The Impact of the Social Norms of Education on Beginning Science Teachers' Understanding of NOS During their First Three Years in the Classroom

by

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ABSTRACT

An understanding of the Nature of Science (NOS) remains a fundamental goal of science education in the Unites States. A developed understanding of NOS provides a framework in which to situate science knowledge. Secondary science teachers play a critical role in providing students with an introduction to understanding NOS. Unfortunately, due to the high turnover rates of secondary science teachers in the United States, this critical role is often filled by relatively novice teachers. These beginning secondary science teachers make instructional decisions regarding science that are drawn from their emerging knowledge base, including a tentative understanding of NOS. This tentative knowledge can be affected by environment and culture of the classroom, school, and district in which beginning teachers find themselves. When examining NOS among preservice and beginning teachers the background and demographics of the teachers are often ignored. These teachers are treated as a homogenous block in terms of their initial understanding of NOS. This oversight potentially ignores interactions that may happen over time as teachers cross the border from college students, preservice teachers, and scientists into the classroom environment. Through *Symbolic Interactionism* we can explain how teachers change in order to adapt to their new surroundings and how this adaptation may be detrimental to their understanding of NOS and ultimately to their practice. 63 teachers drawn from a larger National Science Foundation (NSF) funded study were interviewed about their understanding of NOS over three years. Several demographic factors including college major, preservice program, number of History and Philosophy of Science classes, and highest academic degree achieve were shown to have an affect on the understanding of NOS over time. In addition, over time, the teachers tended to 'converge' in their understanding of NOS regardless of preservice experiences or induction support. Both the affect of different demographics amongst teachers and the 'converging' aspect of their understanding of NOS provide much needed insight for teacher trainers, mentors, and researchers.

To my father who gave me the intellect, fire, and direction to succeed.

To my wife who has always supported me and has acted as counselor, best friend, and love of my life.

To my mother, who taught me to never be intimidated by anyone or anything you are missed.

aut viam inveniam aut faciam

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Introduction

> Teaching is the only major occupation of man [sic] for which we have not yet developed tools that make an average person capable of competence and performance. In teaching we rely on the "naturals," the ones who somehow know how to teach.
>
> --Peter F. Drucker

> Novice: a person new to or inexperienced in a field or situation
>
> --Oxford English Dictionary

In the United States, beginning science teachers are afforded the same responsibilities as experienced science teachers. While schools and districts often support new science teachers through mentors and induction programs, this support is quite often non-content specific and general. In addition, new science teachers are often given the same responsibilities as experienced science teachers (Ingersoll, 2001). Because of the current model of teacher training and support, and the high attrition rate among teachers, science teachers that have very little experience teaching and may be lacking in content knowledge, a developed understanding of science, and science specific pedagogical skills teach millions of students every year.

Assessing the knowledge, understanding of science, and pedagogical skills of these science teachers is therefore paramount in not only determining how best to serve new teachers in the classroom, but also in order to maintain teaching standards that serve students. In terms of science teaching, evaluating teachers' understanding of content specific disciplines (chemistry, physics, biology, etc.) is not enough. In order to have highly qualified beginning science teachers, that can properly serve students, assessments must also determine teachers' understanding of science as a way of thinking and knowing. Without the ability to teach specific content and to teach an understanding of the Nature of Science (NOS), teachers are unable to teach science successfully (Abd-El-Khalick & Lederman, 2000; Lederman 1992).

For over 100 years, understanding NOS has been considered an important goal for all K-12 students and their teachers. Often, writers of educational reform documents have cited an understanding of NOS to be a critical component of education and science literacy (Lederman, 2007). Viewed as a "prized educational outcome" (Lederman, 2007, p. 831), NOS is generally referred to as "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (Lederman, 2007, p. 833). In other words, NOS is separated from inquiry in that it is not about the processes of science or the resulting knowledge that develops from engaging in processes of science, but the "epistemological underpinnings of the activities of science and the characteristics of the resulting knowledge (Lederman, 2007, p. 835).

The *National Science Education Standards* (NRC, 1996) suggests that high quality teaching is the best way in which to improve science education. This is often viewed as an argument for why content knowledge is paramount in the teaching of science. Too often, discussions of content knowledge exclude an understanding of NOS. However, NOS is not only considered as a form of content knowledge it is on equal footing with other science discipline content areas. Both national standards and state standards not only include NOS in the majority of teaching bands, but many integrate it throughout all science specific content areas in science education.

Therefore, in order to teach science, teachers must have an adequate understanding of both what is commonly considered content and NOS (Abd-El-Khalick & Lederman, 2000a; Lederman 1992a). Unfortunately, current research indicates that while the majority of beginning science teachers has content knowledge in their particular science discipline, their understanding of NOS is inadequate. (Lederman, 2007). Furthermore, when they do have a more developed understanding it does not necessarily translate into classroom instruction (Abd-El-Khalick & Akerson, 2004; Lederman, 1999; Lederman et al., 2001).

Exploring beginning secondary science teachers' understanding of NOS is important because not only do they play a critical role in providing students with an understanding of NOS, they are just learning to teach science (e.g., Adams & Krockover, 1997; Luft 2001; Loughran, 1994; Simmons et al., 1999; Trumbull, 1999). As new teachers, they are making instructional decisions that are drawn from their emerging knowledge base for teaching science, which includes NOS. Preservice science teacher education programs are not only tasked with the role of preparing science teachers for the classroom, they are tasked with certifying teachers as ready to teach. This certification is typically based upon course work, feedback from cooperating teachers during student teaching, and some sort of content and pedagogical standardized assessment. However, these assessments do not take into account what factors may impact a teacher's understanding of NOS or other science content one, two, or more years after leaving a preservice program. Because of this lack of insight into how teachers develop their understanding of NOS during their induction years and beyond, effectiveness of preservice programs may be limited. Without insight into the state of working science teachers understanding of concepts such as NOS, issues of preservice curriculum and course designs are limited to only needs and concepts assessed prior to science teachers' entrance into the classroom.

By documenting the NOS of new science teachers, it may be possible to determine how NOS is incorporated into the classroom- thus representing some aspect of a teacher's knowledge. Furthermore, examining beginning teachers' understanding of NOS may show how this knowledge is influenced by such things as induction support, the environment of the school, content area taught by the teacher, and preservice and science specific course work completed prior to teaching.

Purpose of the Study

This dissertation focuses on the nature of beginning secondary science teachers' understanding of NOS and those factors that are related to this level of understanding. Thus it examines how beginning teachers' understanding of NOS may change during their first few years in the classroom. Most research on this subject has focused on preservice teachers, especially those participating in elementary science methods courses (Luft, 2009). Because a great deal of research into NOS is based upon the idea that demographic factors have no impact on understanding NOS (Lederman, 2007), very few current studies examine the impact these factors may have over time on teachers' NOS. This study extends our knowledge of NOS by carrying the examination into the earliest phase of teacher careers. In addition, it examines factors, both prior to teaching and in the classroom that may effect this understanding. This dissertation is guided by the following questions:

1. What demographic factors that influence how beginning secondary science teachers' understand the nature of science? nature of science?
2. Do these factors contribute to significant change in beginning science teachers' understanding of the nature of science over time?

