants. The understanding portion of skill deserves its own discussion separate from this section's judgment of MST. I will now explore the difference between participant views of NOS according to the VNOS and their verbalized understandings of NOS.

Verbalized NOS Understanding as an Intermediary

Via the VNOS questionnaire, most of the participants demonstrated adequate to sophisticated views on most of the NOS tenets. In most cases, however, this did not translate into an ability to discuss NOS with near the same sophistication. When asked to describe their understanding of NOS and their teaching of NOS, accepted tenets were truncated or left out, new tenets were created, and NOS was expanded to include inquiry, critical thinking, and scientific processes. The nature of science that they could describe on paper and under direct tenet-oriented questioning was not the same NOS that they narrated during open questioning.

Most of the participants reported doing most of their NOS instruction sporadically when situations in the classroom called for it. They described this method as largely unplanned and

reactionary. As such, the NOS content that they teach would require instantaneous teacher recall in order to be timely and relevant. This needed recall would much more closely approximate to the immediacy of my NOS lines of questioning than to a thoughtfully planned lesson. Under the duress of my questioning, most of the participants recalled and described an inadequate understanding of NOS that is more than likely comparable to the NOS that they would be able to spontaneously teach to their students during regular science classroom activities. Their confounded definitions of NOS only add to this problem, as they would likely view spontaneous inquiry and critical thinking exercises as a part of adequate NOS instruction.

A distinction between an understanding of NOS as demonstrated by the VNOS and an understanding of NOS as demonstrated verbally through open, teacher-centered questioning is needed in discussions of teacher skill at NOS instruction. Literature on NOS consistently refers to the results of teacher VNOS questionnaires as demonstrations of understanding of NOS tenets (Abd-El-Khalick et al., 1998; Schwartz & Lederman, 2002), but use of the word understanding may not be justified with these participants. Though the VNOS is a qualitative measure that provides for descriptive accounts of knowledge and possibly understanding, it is still a test. Its thoughtful questioning is designed to highlight all of the accepted tenets, even though test takers may not actively connect with each of those tenets or consider those tenets to be a part of NOS. If we intend our science teachers to teach NOS to their students, the VNOS demonstrated conceptions of NOS may not be adequate for translation into classroom settings. In these cases, being able to "pass the test" did not lead to appropriately vocalized understanding or teaching practices. This gets at the difference between knowing and understanding. For teachers, knowing the material is not enough. Teachers must understand the material and be able to verbalize it in a way that is conducive to student learning. This must be the case for NOS as well, and in this

study, six of the seven participants demonstrated a rift between their views according to the VNOS and their ability to verbalize their understanding.

More on Skill: Classroom Practices

Other than the observed inability of most of the teachers to verbalize a view of NOS that is consistent with contemporary conceptions (Lederman et al., 2002), six of the seven had additional skill related issues. Even though four of these six discussed not possessing a specific NOS goal, they still narrated their attempts to teach NOS, which revealed teaching issues comparable to the two members of the NOS Goal Group.

None of these six described their teaching of NOS as explicit or reflective. Most narrated intentional teaching of NOS during the study of either atomic theory or evolution, but described lectures or teacher-centered discussions that lacked activities or sustained student interaction/reflection. All of these teachers described their main NOS instructional technique as being unplanned and reactionary. None of these described practices correlated with the accepted NOS teaching techniques (Abd-El-Khalick & Lederman, 2000a; Clough, 2006) that were highlighted in their graduate studies. The novice teachers had all studied NOS and NOS teaching techniques within three years of this study. In six of seven cases, their verbalized NOS understanding and their discussed NOS practices did not properly reflect their training. While in graduate school all of these students participated in at least one course that spent several weeks reading about, discussing, and doing activities related to the nature of science, but in three years or less, all but one were teaching NOS differently than they were taught. Most expressed regret at how little NOS they taught, but few expressed how this would/could happen beyond just doing more. Ms. Shirley expressed that she should probably make NOS instruction more intentional, which hints at explicitness, but when paired with her conflated verbalized understanding of NOS

this may not lead to appropriate instruction. Even if the teachers changed their practices to be more explicit and reflective, without an overhaul of their convoluted understandings of NOS, appropriate NOS instruction is not likely.

Though the merits of decontextualized NOS instruction are still debated within NOS circles (Clough, 2006), for Ms. Heffernan, her checks lab provided her an avenue for explicit instruction and student interaction that she may not have utilized otherwise. This one activity plus her intentional inclusion of NOS in her introductory class lectures provided the only tangible instructional difference between Ms. Heffernan and the others. This limited decontextualized instruction served to clearly differentiate Ms. Heffernan from her peers and therefore justifies decontextualized NOS instruction as a tool to guarantee even a minimal amount of appropriate NOS instruction into science courses.

Sporadic NOS Instruction

The teachers in this study largely described their NOS teaching practices as unplanned and dependent on student questioning and activities. They did not, however, directly state that NOS learning could be acquired implicitly via classroom activities. Instead they claimed to bring it up and reiterate key points whenever the situation justified it. Though this technique is not specifically recommended by NOS literature for primary NOS instruction, an ability "to capitalize on unplanned opportunities" (Lederman et al., 2001, p. 157) is touted as worthwhile. Being sporadic and reactionary with NOS instruction does have potential to successfully accommodate explicit and reflective practices, but it is not easy. Successfully teaching NOS this way requires not only a correct understanding of NOS, but an ability to quickly and correctly recall NOS content as situations arise. Teachers need to be able to access knowledge about NOS at the drop of a hat and verbalize this understanding to students. Content would have to directly

be connected to NOS concepts at a moment's notice. Successful NOS instruction in this respect would require much more understanding than just what is measurable via the VNOS questionnaire. Teachers would have to be able to describe and analyze science and science content through an appropriate NOS lens directly from memory without planning or objective/goal setting. The level of NOS understanding required for sporadic NOS instruction would have to be quite robust and clear.