Significance of the Study

A review of the literature has pointed out a clear trend in preservice elementary teachers understanding of NOS. As shown by the existing research (i.e. Abell et al., 2001; Akerson et al., 2000; Bell et al., 2000, Craven et al., 2002; Gess-Newsome, 2002; Gustafson & Rowell, 1995) most studies focus on preservice elementary teachers that are participating in a science methods course, with conclusions that reveal the need for explicit NOS instruction. Currently, there is limited work on beginning teachers, specifically beginning secondary science teachers who are in their first three years in the classroom. Content specialists, such as beginning secondary science teachers, have unique pedagogical and content considerations (Stodolsky & Grossman, 1995) but are often not involved in programs that support their content knowledge. By examining the NOS of beginning science teachers it is possible to gain insight into how teachers' conceptions are influenced by pre-teaching and classroom experiences during this formative time (Luft, 2008).

This review also concluded that most tools used to assess NOS are based on a two-point scale that categorizes participants as either those that understand NOS, or those that do not. Similar to Lotter et al. (2009), this study originally implemented a three-point scale that examined secondary science teachers' understanding of NOS that categorized understanding beyond 'naïve' or 'developed'. However, with further review it was decided that a different approach was required entirely. The data from this study was reexamined in a more fundamental manner that allowed a more fine-grained analysis of the data not available through *a priori* 2, 3, or 5-point scalar assessments. By examining the data as a frequency count based upon Lederman's original 6 facets of NOS we were able to create a ratio scale that allowed more precise or differentiated comparison among teachers and over time (Lederman, 2007).

There are four factors that set this study apart from the previous research that has been done in this area. One, participants in this study were practicing secondary science teachers in five different states throughout the United States. Two, this study was relatively large scale as there were 95 participants in comparison to Lotter's et al. (2009) study that consisted of nine individuals. Third, this study also addressed one of Lederman's (2007) fundamental questions concerning NOS which was "How do teachers' conception of NOS develop over time?" (p. 869). This study explored secondary science teachers' NOS understanding over a three-year period in which data collection initially began before the teachers began teaching and the last data collection point after their third year in the classroom. Fourth, this study stands apart from other NOS studies including that of Lotter et al. (2009) in that this work focused on practicing teachers that were not participating in interventions designed to explicitly address aspects of NOS. Whereas other studies evaluated the impact of an intervention on preservice teachers' conception of NOS, this study explored changes in NOS understanding without providing professional development designed to address aspects of NOS.

This dissertation fills a void that is lacking in the literature in that a large scale of beginning secondary science teachers were followed longitudinally for their NOS understanding, with the method of data collection being semi-structured interviews. In this dissertation I address issues concerning the gap in the literature on the development of NOS understanding in induction teachers. Specifically, it focuses on studying a large group of beginning secondary science teachers longitudinally, while emphasizing the effectiveness of a more fine-grained scale in the analysis of NOS.

Overview of Research Methods

The dissertation used a quantitative research approach to identify the understanding of 6 facets of NOS among beginning science teachers during their first two years of teaching in secondary science classrooms. Participants in the study were initially from the Midwest and The Southwest of the United States. For purposes of the larger study, the teachers were divided into four groups based upon their type of support during their first two years in the classroom or their certification status. The instrument used to assess beginning teachers understanding of NOS was a modified version of the View of Nature of Science

Questionnaire Version C (VNOS-C) (Lederman et al., 2002) containing five open-ended questions aligned with the six facets of NOS (Lederman, 2007) as part of a semi-structured set of interviews (see Appendix 1). A simple index (Babbie, 1990) was developed in order to assess the teachers' understanding of NOS. A psychometric strategy for accommodating measurement concerns was used to weight the initial score or count of mentions of target principles relative to the number of target dimensions (Nijkamp &Voogd, 2007; Rust &Golombok, 2009). This was done in order to create a ratio scale to compare teachers in different groups and change over time.

Several different demographic factors were considered in comparing beginning science teachers' understanding of NOS. These data were collected at the beginning of the study, prior to the teachers' first year of teaching. The six demographic factors explored as part of this dissertation were: induction group, gender, highest degree achieved (at the beginning of the study), degree major, certification program, and the number of History and Philosophy of Science classes taken prior to teaching.

Plan for Chapters

Chapter 2 is devoted to a literature review and discussion of appropriate theoretical frameworks. Chapter 3 reports about the larger study from which this dissertation is derived and describes the approaches taken for data collection, measurement, and analysis. The findings of the dissertation research are presented in Chapter 4. The dissertation concludes with a fifth chapter devoted to explaining the findings themselves and fitting them into the larger problems of the field.

Chapter 2

Literature

Nature of science and science education

In the early 1900s NOS was synonymous with the scientific method, but its conceptualization has advanced since then (Abd-El-Khalick & Lederman, 2000; Central Association for Science and Mathematics Teachers, 1907). In the 1960s, science educators focused on scientific inquiry and process skills, and in the 1970s they began to regard scientific knowledge as tentative, public, replicable, probabilistic, humanistic, historic, unique, holistic and empirical (Abd-El-Khalick & Lederman, 2000). During the 1980s, observations were characterized as theory-laden, human creativity was recognized as an integral factor in scientific explanations, and the influence of science organizations, as well as the increased impact of social discourse, became part of the dialogue surrounding NOS (Abd-El-Khalick & Lederman, 2000). In the 1990s, the California Department of Education noted that "science depends on evidence and scientific activities are theory-driven and investigations are conducted from within certain frameworks of reference" (Abd-El-Khalick & Lederman, 2000, p. 668). Driver, Leach, Millar, and Scott (1996), further defined five goals of NOS as critical to education: (1) to make sense of science and technology; (2) for informed decision-making; (3) to value science in culture; (4) to understand the moral norms of science; (5) to facilitate learning science

At the same time the *National Science Education Standards[NSES]* (National Research Council [NRC], 1996) added the roles of skepticism and open communication in science, along with the relationships between personal, cultural, and societal beliefs in advancement of scientific knowledge (Abd-El-Khalick & Lederman, 2000). Today, with the advent of *A Framework for K-12 Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2011), general scientific and engineering practices that include all aspects of NOS continue to be included as one of the major dimensions of K-12 science education. Specifically, the dimension of "Scientific and Engineering Practices" is given the same weight as "Crosscutting Concepts" that includes additional aspects of NOS, and "Disciplinary Core Ideas" that is concept specific.

As NOS has gained prominence in science education, Lederman (2007) has proposed six main facets of NOS that students should know. These are:

1. Recognize the differences between observations and inferences, as observations are "descriptive statements about natural phenomena that are 'directly' assessable to the senses (or extensions there) and about which several observers can reach a consensus with relative ease" (Lederman, 2007, p. 833) while inferences are statements that "go beyond the senses" (Lederman, 2007, p. 833).
2. Recognize the delineation between a scientific law and scientific theory, with the full understanding that theories do not turn into laws and that one is not valued more so than the other. Where laws are "statements or descriptions of the relationships among

observable phenomena" (Lederman, 2007, p. 833), theories are explanations that are inferred from observable phenomena.