Few, if any, of the teachers in this study demonstrated an understanding of NOS sophisticated enough to succeed at sporadic instruction. Their stated convoluted and conflated definitions of NOS were not congruent or clear enough to ensure explicit and reflective instruction. Discussion of this issue as a factor contributing to failure to properly teach NOS content leads to two options. Either their understanding of appropriate NOS teaching techniques was incorrect or to some degree they understood the correct techniques but chose not to enact them. Considering how often excuses were given for limited NOS instruction and that sporadic NOS instruction was often presented as an afterthought, it is possible that sporadic NOS instruction was presented as a face-saving technique and may not be reflective of their exact understanding of appropriate NOS understanding. If this is correct, it is also possible that even less NOS instruction occurred than they described. When other goals and content take precedence, accommodations to and modifications of NOS instruction may be possible. Without more documented observations of NOS instruction or further direct questioning concerning their beliefs about appropriate NOS instruction, it is hard to comment on the specifics of their understandings of how NOS should be taught. We know only how they claimed to teach it, which was not aligned with the literature or the teachings of their graduate school experience.

Application to Previous Studies

In a series of linked articles, where the researchers traded places as lead author (Abd-El-Khalick et al., 1998; Bell et al., 2000; Lederman et al., 2001), Lederman et al. described issues and factors that pre-service science teachers face when teaching NOS in their science classrooms. They discussed a variety of surface-level factors, like time constraints, curriculum constraints, and behavioral issues, but the authors chose to focus on broader issues that they felt were much more endemic to the issue. They highlighted intentions to teach NOS, NOS knowledge, subject matter knowledge, and pedagogical knowledge as the four most influential factors in participant NOS teaching efforts (Lederman et al., 2001). These factors have correlates within this study, and the contents of this study possess the ability to add to the knowledge gained by these factors.

In a 2002 case study of two novice teachers, who were a subset of the original pre-service teachers in Lederman et al.'s 2001 study, Schwartz and Lederman (2002) describe the "critical importance of intentions when teaching" (p.231) NOS. This concept of *intentions* is never clearly defined but is often described in conjunction with beliefs about the importance of NOS. In at least three separate papers, mention of intention is truncated and immediately followed by discussion of issues with negative beliefs. Schwartz and Lederman (2002) follow mention of intentions by saying, "If one does not feel NOS is important, relevant, or attainable by students, one is not likely to teach NOS" (p.231). Similarly, Lederman et al. (2001) say "individuals who did not believe NOS to be an important educational outcome did not make many attempts to teach it" (p.157) and then directly link importance beliefs to instructional intentions. Internalization of instructional importance (Lederman, 1999; Sweeney, 2010) is certainly important, but this cannot possibly be the only component of specific teacher intention to teach

NOS. If intention is somewhere between a plan and a goal to include NOS content within a science course, MST and its components of motivation provide a much more detailed picture of the components that affect intention. Emotions toward a goal, as described by MST, could easily account for beliefs about the importance of NOS, but more plays into intentions than just that. Beliefs about capability and context also affect a teacher's intention to teach NOS. Inclusion of capability beliefs and context beliefs into discussion of intention allows for the other factors, which Lederman et al. (2001) largely discussed in isolation, to rightfully accept their place in the larger equation of NOS instructional success. Be they founded or not, teacher beliefs about state mandated curricula, formalized EOC's, time constraints, student behavior, and their own ability to teach NOS all affect a teacher's intentions (or goals) to teach NOS (Sweeney, 2010).

Lederman (1999) also claims that:

> *Once teachers have internalized the importance of the nature of science and their intentions to address the topic are firmly in place, both beginning and experienced teachers will need to develop the instructional skills and abilities necessary to transform their knowledge into classroom practice (p. 927).*

This describes a step-wise function where intention to teach NOS is a prerequisite for learning how to appropriately teach NOS. This, once again, ignores the power of capacity beliefs and context beliefs on intentions and goals. Confidence in one's ability to teach NOS surely has an impact on one's intentions to teach NOS, as would an understanding that contextual barriers do not inherently block NOS instruction, both of which can be bolstered by NOS instructional training. Additionally, this notion of intention as a prerequisite for NOS training was not evident in this study. The one participant who taught the most NOS and therefore demonstrated the most skill for teaching NOS, Ms. Heffernan, probably also expressed the lowest internalization of the importance of NOS instruction. Contrary to Lederman's (1999) assumption, Ms. Heffernan's lack of belief in the importance of NOS and her lack of a specific NOS goal did not affect her

acquisition and demonstration of NOS teaching skill. This is not to say that intention is not important, but perhaps the connection between intention NOS related skills is more nuanced than a step-wise condition.

Other than intention, Lederman et al. (2001) also describes NOS knowledge, content knowledge, and pedagogical knowledge as being important factors in NOS instruction. Little in this study directly dealt with role of regular content knowledge in NOS instruction, so nothing can really be said in regards to content knowledge beyond the obvious assumption that better content knowledge would potentially lead to better and more avenues for contextualized NOS instruction. Several of the participants struggled to think of curricular units (besides evolution and atomic theory) where they could teach more NOS. It could be argued that this deficiency was due to a lack in content knowledge, but it likely deals with deficiencies in content knowledge, NOS knowledge, and pedagogical knowledge. The skill section of MST could easily accommodate these three factors into discussion of NOS teaching goals.