3. Recognize that scientific knowledge relies on observations of phenomena, as well as human creativity and imagination (Lederman, 2007). Along with rational and logical thought processes, creativity and imagination are required in order to conceive of explanations about the natural world.
4. Recognize that scientific knowledge is influenced by beliefs, prior knowledge, preparation, experience, and expectations. It is not only theory-laden, but also subjective to the individual (Lederman, 2007).
5. Recognize that science is embedded within socio-cultural contexts in which it is heavily influenced by factors such as "social fabric, power structures, politics, socioeconomic factors, philosophy, and religion" (Lederman, 2007, p. 833).
6. Recognize that scientific knowledge is not absolute; scientific theories, laws, and facts are all subject to change as new evidence is discovered (Lederman, 2007).

However, just as there is, according to Lederman's facets of NOS, no one universal scientific method; there is also no one agreed upon definition of NOS. Other researchers have expressed concern as to the philosophical underpinnings of Lederman et al. definition of NOS, its facets, and how it is researched. Specifically, (Alters, 1997) claimed that philosophers of science have called into question the ‘basic tenets’ of NOS as currently used. Alters continues, stating that the basic criteria that science education uses to define NOS must be reconsidered. This argument drew immediate fire from Smith, et al. (1997) and later Eflin, et al. (1999). Both stated that Alters research methods were flawed and therefore his conclusions were inaccurate and overstated. The arguments, between what have become two differing camps of the nature of NOS, continue into the present.

In addition, a unified application of NOS has created problems for curriculum development in schools. Continuing work conducted by education researchers since the 1960s has caused a variety of conflicting views about NOS. Since what has been often recommended is a unified view, this plethora of definitions has proven unwieldy and contradictory. Therefore, some researchers have rejected the idea of a single concept of NOS for all of science and have proposed separate NOS’s for each discipline (Rudolph, 2000). However, this view has not been reflected in current or past national standards (NRC, 1996; NRC, 2011). Due to this lack of clarity concerning NOS, incomplete and, at times, nebulous curricula have been spawned that can be confusing to teachers and teacher trainers. This confusion has led NOS to be de-emphasized in comparison to more clearly defined teaching goals such as content specific science topics.

Research into Teachers’ Understanding of NOS

Research into teachers’ conceptions of NOS has mainly focused on preservice elementary teachers. These studies have consistently reported that NOS should be explicitly taught during preservice instruction. For example, in order to improve a teacher’s understanding of NOS, Gess-Newsome (2002) found that direct NOS instruction in an elementary science methods course resulted in participants holding a more sophisticated view of science as a body of knowledge. Similarly, Craven, Hand and Prain (2002) found positive change in participants' language use to describe the nature and structure of the scientific enterprise after explicit instruction of NOS in a science methods course. While these and other studies show a positive relationship with explicit NOS instruction and participants' understanding of NOS, another group of studies suggests that preservice science teachers need specific instruction in order to use NOS in their classrooms. Even when working with in-service teachers Posnanski (2010) found that explicit instruction was necessary, but not necessarily sufficient to improve NOS. Both, Bell, Lederman, and Abd-El-Khalick (2000) and Abell, Martini, and George (2001) found that preservice teachers who did not themselves receive explicit instruction about teaching NOS, did not include NOS in their lesson plans. From this they concluded that direct, explicit instruction is required in order to increase a teacher's understanding and use of NOS.

In contrast to this, Palmquist and Finley (1997) observed an increase in preservice science teachers understanding of NOS in certification programs that provided no explicit NOS instruction. More recently Turgut (2011) found that science education instruction that did not explicitly teach NOS, but that was presented in the context of demarcation, which involved eliciting preconceived notions of phenomena and comparing them to more current science concepts, led to an increased understanding of NOS.

Unfortunately, a great deal of the research done on NOS suffers from several flaws. The most common problem with the research is small sample size. Many studies, including those conducted by Bell, Lederman, and Abd-El-Khalick (2000) and Abell, Martini, and George (2001), are conducted with less than 30 participants. Similarly, Schwartz and Lederman (2002) and Akerson et al. (2010) made conclusions about program suitability based upon two preservice teachers apiece. Small sample size problems plague larger studies also when it comes to comparison groups. Abd-El-Khalick & Lederman's (2000) study that followed teachers through a series of History of Science courses had an overall sample size of 181 participants, however only 15 of these were preservice teachers. A similar study conducted by Abd-El-Khalick several years later had a greater number of preservice teachers, but, do to the nature of the intervention, compared a large control group (N=56) to a much smaller treatment group (N=10) when making his claims.

A second problem with current research is in terms of the length of study. The majority of research done on NOS is conducted either over the course of a specific professional development (PD) intervention that provides explicit instruction about NOS or as part of a science methods course for preservice teachers (e.g., Yacoubian & BouJaoude, 2010; Turgut, 2010; Posnanski, 2010; Palmquist & Finley, 1997). These studies fail to address issues of longevity of 'understanding' of NOS, nor can they address possible change or development of NOS over a lengthy period of time. Participants are rarely given time after the intervention to internalize NOS, nor is there an effort to discover if different aspects of their in-service teaching environment effect their understanding. Some notable exceptions to this are Abd-El-Khalik and Lederman's (2000) and Abd-El-Khalick's (2007) studies that followed college students over the duration of two semesters and Schwartz & Lederman's (2002) study that followed preservice teachers into their first year of full-time teaching. However, these studies are the exception to the overwhelming number of short-term studies that lack longitudinal data.

A third problem with current research concerns a lack of discussion about demographics of the participants. In almost all of the studies participants were not disaggregated except as to whether they were undergraduate or graduate students. It is often assumed that no other factors such as gender, college major, or science discipline taught have any effect upon an understanding of NOS or a change in that understanding. Besides Lederman (2007), rarely do researchers question the position that anything but direct, explicit intervention can have any effect on NOS. Abd-El-Khalick (2000) discusses demographics in terms of students with different majors enrolled within different type of History of Science classes, but makes no claims as to any effects. This lack of research into different factors beyond explicit instruction that might effect NOS over time have left a gap in the research that is only hinted at by Rudolph's (2000) critique of a unified NOS for all sciences.

Except for some rare exceptions (e.g., Schwartz & Lederman, 2002) research pertaining to the actual use of NOS in the classroom among new science teachers is rare. While it seems logical to assume that new science teachers who have explicit NOS instruction during their preservice program may use NOS in their classroom, there are few studies that explore this assumption. Within the group of understudied teachers are those that teach secondary science. As these teachers often represent the last opportunity for K-12 education to engage students in NOS, it is important to know if secondary science teachers understand NOS and teach it in their classrooms. Although Lederman (1999) suggests that academic background does not have an effect on a teacher's conception of NOS, these teachers are more likely to have been exposed to science concepts such as NOS during science content classes or History and Philosophy of Science classes prior to entering into preservice programs than non-science specific teachers.