The teachers in this study struggled greatly with skills related to NOS. Most of the participants provided adequate to sophisticated responses to most of the VNOS tenets that are aligned with the NOS expectations of the current science reform documents. Considering the amount of NOS training that each received in graduate school, this finding is congruent with previous studies (Faikhamta, 2013; Lederman, 1999). It is similarly not surprising that these teachers who possessed adequate to sophisticated views of NOS did not necessarily teach NOS. Previous research has consistently shown that there is no clear connection between teachers' conceptions of NOS and classroom practices concerning NOS (Abd-El-Khalick et al., 1998; Brickhouse, 1990; Lederman et al., 2001). This disconnect has often been connected to a lack of intentions to teach NOS (Lederman et al., 2001; MacDonald, 1996) and, in studies of pre-service

and novice teachers, has also been linked to issues with classroom management (Abd-El-Khalick et al., 1998; Schwartz & Lederman, 2002), where dealing with student behavior issues was perceived as being more important and time consuming than NOS instruction. Though student behavior could be considered a competing context belief that could be accommodated for by MST, it was not documented as a factor that this study's participants reported. Additionally, the findings of this study do not support a flat view of one cause, like intention or student behavior, standing in the way of NOS instruction. Instead multiple issues and beliefs interplay to create a complex web of factors.

One of the biggest factors that was uncovered by this study but is not commented on in the literature is the ability of a teacher to articulate his/her understanding of NOS in a coherent and conceptually correct way. A teacher's answers to a VNOS survey are often cited as equivalent to that teacher's understanding of NOS. Teachers who answer VNOS questions with answers that are in agreement with the consensus tenets are described as possessing adequate or sophisticated understandings of NOS and discussion turns toward their classroom practices concerning NOS. Often their classroom practices are described as lacking or altogether missing, despite their supposed NOS understanding. This leap from VNOS stated "understandings" to successes and failures in NOS instruction fails to recognize one of the primary findings of this study. Six of the seven participants in this study failed to vocalize an understanding of NOS that corresponded with the views of NOS that were revealed by their VNOS questionnaires. When asked to talk about NOS they talked about very different things than the answers they gave to the VNOS questionnaire. Whether their VNOS answers revealed naïve or sophisticated understandings, their open-ended discussions of NOS left out tenets, added new tenets, and conflated NOS with inquiry, critical thinking, and scientific processes. This is especially

problematic if we expect these teachers to teach these skills. This issue and others will soon be discussed in the implications section.

Summary

This study reported on the cases of seven novice science teachers and their dealings with the nature of science. Observed and reported through a Motivational Systems Theory (MST) lens, each case discussed and analyzed that teacher's goals, emotions, beliefs, motivation, skills, and environment. Each case detailed the story of a novice teacher's ambitions and realities during one school year. Free from the oversight of mentor teachers, intern supervisors, and professors, these novice teachers were free to establish themselves in their classrooms in their own unique way. They all dealt with issues and addressed NOS differently, so each case stands on its own as a testament to the realities of individuals. There were, however, commonalities between the cases that merited report and analysis. These commonalities were slowly built through data and discussion to portray a limited conglomeration of factors that affect the NOS instruction of novice science teachers.

The participants in this study demonstrated and reported many issues and deficiencies related to NOS instruction. From the very first interview, none of the participants reported personal or institutional goals related to NOS. NOS instruction was not a major focus for any of the teachers' classroom plans. Without specific mention of NOS, NOS was never even discussed by any of the participants.

When directly asked about NOS, only two of the participants reported NOS as a goal for their classrooms. Their claims of a goal focused on their understanding that NOS should be taught in the science classroom, but the specifics of their goals and plans were vague. These two participants, the NOS Goal Group, reported emotional connection to the importance of NOS,

positive beliefs about their capability to successfully teach NOS in their classrooms, and positive beliefs about the support of NOS instruction by their administrators, school district, and state. Of the five participants who claimed to not hold NOS specific goals, the No Goal Group, all reported weak or wavering beliefs in at least one of the emotions, capability beliefs, and context beliefs categories. With this population, internalization of the importance of NOS along with positive perceptions of capability and context appear to be prerequisites for goal setting related to NOS instruction. Without all three of these components, the participants in this study were reluctant to commit to an NOS-related goal. Since acknowledgement of a goal meant the possibility of failure at that given goal, the teachers in this study selected goals that they felt they could accomplish, thus changing the shape of MST theory related to NOS goals. MST normally portrays possession of a goal on equal footing with emotions, capability beliefs, and context beliefs, but for these teachers, positive connections to the later three were required for goal acknowledgement. Doing so, for these participants, equates goal setting with goal motivation. Acceptance of a goal inspires and directly leads to motivation toward goal achievement.

The NOS instructional skills demonstrated and discussed by the participants in this study were varied and noteworthy. Skill was subdivided in this study to separate NOS understandings from NOS instructional practices. The participant answers to the VNOS questionnaire (Lederman et al., 2002), the most commonly used test of NOS understandings (Chen, 2006a), varied greatly between participants. Most of the participants struggled with identifying the difference between scientific theories and scientific laws, but other than that tenet, there was little consensus among participants. Each struggled with his/her own tenets and struggled with different numbers of tenets. The composite VNOS-based understandings of individual participants varied from naïve to rather sophisticated. The two members of the NOS Goal Group

were also the two participants with the most naïve overall NOS understandings, which could have contributed to increased confidence or intentions.