Assessing NOS

Measurement of NOS has been the subject of much debate. Many of the NOS assessment tools created since the 1960s have come under criticism. After reviewing various NOS instruments, Lederman, Wade, and Bell (1998) and Lederman, Abd-El-Khalick, Bell, & Schwartz (2002) found three main issues. First, data from the instruments can be interpreted in a biased manner. The problem with interpretation resides in the instrument construction, which often assumes only one way of thinking about NOS. Those studying NOS have not reached consensus on the facets of NOS (Cotham & Smith, 1981; Lederman et al., 1998). In light of the fact that there is no uniform view of NOS, researchers must present their views, devise how to assess them, and collect and analyze data. This very process allows for bias because of the subjective nature of the methodology.

The second issue with some NOS assessments is that they appear to be constructed poorly (Lederman et al., 1998). Paper-and-pencil tests have been criticized for discrepancies between a participant's written responses and interviews. These tests have also been criticized for their limited assessment of understanding, as they often do not elicit how an understanding of NOS impacts behaviors and choices (Lederman et al., 1998). Interviews provide additional detail when compared to paper-and-pencil tests, but issues still persist with this method. For example, some interviewers do not record the questions they asked during the interview, which "prevents adequate assessment of the interview's validity and precludes the possibility of replication in other settings, not to mention the overall validity of the research findings" (Lederman et al., 1998, p. 610). Classroom documents and observations suffer from the same constraints as interviews because they often insufficiently describe the data collection and analysis process.

The third issue concerns the usefulness of standardized instruments (Lederman et al., 2002). Standardized tests are appropriate for large-scale assessments, and for generating an adequate measure of various aspects of participants' understanding of NOS, but they typically categorize participants' views as "adequate or inadequate" (Lederman et al., 2002, p. 503). For example, *Wisconsin Inventory of Science Processes (WISP)* (Scientific Literacy Research Center, 1967) contained 93 statements that participants either categorized as "accurate", "inaccurate", or "not understood". "Inaccurate" and "not understood" were later combined when the assessment was scored. *Science Process Inventory*

(SPI) (Welch, 1967) was a forced-choice instrument where participants could select “agree” or “disagree” on 135 items. Having only two categories that classified participants as to whether they held adequate or inadequate amount of NOS knowledge resulted in a narrow view of the participant’s NOS knowledge. To further complicate the issue, in some cases in which numerical values were reported, the developers did not clarify the numerical values associated with an adequate or inadequate understanding of NOS (Lederman, 1986). It seems that standardized assessments were able to include a large number of participants, but the findings did little to reveal a complete picture of the level or depth of the participants’ understanding of NOS.

Of the instruments that were reviewed for Lederman’s study, two assessed participants’ views of NOS on a three-point scale. The first study, *Views of Nature of Science (VNOS)*, assesses the participants’ ability to express their views of NOS (Schwartz, Lederman, & Crawford, 2003). Preservice secondary science teachers’ views of NOS were explored as they participated in a research internship course. Forms of data collection included interviews as well as the implementation of VNOS-C. After the analysis, the participants were rated with a “+” if they agreed that a specific aspect represented NOS, a “++” if the participant could express the meaning of the aspect in his/her own words, or a “+++” if the participant could express the meaning and provide additional examples (Schwartz et al., 2004). Although VNOS-C used a three-point scale do you mean + scale?), the focus was on the participants’ ability to express their views of NOS. In other words, this analysis using the VNOS-C questions appears to assess participants’ ability to communicate their views of NOS instead of their actual understanding of NOS.

Lotter, Singer, and Godley (2009) conducted another study that employed an instrument with a three-point scale. In their study, they followed nine secondary science teachers through three cycles over approximately seven months. Each cycle consisted of practice teaching and reflection that emphasized foundational pedagogical ideas for middle and high school classroom settings. Utilizing multiple sources of data, including interviews implementing Lederman's (2005) *Views of Scientific Inquiry (VOSI)* instrument, reflection papers, and teacher portfolios, they found that teachers improved their utilization of nature of science and inquiry in the classroom. Using a three-point scale allowed Lotter et al. (2009) to document the growth of preservice teachers as they varied between 'naïve', 'transitional', and 'informed'. Participants with the lowest level of NOS understanding were labeled 'naïve' when they held numerous misconceptions about the NOS. Respondents were labeled 'transitional' if they held views that partially matched reform statements, but contained some misconceptions. If the participant was placed in the 'informed' category, he or she viewed NOS as an orientation that included multiple methods; collaborative endeavors; and acknowledged the impact of social, cultural and personal aspects on an individual's ideas (Lotter et al., 2009). This study is feasible for large-scale studies, which are beneficial in generalizing conclusions to a larger population. However it views knowledge as discrete rather than continuous. This causes problems in terms of analysis in that any scale created assumes an equal ‘distance’ between all responses. This is not necessarily accurate when it comes to knowledge or beliefs and can exacerbate a tendency to regress to the mean, skewing the data to a middle region.

Dissertation Rationale

A review of the literature has pointed out a clear trend in preservice elementary teachers’ understanding of NOS. As shown by the existing research (i.e. Abell et al., 2001; Akerson, Abd-El-Khalick, & Lederman, 2000; Craven et al., 2002; Gess-Newsome, 2002), most studies focus on preservice elementary teachers participating in a science methods course, with conclusions that reveal the need for explicit NOS instruction. Currently, there is limited work on beginning teachers, specifically secondary science teachers who are in their first three years in the classroom. Content specialists, such as beginning secondary science teachers, have unique pedagogical and content considerations (Stodolsky & Grossman, 1995). By looking at the NOS (and other forms of knowledge) of beginning secondary science teachers it is possible to gain insight into how teachers build their knowledge during this formative time (Luft, 2007).

A review of the research also led to the conclusion that most tools used to assess NOS are based on a two-point scale that categorizes participants as either those that understand NOS, or those that do not. Similar to Lotter et al., (2009), the present study, from which this dissertation is drawn, implemented a three-point scale to provide a more nuanced examination of secondary science teachers’ understanding of NOS. Four factors set the study apart from the previous research that has been done in this area. 1) The participants were practicing beginning secondary science teachers in five different states throughout the United States. 2) The study was relatively large scale, with 73 participants in comparison to Lotter's et al. (2009) study of nine individuals. 3) The study also addresses one of Lederman's (2007) fundamental questions: "How do teachers' conceptions of NOS develop over time?" (p. 869). The study explored secondary science teachers' NOS understanding over a three-year period in which data collection began before the teachers started teaching and ended with the last data collection point after their third year in the classroom. 4) Unlike other NOS studies including that of Lotter et al. (2009), the work focused on practicing teachers that were not participating in interventions designed to explicitly address aspects of NOS. Whereas other studies evaluated the impact of an intervention on preservice or in-service teachers' conception of NOS, the study explored changes in NOS understanding without providing professional development designed to address aspects of NOS.

This dissertation fills a void that is lacking in the literature in that a large scale of beginning secondary science teachers were followed longitudinally for their NOS understanding, with the method of data collection being semi-structured interviews. In this dissertation I address issues concerning the gap in the literature on the development of NOS understanding in induction teachers. Specifically, it focuses on studying a large group of beginning secondary science teachers longitudinally, while emphasizing the effectiveness of a more fine-grained scale in the analysis of NOS. In addition, this dissertation adds to our understanding of how teachers' views of NOS change over time and what demographic factors mitigate this change. This knowledge can be used to help support beginning teachers in classrooms and to inform preservice programs as to how to better prepared teachers before the begin teaching.

Chapter 3

Methods

Overview

This chapter discusses the methods used to assess both teachers' beliefs about teaching science and their understanding of NOS. The initial conditions of the study from which this dissertation is drawn are described in terms of experimental design, demographics of the participants and instruments used to gather the first phase of quantitative data. In addition, the methods used for the second phase of qualitative data collection are also described, as well as the methods used to assess this data. Overall, this dissertation attempts to explain the mechanism of the change found during the quantitative phase of a larger NSF funded study in novice teachers' understanding of the nature of science during their first few year of teaching.

According to Crotty (1998) there are four basic elements in any research process: epistemology, theoretical perspective, methodology, and methods. Crotty defines epistemology as "the theory of knowledge embedded in the theoretical perspective and thereby the methodology" (p. 3). He further defines a theoretical perspective as a philosophical stance the researcher takes which informs the methodology and provides context for the process. Methodology of the research program is "the strategy, plan of action, process or design lying behind the choice and use of particular methods" (p. 3). In addition, methodology links choices to desired outcomes. Finally, the methods are the procedures the researcher uses in order to gather and analyze data in order to answer particular research questions or support or attack a hypothesis. These four elements inform each other and their relationship can be seen in Figure 3.1, adapted from Crotty (1998).

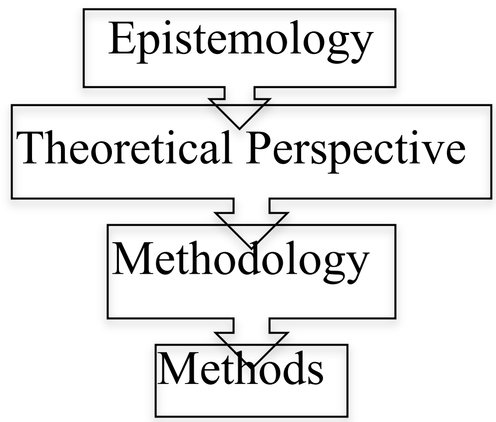

Figure 3.1. Elements of research design process (Crotty, 1998).

Constructionism as an Epistemology

This study utilizes the epistemology of constructionism and the theoretical perspective of symbolic interactionism in order to examine beginning teachers' understanding of NOS. With a constructionist perspective, the assumption is that individuals and groups interact with their environment and this interaction creates meaning. Crotty (1998) defines constructionism as "the view that all knowledge, and therefore all meaningful reality, is contingent upon human practices, being constructed in and of interaction between human beings and their world, and developed and transmitted within an essentially social context" (p. 42).

Knowledge is derived from everyday concepts, activities, and interactions in which humans engage with everyday. This continuous engagement creates meaning for the individual in terms of how she or he understands her or his environment. Experience is necessary in order to understand any particular object, event, or interaction, and these things cannot be understood in isolation

(Crotty, 1998). Therefore, in order to examine the socially constructed meanings of participants, one must enter into the aspects of the social context in which the subject inhabits, reconstruct the meanings that the subject holds, and report them in socially constructed scientific language.

Symbolic Interactionism as a Theoretical Perspective

The questions for this dissertation derive from the basic problem of the extent to which teacher education actually contributes to better teaching, or the extent to which teacher training contributes to better education. This is a problem of long standing (Koerner, 1963). Common sense would seem to hold that teacher certification is an aid in teaching (rather than sheer experience alone), but the empirical question is whether is this the case and, if so, to what extent? Is it possible that other factors are involved in influencing what is done in the classroom and these factors influence the outcome of teaching.

A general theoretical orientation by which we may focus upon this problem is Symbolic Interactionism (Goffman, 1959). Symbolic interactionism, a social psychological perspective usually identified with the discipline of sociology, provides one approach to understanding how the culture found within schools creates change in their understanding of the nature of science.

The roots of symbolic interactionism are traced to the work of Mead (1934) who introduced the concept of “the looking glass self” whereby he posited that people learn about themselves by observing and interpreting the reactions of other people to them. Through decades, this beginning was refined into a collection of concepts—most formidably by Goffman (1959) and Blumer (1969).

Blumer generalized the perspective saying that it is a general framework meant to apply to all problems of sociology from micro (individual behavior) to macro (organizational and institutional behavior) levels. The more mainstream view is expressed by Stryker (1987) who argues that: (1) Interactionism can be seen best as a broad theoretical framework for viewing individual learning and behavior; (2) that it can spawn 'models' or specific linking of concepts for narrow research purposes but is not itself intended to be a formal set of propositions arranged in deductive format; and (3) its core ideas are meant as a menu of concepts to aid in understanding and scholars should choose among them and emphasize them as appropriate to the problems they confront. Stryker and Anne Statham (1985) support this view with an exhaustive review of the history and applications of symbolic interactionism.

The principal premise of symbolic interactionism is that social reality is constructed through an individual's interpretations of social interaction. It is not strictly a phenomenological approach, for shared meaning among individuals is both possible and the basis for learning. But it is fundamental that people organize their behavior in terms of meaning they attach to on-going social interaction and process, thereby making learning susceptible to change through a variety of mechanisms. The mechanisms are better called concepts. There are five dimensions that form the core of symbolic interactionism. These are as follows:

(1) Definition of the situation; the conclusion that an individual reaches about a given "social moment" or about a conclusion with respect to

what behaviors are appropriate for a given environment or to reach a given goal. For example, in a classroom setting, a student may observe that others do not raise questions about lecture material, the teacher makes no efforts to pause or acknowledge queries from the audience and the student may define the situation as one in which questions are not appropriate.

(2) Roles; the interactionist treats these as the fundamental units or positions that capture expectations for given situations or interactions (some sociologists also use the term exchanges). The society is composed of roles; an individual occupies multiple roles simultaneously (mother, sister, physician, volunteer), the roles occupied change over time (daughter, mother, grandmother) and all roles have multiple incumbents (many different individuals are "teacher").

(3) The self; ever changing based on social interaction and learning, the self is the individual's vision of their psychological and social being based upon their interpretation of the social value and meaning of the collection of roles that they occupy at a given time. It is the repository, not just of systematic social and personal responsibilities (organized as roles), but also includes the evaluation or valence that the person believes others attribute to the constellation of roles.