A greater surprise came from the gained awareness of the rift that existed between the VNOS-based NOS understandings of the participants and the understandings that they narrated during interviews. Without tenet-inducing prompts, six of the seven participants conversed about NOS in terms that were very different than the consensus definition of NOS and their supposed understandings of NOS that was deduced based on the VNOS questionnaire. Without the intentional tenet-encompassing questions of the VNOS, these six participants were unable to describe a comparable understanding of NOS. Their verbalized NOS understandings consistently included significantly less of the consensus tenets, often added new tenets that were either more naïve or more empiricist, and most significantly always conflated NOS with inquiry, critical thinking, and/or scientific processes.

The discussions of NOS that included inquiry, critical thinking, and scientific processes also spilled over into their discussions of how they taught NOS. These six teachers described that they did not teach much NOS and the NOS instruction that they did describe often centered on teaching inquiry, critical thinking, and scientific processes. These separately important science teaching methods and content were not often observed during the classroom observations of this study, but consensus NOS content was even less frequently observed. In fact, in 41 classroom observations, teaching of NOS content was observed only twice. Neither mentioned the term NOS, and one was very short. The other was quite lengthy and was very explicit, but did not allow for much student discussion or reflection. The NOS instruction that the participants described as occurring the times of the year when I was not in their classrooms tended to follow two themes. Six of the seven described intentionally planning NOS lessons into lessons about

atomic theory or evolution, and six of the seven described all other NOS instruction as being sporadic, unplanned, and largely reactionary to student questions.

One teacher, Ms. Heffernan, was an outlier in most of these regards. She was the only teacher to describe the importance of explicit instruction to NOS learning and similarly described how she taught NOS explicitly in her classroom. Though she described giving NOS no particular emphasis over any other content, Ms. Heffernan explicitly wove NOS content into her beginning of the year introduction to science class activities. She even described a specific decontextualized NOS activity that she found on the internet and used with all of her classes. She described emphasizing and reiterating this activity and all of her NOS lessons with specific intent at later times in the year. Despite her claims to not emphasize NOS and that she did not have any specific NOS-related classroom goals, Ms. Heffernan taught the most NOS content of any teacher in this study.

Ms. Heffernan likely taught the most NOS, because she interpreted the state curriculum standards to include NOS. To her, NOS instruction was a professional obligation, and she did not see it as an option to not teach NOS. This belief alone, which may have classified NOS instruction as an institutional goal for her, was more than enough motivation to ensure that she would teach NOS content in her science courses. The other teachers in this study did not interpret the state science curriculum standards for the courses that they taught to include NOS instruction. For them, the belief that NOS was external to their professional obligations created a significant barrier toward NOS instructional inclusion that would have required all of the parts of Motivational Systems Theory. These teachers would have needed a strong emotional attachment to NOS, positive capability beliefs, positive context beliefs, a clear NOS related goal, motivation to achieve that goal, skills to achieve that goal, and an environment that was responsive to the

success of that goal. Four of the teachers in the study described insufficient capability or context beliefs towards NOS instruction. Three of these also cited mixed emotional dedication to the importance of NOS instruction. Therefore, these four teachers failed to establish intentional and explicit NOS-related goals, which led to insufficient NOS content inclusion in their classes. Two participants, Ms. Platypus and Ms. Williams, did express overall positive emotional connections, capability beliefs, and context beliefs about NOS, which allowed them to create NOS goals and be motivated to achieve those goals. These teachers, however, lacked the NOS knowledge and instructional skills to succeed at their NOS goals. They were not necessarily aware of these deficiencies, but they were aware that they did not achieve their goals. They both recognized that NOS instruction did not happen often in their classes and was largely unplanned.

All of the teachers who viewed NOS content as external to their state science curriculum standards acknowledged that NOS instruction did not happen much in their classrooms. Many expressed regret or guilt that it does not happen more often. All six of these participants offered many factors that affected their ability to teach NOS. These factors varied by participants, but the most frequently mentioned factors dealt with curriculum standards and testing. All six of these teachers discussed the emphasis that they felt needed to be placed on completing the required curriculum standards for the classes that they teach. They described the stress that end of course tests placed on them and their students. They described that there was not enough time to cover all of the standards that are required for the EOC and to cover much NOS. Contextual factors like these were mentioned often and emphatically, but they were also described as not directly opposing NOS instruction. Though NOS was described as not being on the EOC, no one felt that he/she should not teach NOS. Instead, contextual factors were described as competing for classroom time and emphasis. Capability factors were also described, but much less frequently.

Some of the participants felt that additional training in NOS would be useful, while others described wanting pre-planned lessons and activities to inspire them to teach NOS more. Only two participants described their understanding of NOS as a factor that affected their NOS understanding. These statements were not, however, made by the participants whose answers to the VNOS questionnaire revealed the weakest understandings of NOS. This parallels a greater issue. Six of the seven participants verbalized confused and confusing understandings of NOS and failed to describe teaching practices that were aligned with their graduate school courses or science education literature, but yet, only two participants expressed insufficient NOS understandings and only two expressed desire for further NOS training. This division between their perceptions about NOS and my perceptions about their NOS is the main cause for further discussion of implications.

Implications of the Study

The findings of this study showcase a variety of issues for novice science teachers concerning NOS. Since novice science teachers are unlikely to read this paper, recommendations will be aimed at those who may: policy makers, science teacher educators, and professional development/induction program overseers.