(4) Learning roles; since roles are seen as both the fabric of society and the path to defining the activity of individuals, their acquisition is an

important part of symbolic interactionism. An early criticism leveled at the perspective was the notion that neither research nor intuition supported the notion that societal roles were specifically defined enough (with sufficient consensus among individuals) that a person could "assume" one or more roles without experiencing ambiguity. Turner (1962) addressed this criticism by introducing two new concepts as a means of clarifying role-based processes. Turner noted that there is variation in how closely defined (and restricted) roles are, with occupational roles (such as classroom teacher) tending to be more defined than others. However, he argued that individuals adopt roles (role taking) based on the information about responsibilities and required actions that are presented to them by authority figures and then fit the role to themselves (role making) by attending to feedback from social interactions. The initial vision of a classroom teacher role may come from the individual's interpretation of the behavior of personal graduate schoolteachers, classroom instruction, specific training programs, and the job expectations presented by both job descriptions and supervisors. The role making part may reflect what the individual finds comfortable behavior (personally), and on interpretations of feedback from fellow teachers, immediate supervisors, students, recent training experiences, and so on. In this example, it is important that "teaching" is a different role than "practicing" content; a school counselor may engage one set of role skills and responsibilities when engaged in carrying out the job and an entirely different set when teaching another to be a counselor.

(5) Differentiation of feedback based on interaction. Hewitt (1997) acknowledged that behavioral (operant learning theory-oriented) sociologists argued that the symbolic interactionist position was less tenable because individuals routinely receive feedback (some consistent, some conflicting, some blank) from many sources and therefore could not possibly behave in terms of all of it. Hewitt responds by pointed to Mead's seminal work which distinguished the notion of "significant others" or "significant exigencies". It was certainly acknowledged that the individual evaluates the sources of feedback and acts upon them (and the feedback provided) differently. Most interactions and feedback come from what Mead called the "generalized other"; people encountered by the individual who are not critical to the self or any given role. Those to whom individuals attend are referred to as "significant." Some of this attention is volitional where the individual pays attention because of personal regard for the significant other, and some is imposed institutionally where attention is demanded if an occupational role is to be sustained. For a classroom teacher, their own mentor or an experienced teacher next door may be a significant other, while their school principal may be a significant exigency. Van Sickle and Spector (1996) used a symbolic interactionist perspective to examine the role commitment of teachers

> in science classrooms. Their focus was upon two of the tenets of symbolic interactionism—roles and role learning—although the underlying mechanism for their research on the extent to which teachers developed commitment to students and class content. Their research found clearly that as teachers spent more time in the classroom, the strength of role relationships increased and as a result, teachers formed "expectations of self" that changed over time (Van Sickle and Spector, 440-441).

If one is interested in the role of teacher certification in beliefs about teaching science, classroom practices, and understanding of the nature of science, one is asking multiple questions from a symbolic interactionist perspective. All of these questions have a "current context" and a "historical context," but collectively they form a significant part of the role of science teacher. Certification is a current context that affects how an individual performs now. It is a socialization process that shares with individuals specific expectations for role performance. One may elect to undergo certification or it may be imposed as a condition of employment. In either case, it is a structurally provided set of guidelines for thinking and behavior. Other "sources" may also compete or compliment certification messages and their adoption. Individual behavior is especially affected by "regency" of interactions. Thus one might expect that as certification becomes more distant training, individual role performance will be more shaped by current interactions with significant others. Symbolic interactionism can be seen as a driving force behind changes in terms of the beliefs and understandings of the new teachers.

In terms of the specific questions asked in this dissertation, symbolic interactionism helps explain why change might occur over time. Teachers' background, education, preservice experiences and classes, induction program, and curriculum all interact to form their ideas, understandings, and beliefs about teaching science and NOS. By using the lens of constructionism through symbolic interactionism, we can examine the factors that may influence teachers' NOS over time, even if these factors are not present directly in the classroom in which they teach.

Methodology

The methodology of a research study needs to be consistent with the epistemology and appropriate for the theoretical perspective. The methodology in this study will based upon magnitude estimation (ME) discussed in Meek et al. (1992). This allows the researcher the freedom to create scaled scores based upon the strength and breadth of the knowledge of the participant in terms of NOS. These scaled scores cluster into discrete ranges of score groups. From these clusters the researcher can make comparisons between various participants and groups without relying on preconceived categories that are not necessarily scalable. This comparison can be accomplished using a Linear Regression Model.

Methods

Research Setting: The PERSIST Project.

This study resided within the Persistent, Enthusiastic, Relentless: Study of Induction Science Teachers (PERSIST) research project which was funded by National Science Foundation grant #0550847. This study was designed to explore the impact of four different types of induction programs on beginning secondary science teachers located in five states of the Southwest and Midwest regions of the United States. The induction groups involved were categorized as: 'general', 'intern', 'science-specific', and 'electronic mentoring'.

Table 3.1.

Induction Programs Studied in the PERSIST Project

General	Intern	Science-specific	Electronic mentoring
School or district program Assigned mentor is a teacher that may or may not be in field Focus on general induction Meetings vary	Educational coursework while learning to teach Mentors may or may not be in science Focus on general instruction	University developed Focus on teaching science Faculty and district mentors Monthly classroom visits, monthly university sessions, annual science education conference	University and organization developed Focus on science teaching Mentors who are experienced teachers Active on-line community Meeting once a year

Note. Adapted from "Beliefs and practices of beginning secondary science teachers: The first two years in the classroom," by S. Wong, E. J. Bang, J. A. Luft, K. Adams, J. Firestone, and J. Neakrase, April 2009, Paper presented at the meeting of National Association for Research in Science Teaching, Garden Grove, California,

General group teachers received support from their school or district and focused on general topics like general teaching strategies and administrative responsibilities. Intern teachers received general support from their schools but did not have a formal teaching certificate and were in pursuit of certification while teaching. Teachers in the science-specific induction program received monthly face-to-face mentoring by science teacher educators or science teachers at a university in the Southwest. Teachers in the electronic mentoring program also received science-specific support but did so by participating in an online community and meeting face-to-face once a year. The induction programs lasted for the first two years for all teachers. The induction programs studied in the PERSIST project can be found in Table 1 (Wong et al., 2009). A complete discussion of the research project can be found in Luft (2009).

Participants

This dissertation uses the data from 95 teachers, who came from five states in the United States (Table 2). Overall, the teachers included were mostly female, held bachelor's degrees, and resided in the Southwest region and Midwest regions of the United States. The teachers in this pool participated in one of four identified induction programs which have been described previously: Science-specific (ASIST), General (GEN), Electronic mentoring (eMSS), or Interns (INTERN). During the first year of the study, the teachers were selected to participate in the study if they were engaged in one of the identified induction programs. The initial selection process aligns with purposeful sampling, which entails identifying individuals based on specific questions and the purpose of the research (Henry, 1990). For this study, however, the data is drawn from teachers who participated through their first three years of teaching. Those that did not complete interviews during the three years of data collection were excluded since these points of data were critical in studying teacher change over time.

Table 3.2.