Recommendations for policy makers. New teachers often struggle during their first years of teaching to find themselves within the profession. All too often novice teachers end up joining the status quo or leaving teaching altogether (Long, 2004). Emphasis on curricular content and preparation for standardized testing is often a considerable part of the status quo that novice teachers often fall into. Several teachers in this study acknowledged that they were not fully aware of the importance that end of course testing held for teachers until they were fully integrated into the system. All of the teachers in the study came to accept their fate related to

standardized testing and actively discussed the role that curriculum standards and testing play in daily lesson planning and on their NOS instruction. The explicit discussion of NOS content in the National Science Education Standards (National Research Council, 1996) was lost on most of the participants of this study, because the students are not tested on those standards. With these participants, the failure of the state and county to sufficiently transfer explicit NOS expectations to the curriculum standards relegated NOS instruction to an external, outsider status and led to limited classroom emphasis. In the state of this study, the state curriculum standards include the essence of NOS, but without the vocabulary that novice teachers studied during graduate school and without the explicit and reflective teaching recommendations of science education literature (Abd-El-Khalick & Lederman, 2000a). This established a grey area where novice science teachers must consciously or unconsciously decide whether NOS is included in and supported by the state curriculum standards. Six of the seven participants in this study decided that NOS is not a part of the science curriculum standards. Only one participant acknowledged the existence of NOS in the state standards, which corresponded to her being the participant who taught the most NOS content during the course of the study. Her NOS inclusion was limited, however, because she, like the others, felt that NOS was not included on the EOC tests of her courses.

Though NOS is thoroughly included in national reform movements (American Association for the Advancement of Science, 1989; National Research Council, 1996), it does not always translate properly into state and county curricula and standardized testing. Proper inclusion, which could extend as far as emphasized inclusion, could expedite teacher recognition of NOS instruction as a professional obligation and of instructional importance. Efforts from policy makers and administration to develop policies and curricula that parallel the ideals of their novice teachers' research-based science education training could go a long way to help novice

science teachers integrate into successful classroom teaching. Novice science teachers deal with many issues and goals in their first years of teaching, many of which are new to them and often compete for attention and emphasis, so any effort to reduce conflict and increase consistency would likely be helpful.

Recommendations for science teacher educators. With or without proper inclusion of NOS concepts in state curriculum standards and high-stakes EOC testing, science teacher educators need to help pre-service science teachers come to see NOS as included in the state standards with which they will be working. Though all of my participants were looking at the exact same Embedded Inquiry standards that are present in every science course curriculum in their state, only one participant translated what she read as including NOS. Explicit examination of the state curriculum standards during the study of NOS during graduate school may have helped more of the teachers come to this same conclusion.

Additional recommendations for science teacher educators can also be gleaned from this study. Each of the participants in this study was less than three years out of graduate school and therefore less than three years out of NOS training, but yet, most demonstrated insufficient vocalized NOS understanding, ineffective understanding of appropriate NOS instructional techniques, and underdeveloped internalization of the importance of NOS instruction. Either appropriate connections with NOS were never gained or they were somehow lost during the novice teaching years.

The teachers in this study did, for the most part, demonstrate via the VNOS questionnaire adequate to fairly sophisticated understandings of most of the consensus NOS tenets. On paper, these novice science teachers were able to answer targeted NOS questions with thoughtful sophistication, but they could not do anywhere near the same in open-ended conversation about

NOS. Just as ability to provide adequate answers to the VNOS does not inherently lead to increased NOS instruction (Abd-El-Khalick et al., 1998; Brickhouse, 1990; Lederman et al., 2001), ability to provide adequate answers to the VNOS equally does not appear to lead to an ability to adequately and intelligently discuss NOS. This logically extends that a teacher who cannot adequately discuss NOS likely cannot adequately teach NOS concepts in the classroom. This rift between VNOS understanding and verbalized understanding speaks to the difference between knowledge and understanding of NOS. In regards to understanding as a goal in science education, Smith and Siegel (2004) describe understanding as including the ability to connect ideas together, make sense of ideas and apply meaning to them, apply ideas to academic and non-academic settings, and justify the stated claims. Since knowledge and understanding are goals of science education (Smith & Siegel, 2004), if we expect our students to do these things with science content and NOS content, then we should certainly expect our science teachers to be able to do the same. This description of understanding far exceeds the narration of knowledge that is required for adequate VNOS-based evaluation. It is, therefore, my recommendation based on this study for graduate schools to consider challenging pre-service teachers beyond tenet recognition and practice of NOS teaching skills. Instead, pre-service teachers probably need to be explicit and reflective with their learning of NOS and NOS instructional practices. They also probably need to directly articulate their understandings and intentions for assessment and analysis and argumentation. The NOS instruction and NOS teaching instruction that these participants received in graduate school was likely not sufficient enough to solidify appropriate understandings of NOS or internalization of the importance of NOS.

Extended interaction with NOS including but not limited to explicit connection to state curriculum standards, promotion of internalization of the instructional importance of NOS, and

assessment of verbalized understanding are recommended to science teacher educators for improvement of pre-service and novice science teacher NOS instruction.

Recommendations to professional development and induction program overseers. The contents of this recommendation should be really obvious. Novice teachers are still new to the field, but yet they are expected to address all of the same responsibilities as experienced teachers (Menon, 2012). Novice teachers are faced with many challenges and responsibilities (Avalos & Aylwin, 2007; Meister & Melnick, 2003). On top of all the regular issues and responsibilities, novice science teachers are tasked with teaching NOS and promoting science literacy. As evidenced by this study, expectations that they will remember and carry out the NOS intentions of the recent graduate training may be asking too much without providing adequate and continuous support (Akerson & Abd-El-Khalick, 2003). Induction programs may be an appropriate means to continue the education and indoctrination of novice science teachers concerning NOS and other science education reform priorities. Though not as continuous or supportive, professional developments aimed at novice science teachers may also be useful to NOS instruction. Novice science teachers, who have recent graduate degrees in science education, represent a different population with different needs than their experienced teacher co-workers. Novice science teachers would likely benefit from professional development activities that are tailored to their educational needs, both NOS-related and not.

Limitations of the study. Several limitations affected this study. First, time constraints, classroom schedules, and transportation greatly affected the number of classroom observations. Though the goal numbers were achieved, additional data could have proven useful, if for no other reason than it may have allowed for even the slightest bit more NOS instruction to be observed. Secondly, valuing insight and discovery (Merriam, 1998), this study’s methodology

and interview protocol intentionally focused on teacher perceptions of NOS and NOS instruction. I allowed the participants to carry the conversations in their own directions, even when that direction steered away from consensus definitions and instructional expectations. This allowed for complex portrayal of their individualized understanding, but it conversely left holes in my understanding of their perceptions of the tenets and instructional practices that I care about. Because of this, I never got to discuss the tentative nature of science with Mr. Solo or *explicit and reflective* teaching expectations with any of the participants. This made for some interesting conversations, but it was a research decision that had to be made.

Lastly, the qualitative case study methodology of this study paired with my friendly disposition opened the door for the introduction of my own biases. My engagement with the participants and the data served to limit my analysis and the lens that I have discussed it through.

Generalization. This study of novice science teachers and NOS focused on a population of only seven teachers. Not only is this a relatively small number of participants, but all of them attended the same graduate school for their teacher training. This provided a useful commonality between their cases, but it does limit the generalizability of this study. The diversity of the science courses taught by the teachers, the schools at which they taught, and their personal histories is impressive, but it is not enough to generalize these findings to a larger population. Instead, the results may be transferable to similar contexts (Guba & Lincoln, 1989), but even this should be done cautiously. More so, it is my hope that the stories and comparative discussion can serve to inform, intrigue, and start related conversations. The situations of novice science teachers deserve to be heard and discussed.

Recommendations for future research. Several recommendations for future research can be taken from this study. The obvious first suggestion would be to conduct similar studies

that investigate different novice science teachers under different circumstances. Different NOS training regiments from different universities would likely yield different participant beliefs and practices that could contribute more widely to the field. Identification of successful cases of novice science teacher NOS instruction would provide contrast and could provide more usefully transferable lessons for science teacher educators.

Another useful avenue for future research would concern MST and goal setting for other reform-based practices and content. The teachers in this study failed to commit to or acknowledge personal goals without establishing emotional connection and positive capability and context beliefs. The transference of this conjecture to other extra-curricular potential goals seems logical, but deserves further research.

The gap between an adequate VNOS-based NOS understanding and successful NOS instruction is also worthy of significantly more research. The potential for verbalized understanding to fill in a portion of this gap deserves investigation as do all of the other missing or under-documented potential puzzle pieces.

Reflection on My Learning

After I passed my comprehensive exams, a professor shook my hand, congratulated me, and then said, “You are halfway done!” I gave a hearty laugh and rolled my eyes a bit. His statement shocked me, but I thought I understood the point he was trying to make. Not until today can I fully grasp the gravity of his words. The amount of time, energy, and dedication required to complete a project like this is incalculable. I have never felt this much self-doubt or determination until these past months.

Devising, writing, and implementing a methodology for a project this large proved to be the most educational experience for me. Balancing multiple sites, teachers, and principals was

challenging enough, but balancing protocol, creativity, and time constraints was even harder. I struggled to focus on the beliefs and realities of my participants while trying not to pass on my beliefs to them. Hearing their vocalized NOS understandings and adapting my protocol to match their perceptions was not easy. On many occasions I could have been tempted to impose my definition of NOS or my understanding of appropriate NOS instruction on them, but this would have changed their reality and tainted the data. Their confusion and their understandings were more important to this project than "teaching" them my ideas. Imposing my theoretical framework and an NOS focus at times felt rather constrictive on their own.

On that note, I was rather skeptical of theoretical frameworks at first, but I am glad that I settled on one and stuck to it. Though it was not always a perfect fit, it provided a starting point and some structure that helped shape how I planned, how I observed, how I analyzed, and how I wrote. My brain has been way too distracted and jumbled to have made any logical sense of my enormous data set without Motivational Systems Theory (Ford, 1992, jk).

The world of novice science teachers is complicated. This project has only helped to confirm how little I and the research community know about novice science teachers. The challenges they face when transcribed and analyzed seem insurmountable, but yet every one of my participants woke up every day and fought on. (In fact all but one will continue to fight on next year. The non-returner plans to return to the profession after a one year hiatus with her new baby!) I am constantly in awe of my novice science teacher participants. Despite their issues with NOS, each is still a success story and a fine teacher. I learned a lot of content and pedagogy through my classroom observations and interviews that will affect my future teaching, and for that I am grateful.

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Appendixes

Appendix A - Informed Consent

You are invited to participate in a research study. **The purpose of this study is to investigate the motivation and achievement of goals in the science classroom by novice science teachers.** This study will involve interviews, classroom observations, and questionnaires. Four or five semi-structured interviews will take place over the course of the semester. Interviews will take 30-45 minutes and will take place at your convenience. Digital recordings of the interviews will be made for transcription purposes. Additionally, the researcher would like to observe your teaching practices via four or five classroom observations, where the researcher will quietly sit at the back of your classroom and take notes. Participants will also be asked to complete a demographic questionnaire and the VNOS-C assessment of nature of science understanding, which will take approximately 20 minutes and 45 minutes respectively.