Demographics of Participants

	GEN	eMSS	ASIST	INTERN
Total	19	17	19	8
Male	9	8	9	1
Female	10	9	10	7
Degree Certification Program				
B.Ed.	7	6	1	0
Post-Bacc:	8	3	4	0
M.Ed.	4	8	12	3
Other	0	0	2	2
None	0	0	0	3
Academic preparation				
BS/BA	15	11	13	6
MS/MEd	4	6	4	1
MS Science	0	0	2	0
PhD/EdD	0	0	0	1
History & Philosophy of				
0	16	12	6	7
1	3	2	5	1
2 or more	0	3	8	0
Degree Major				
Biology	8	9	6	6
Chemistry	4	2	5	0
Earth Science	2	0	2	1
Physics	0	1	2	0
Engineering	0	1	0	0
Other Science	1	0	0	0
Non-Science	4	1	1	1

Data Collection

For this study, data collection occurred over a three-year period. Prior to the study, demographic information was collected from each teacher. This included gender, the teachers' type of preservice certification program, the number of history and philosophy of science classes that the teacher had taken during preservice, location of preservice program, type of school and location at which the teacher was working, and the degree major and highest degree that the teacher had achieved prior to the beginning of teaching. At this time (T1 for time one) a 'general interview' was conducted that provided background and supporting information pertaining to the teachers and also delved into their attitudes towards the usefulness of their preservice program and their attitudes towards their current school assignment.

At this time the teachers were given additional interviews designed to assess their beliefs about teaching science, their understanding of NOS, and their Pedagogical Content Knowledge (PCK). In addition, the teachers were given a written questionnaire in order to assess their Knowledge of Pedagogy (PK) and they were asked to create two concept maps in order to assess their understanding of subject specific science content. The interviews were conducted in person or over the phone and recorded digitally with the permission of the participants. Each portion of the interview ('general', Beliefs, NOS, PCK, etc.) lasted from 15 to 45 minutes, with the interviews generally lasting from one and a half to three hours in total.

At the end of each subsequent year (T2, T3, and T4) (Table 3), all of the interviews were repeated in order to reassess beliefs, NOS, PCK, PK, and content knowledge along with the 'general interview'. These interviews were generally conducted at the very end of the school year or at the beginning of the summer break. For teachers working in year-round schedules, the interviews were conducted as closely as possible to the other participants. Any changes to the demographic information (i.e. state in which the teacher was employed or type of school at which the teacher taught) were also noted at this time.

Table 3.3.

Data Collection Schedule

Interview Name	*Collected*	*Year*
T1	Pre year 1	Summer 2005
T2	Post year 1	Summer 2006
T3	Post year 2	Summer 2007
T4	Post year 3	Summer 2008

NOS Instrument

In order to gauge teachers' understanding about science, we used an interview protocol modified from "Views on the Nature of Science – C" (Abd-El-Khalick, Bell & Lederman, 1998) with an additional question that focused on how teachers' represented the discipline of science in their classrooms (Brown, Luft, Roehrig, & Kern, 2006). Semi-structured interviewing was the process utilized for data collection due to its adaptability during an interview (Fylan, 2005). The flexibility of semi-structured interviews allows the researcher to alter questions during the interview in order to gain greater understanding of the topic (Fylan, 2005). It is possible to "talk around the area with the participant, and find out from him or her about what is important, and why" (Fylan, 2005, p. 66). Semi-structured interviews also allow for access to teacher thinking: particularly such aspects of it that could not be obtained through observation or other data collection methods.

Teachers were asked interview questions by a trained researcher. The researcher would ask follow-up questions in an attempt to elicit responses that represented the participant's knowledge of NOS. The initial researcher that conducted the interview recorded the interview for later analysis and also took notes as a supplement to the recordings. Coding of responses followed the consensus model in which the two independent researchers collaborated to reach unanimous agreement and resolution (Herrera, Herrera-Viedma, & Verdegay, 1996).

Data Analysis

This process follows Lederman's (2000) recommendation in determining the understanding of NOS amongst participants. Lederman points out that there is no singular question that depicts NOS, or a particular answer that reflect understanding of NOS. In fact, quite often teachers will hold mixed or contrary views about NOS depending on the subject. For example, a teacher might be considered 'developed' in terms of his or her understanding of the scientific method, but responds in a 'developing' fashion in terms of his or her understanding of the roles of theories and laws in science. Therefore, separating the VNOS-C into individual questions for analysis does not yield a complete characterization of a participants understanding NOS.

Issues with past NOS analyses

Past analysis of NOS using assessment tools such as the VNOS-C have relied on assessing each answer separately and assigning a category into which a particular response should be placed (i.e. naïve, developed, etc.). After this, researchers have either qualitatively characterizing the individual's understanding of NOS as a whole or have assigned numeric value to each category and quantitatively assessing the NOS as a sum or an average (Lederman, 2007). Both of these techniques face several challenges.

In terms of a qualitative analysis of the individual based upon their responses, it becomes difficult to compare individuals or groups to each other with large sample sizes. While this technique may lead to well-developed depictions of teachers' NOS, the time require to create such descriptions prevents any assessments on large scales and even may preclude many longitudinal studies of NOS.

On the other hand, quantitative analyses lend themselves to large sample sizes and repeated measures. However, the assignment of numerical values to aspects of NOS is problematic for two reasons. First, by assigning a numeric value, researchers create a hierarchy of responses from their participants. Certain responses are rated higher or lower, numerically, giving more or less weight to responses that, by the nature of the assignment of the number, more or less desirable. This becomes most evident when analysis either sum or average the 'scores' from a NOS assessment tool and then compare these numbers to each other.

Second, by assigning a numeric value to each category within a scale, researchers are making the assumption that the 'distance' between one category and another is equal across the entire scale. For instance, researchers may assign a '1' to responses deemed to be 'naïve', '2' to responses deemed to be ‘transitional’, and ‘3’ to responses deemed to be ‘developed’. This then assumes that the ‘difference’ between ‘naïve’ and ‘transitional’ is the same as the distance between transitional and developed. In response to this, researchers have created a more fine-grained scale with four, five, or seven categories in which to assign values (Wallace et al, 2011). While this may create a more nuanced scale and a broader range of ‘scores’, it does not solve the problem of unequal distance between values.

New NOS assessment

In response to the aforementioned problems a new method of analyzing responses to existing NOS assessments is needed. One that can not only be used to get an accurate, robust, and descriptive analysis of participants’ understanding of NOS, but can also be used in large-scale studies over time. Finally, the scale should also have the benefit of being adaptable to differing needs of the researcher in terms of creating various types of comparison groups within the subject pool.

Coding

The specially trained coders reviewed a digital audio copy of each interview and created a simple count of the number of times the participant mentioned any of the 6 principles of NOS created by Lederman (2007). Only references that were in agreement with one of the 6 principles were counted. Using a NVIVO8, a computer based audio, video, and text analysis program, portions of the audio files in which the teachers referenced one of the 6 principles of NOS were directly labeled. The number of references, their location within the recording, and a brief synopsis of the coded text were all recorded and tallied within the program. This allowed for a much more rapid assessment of the NOS traits than could be done with transcribed interviews and also automatically created a categorized tally of the references.