BENEFITS

There are no direct benefits from participation in this research. Your participation may aid in your understanding of your own goals and practices concerning your science teaching.

RISK OF PARTICIPTION

There are no physical, psychological, legal, or other risks associated with this study.

CONFIDENTIALITY

Your identity will remain confidential. Your name will not be attached to any data. Pseudonyms will be used for all people, proper nouns, and identifiable events. No references will be made which could link you to the research. Digital recordings of interviews will be deleted upon the completion of transcription. All electronic data will be password protected.

RESULTS

The investigator will present the results of this study in the form of a dissertation and possible published papers and presentations. At no time will the individual identities or names be used and no direct references will be made in oral or written reports which could link you to this study.

PARTICIPATION

Your participation in this study is strictly voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time. If you withdraw from the study before it is complete, your data will be destroyed. Your cooperation in this study is greatly appreciated.

CONTACT

If you have any questions at any time about the study or the procedures, you may contact Bennett Adkinson at bennett@utk.edu or 865-604-0963 or Dr. Mehmet Aydeniz at maydeniz@utk.edu. If you have questions about your rights as a participant, you may contact the Compliance Section of the Office of Research at 865-974-3466.

CONSENT

I have read the above information, and I have received a copy of this form, and I agree to participate in this study.

Participant's signature ______________________________ Date __________

Investigator's signature ______________________________ Date __________

Appendix B - Introductory Interview

1. Tell me a little bit about yourself.
2. Why did you decide to be a teacher?
3. How long have you been teaching?
4. What courses are you teaching this semester?
5. What is your favorite course to teach? Why?
6. When you are writing a syllabus and creating a schedule for a course, what influences what you write?
7. What are your goals for your science courses this semester?
    a. Do you have any other goals for your science courses?
8. Why do you have these goals?
9. What do you plan to do to meet these goals?
10. How do you feel about these goals? What emotions do they arouse?
11. Does your school and school district support these goals?
12. What is your favorite thing about being a teacher?
13. What is your least favorite thing about being a teacher?

Appendix C - Interview 2

1. How has your class been going since we last talked?
2. Have your goals changed at all since we last met?
    a. If so, why?
3. How are you doing at meeting your goals?
4. What factors affect your ability to achieve your goals?
    a. Internal or external.
    b. Positive or negative.
5. Sometimes institutions establish goals that teachers are expected to achieve. Institutions can be people, groups of people, documents, and any number of external structures. Do any institutions have goals that affect your science classroom?
    a. Please explain
    b. Can you think of anymore?
    c. How much do these actually affect your classroom? How so?
6. How do you feel about these institutional goals?
    a. What emotions do they arouse?
7. Could you tell me about the role that state standards and county curricula in your instructional plans and practices?
8. Could you tell me about the role that frameworks and national science standards and county curricula in your instructional plans and practices?
    a. How so?
9. What percentage of you classroom decisions are determined by other people/groups?
    a. How did you come to this number?
    b. Is this ok with you?

Appendix D - Interview 3

1. How have things been going since the last time we spoke?
2. Have you been successful at accomplishing any of your goals for the science classroom?
    a. How do you measure success?
3. What is your understanding of scientific literacy?
    a. How do your classroom practices promote scientific literacy?
    b. Do you measure student scientific literacy? How?
4. Fun science nerd question: How is scientific knowledge constructed?
5. What is your understanding of NOS?
6. Do you teach NOS in your classroom?
    a. If so, how do you do it? When do you do it?
    b. If not, why don't you?
7. Could you tell me about the last time you taught NOS?
8. Is teaching for student understanding of NOS a goal for your classroom?
    a. How did you come to your understanding of the importance of teaching NOS?
    b. Would you classify it as a personal goal or an institutional goal or neither?
9. How do you feel when you think about teaching NOS?
10. How do your students respond to NOS instruction?
    a. How does this influence your NOS instructional decisions?
11. Thinking about your principal, other science teachers, and other institutions, how do think others feel about the teaching of NOS?
12. What factors affect your ability to teach NOS?
    a. Negative factors?
    b. Positive factors?

Appendix E – Interview 4

A. VNOS clarification questions

Structure varies for each participant based on answers to the VNOS questionnaire. Questions are specifically aimed to clarify vague answers and to confirm researcher categorizations. Questions may resemble:

1. You mentioned that scientific knowledge uses evidence to prove a concept true. Could you please explain what you mean by this?
2. When do scientists use creativity?
3. You said that science can change as new discoveries are made. Why does this happen? Can is change in other ways?
4. How are theories important to science?
5. What is the difference between a theory and a law?

B. Regular interview questions

1. Did you achieve your personal goals for your science classroom this semester? How?
    a. What factors contributed to this?
2. Did you achieve the goals set for your science classroom by your school? How?
    a. What factors contributed to this?
3. Did you achieve the goals set for your science classroom by your school district?
    a. What factors contributed to this?
4. Did you achieve the goals set forth by any other institutions? Please explain.
    a. What factors contributed to this?
5. How much NOS do you think your students learned during your courses?
    a. How do you know this?
    b. What aspects of NOS did your students best learn?
    c. What aspects did they find difficult?
6. Were you able to teach much NOS content this semester?
    a. How did you teach NOS?
    b. How often did you teach NOS?
    c. Which aspects of NOS were you able to address in your classroom?
7. What factors positively contributed to your ability to teach NOS?
    a. How did they contribute?
8. What factors negatively contributed to your ability to teach NOS?
    a. How did they contribute?
9. How confident are you in your ability to successfully teach NOS? why?
10. How much interest do you think your school and your school district place on the teaching of NOS?
    a. Why do you think this?
11. What effect do you feel that standardized tests and curriculum standards have on your ability to teach NOS?
12. If you were to teach NOS in the future, what would help you achieve this?

Appendix F - Demographic Survey

Name
Undergraduate Major
Courses taken for Secondary Education Minor

- ☐ Educational Psychology 210 – Psychoeducational Issues in Human Development
- ☐ TPTE 352 – Field Study in Education
- ☐ TPTE 355 – Introduction to Secondary Schools
- ☐ TPTE 486 – Integrating Technology into the Curriculum
- ☐ Educational Psychology 401 – Professional Studies: Applied Educational Psychology
- ☐ Special Education 402 – Professional Studies: Special Education and Diverse Learners

Master's Degree Major
Courses taken for Master's Degree (place checkmarks by all that apply)

- ☐ TPTE 517 – Trends and Issues in Education
- ☐ Science Education 496 – Teaching Science Grades 7-12
- ☐ Reading Ed 461 - Developing Reading Skills in the Content Field
- ☐ Education 574 - Analysis of Teaching for Professional Development
- ☐ Education 575 - Professional Internship in Teaching
- ☐ Education 591 - Clinical Studies
- ☐ Science Ed 506 - Science Education Studies in Natural Environments
- ☐ Science Ed 510 - Theoretical Foundations of Environmental Education
- ☐ Science Ed 572 - Nature of Mathematics and Science
- ☐ Science Ed 596 - Curriculum Trends in Science Education
- ☐ Science Ed 565 - Instructional Trends in Science Education
- ☐ Other - ____
- ☐ Other - ____

What was the topic of your Action Research?
Why did you choose your Action Research topic?
Current Job and Location
Courses Currently Teaching
Courses Taught in the Past (as a full time teacher)
Courses Taught/Co-taught as an Intern
Did you go straight from undergrad to the internship? If not, what did you do and for how long?
Goals for your science classroom
Science teacher metaphor (create one metaphor that symbolizes the role of a science teacher)
What part of graduate school impacted your current teaching the most? Why?

Appendix G – VNOS-C Questionnaire

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. What is an experiment?

3. Does the development of scientific knowledge require experiments?
   If yes, explain why. Give an example to defend your position.
   If no, explain why. Give an example to defend your position.

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

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting the nucleus. 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?

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?

8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypothesis formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

   If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.

   If you believe that science is universal, explain why. Defend your answer with examples.

10. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

    If yes, then at which stages of the investigations do you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.

    If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

Appendix H – Participant Analysis Synopsis

Participant Analysis Synopsis 1

	Years of Prior Teaching Experience	Courses Taught	Explicit NOS Goal	Goal Group	Emotions	Capability Beliefs	Context Beliefs	Motivation
Mangrove	1	Chemistry, Physical Science	no	No Goal Group	~	~	-	no
Williams	0	Chemistry, Physical Science	yes	NOS Goal Group	+	+	+	yes
Shirley	1	Physical Science, Ecology, CSI	no	No Goal Group	~	~	contingent,+	no
Solo	2	Biology, Wildlife Principles	no	No Goal Group	+	~	contingent,-	no
Heffernan	0	Ecology, Biology	no	No Goal Group	~	+	+	no
Platypus	1	Biology, Language!	yes	NOS Goal Group	+	+	+	yes
Stevenson	0	Chemistry, Physical Science	no	No Goal Group	~	-	~	no

Note . + = positive, - = negative, ~ = mixed.

Participant Analysis Synopsis 2

	VNOS-based Understanding	Verbalized NOS Understanding	Classroom Practices
Mangrove	adequate/soph	Scientific processes, tentative, repetition, inquiry	atomic theory, sporadic
Williams	borderline adequate	tentative, exceptions to rules, inquiry	atomic theory, sporadic
Shirley	largely sophisticated	tentative, lack of scientific method, inquiry, critical thinking	evolution, sporadic
Solo	largely sophisticated	inquiry, higher-order thinking	sporadic
Heffernan	largely sophisticated	theories, tentative, bias removal	beginning of year, evolution, sporadic
Platypus	naïve	tentative, exceptions to rules, empirical, critical thinking	evolution, sporadic
Stevenson	largely sophisticated	discovery, observation/inference, scientific processes	atomic theory, sporadic

Vita

Bennett Alexander Adkinson was born in Nashville, TN, to parents Thomas and Lois Adkinson. He is a middle child, born between siblings Austin and Ruth. Bennett attended Percy Priest Elementary School, Stokes Middle School, John Trotwood Moore Junior High School, and Hume-Fogg Academic Magnet High School. After graduation he headed three hours east to Knoxville, TN and the University of Tennessee, where he stayed for quite some time. Bennett obtained a Bachelor of Arts degree in College Scholars with an emphasis in Physics, Theatre, and Secondary Education in 2004. In 2005, he earned a Master of Science degree from the University of Tennessee in Teacher Education. From there he went on to teach physics and other science courses at Austin-East Magnet High School and the Tennessee Governor's Academy for Mathematics and Science. Bennett began his doctoral studies in the fall of 2008 at the University of Tennessee and plans to soon graduate with a Doctorate of Philosophy in Education with an emphasis in Teacher Education. Though his diploma will not technically say it, his work and his passion are in science education.