Assessing NOS

A simple index (Babbie, 1990) was developed based on this information. Each of the six principles of NOS is of equal importance theoretically and conceptually for the practice of NOS. However, the number of different principles or dimensions mentioned by the participant is considered substantively important as indicative of the breadth of understanding of NOS.

Consequently, one would not want to score as equal two participants, one of whom mentioned a single dimension of NOS six times when the other participant mentioned each of the six principles once. A common psychometric strategy for accommodating such measurement concerns is to weight the initial score or count of mentions of target principles relative to the number of target dimensions (Nijkamp & Voogd, 2007; Rust & Golombok, 2009). In this strategy, researchers multiply the original score (e.g. number of mentions of any principle of NOS) by the number of principles or dimensions represented in the interview. Thus a person who mentioned one dimension six times is assigned a score of six, while a person who mentioned each of the six principles once obtains a score of 36 (6 mentions times 6 principles).

For example, Melvin referenced or discussed the six facets of NOS 11 times during his first interview. Of the 11 references, four concerned the second facet of NOS, recognizing the delineation between a scientific law and scientific theory, and seven concerned the fifth facet of NOS, recognizing that science is embedded within socio-cultural contexts. His combined score of NOS was 22 (11 references multiplied by 2 different facets). In contrast to this, Sharon referenced or discusses the six facets of NOS 15 times during her first interview. Of the 15 references, all concerned the third facet of NOS, recognizing that scientific knowledge relies on observations of phenomena, as well as human creativity and imagination. Her combined score of NOS was 15 (15 references multiplied by 1 facet). Even though Sharon mentioned NOS more often within the context of the six facets, her score was lower because she only discussed one facet of NOS.

This type of score can range from zero (no mentions of any dimension) to a potentially large, but unspecified upper limit. In spite of an unspecified upper limit, the scoring retains interval status, based on its monotonically increasing characteristic (Mas-Colell et al., 1995). This approach has been commonly used in differentiating of the diagnostic skills of nurses (Meek et al, 1992; Kinnery & Guzzetta, 1989). This coding method is vital in order to depict the understanding of NOS among teachers. If a pure frequency count were used, teachers who continually discussed one facet of NOS would be rated higher than teachers with a broad range of NOS understanding and fewer references. In addition, if only the number of different facets were scored without a method of determining the frequency of overall NOS facets discussed then teachers who quickly mentioned several topics of NOS, but with no follow-up discussion would be unfairly rated higher than those that discussed NOS throughout their interview. By combining both the number of references and the number of different facets mentioned, not only is the understanding of NOS more fully explored, but a wider range of scores are possible, thus allowing a more fine grained assessment of teachers within the study.

Triangulation, Reliability, and Validity

Denzin (1978, p. 291) characterized triangulation broadly as "the combination of methodologies in the study of the same phenomenon" in an effort to ensure the capture of appropriate meaning. In so doing, he extended the notion of combining validation (or concept validity) pioneered by Campbell and Fiske (1959). The notion in particular is that in examining validity, the likely connection between a measure such as the one used here and the abstract concept that it represents, one must resort to a logical analysis (because we are dealing with one intangible concept) coupled with multiple approaches to examining the tangible measure itself. The logical analysis was conducted in the preceding section "assessing NOS" wherein the measure itself was presented, the reasoning behind its use elucidated and these elements compared with the concept of NOS as derived from the literature review. Thus, the discussion examines the epistemic correlation (Kaplan, 1964) between the measure itself and the concept or idea it is intended to measure. The argument is that by insuring adherence to principles of NOS in selecting and accumulating teacher answers, one has achieved an accurate representation of the original concept (Flick, 1992).

The notion of approaching the same phenomenon from different "methodologies" is captured here directly by concerns about reliability and in so doing indirectly also approaches the concept of validity. In developing the instrument, coding of responses followed the consensus model in which the two independent researchers collaborated to reach unanimous agreement and resolution (Herrera, Herrera-Viedma, & Verdegay, 1996). Prior to this study, a pilot study with a subset of the participant population (n=12) was conducted. During this pilot study two researchers independently coded the audio files. The tallies of NOS references were compared between the two coders. Any discrepancies were debated until an agreement of the appropriate number and type of references could be reached. In addition, issues of face validity were discussed and accuracy of the responses in terms of the 6 principals of NOS was determined. Thus, two different coders, operating on the same definitional schema, brought their measures together using a system of successive approximation to consensus. This tactic brings together and integrates multiple views of the concept and strengthens the captured meaning, which in turn enhances both the reliability of the measure and the validity with respect to the concept.

Benefits of the new scale

Based upon these results I have proposed a plausible method of assessing teachers understanding of NOS using a ratio scale based on Lederman's Six Facets. This scale is not dependent upon arbitrarily selected classification schemes and therefore provides a common scale for use by researchers. In order to more adequately depict teachers' understanding of NOS researchers can define the grain-size and classification scheme that best suits their purposes.

For example, in the analysis a person is considered 'knowledgeable' in their conception of NOS if he or she referred to each of the six facets of NOS at least once. Using the ratio NOS scale that person would score a minimum of 36 (1 entry for each of the 6 facets and multiplied by the number of facets). A person would have an extremely limited or 'naïve' conception of NOS if he or she scored 0 on the new scale. Therefore a score of 0 could logically be considered an endpoint in the ratio NOS scale. In order to make a more fine grained groupings of scores the range can be further divided into 4 classification groups to indicate a subject's NOS score: Naïve (0-11), Emerging (12-23), Developing (24-35), and Knowledgeable (≥36). An "expert" understanding of NOS remains to be defined.

In terms of exploring the possible change in the understanding of NOS and factors that may impact a teachers understanding of NOS, several factors were considered. These included the type of induction program in which the teacher was enrolled, the highest degree that the teacher had completed prior to teaching, the subject in which the teacher had a degree, whether the teacher took courses in the history and philosophy of science and how many courses he or she may have taken, and the gender of the teacher. In order to compare the induction groups and various demographic characteristics, as well as to determine if there had been a change in the understanding of NOS during the first three years in the classroom, a series of two-way repeated-measures Analysis of Variance (ANOVA) statistical tests were conducted.

Delimitations

The limitations of this study concern the timing and nature of the interviews, and the modifications made to the original instrument. In terms of the timing of the interviews, the teachers were interviewed at the beginning or end of each school year. Due to the length of each interview, this was deemed the best schedule to capture desired information without overtaxing the teachers. In addition, the nature of the semi-structured format made some aspects of the interview uneven. At times teachers were reluctant to speak about aspects of their teaching or understanding due to time constraints of the working teachers or fatigue. This issue was mitigated as much as possible by the trained researchers during the interviews. Due to modifications to the VNOS-C instrument, some of the facets of NOS were not as heavily probed as others. These changes were made in order to glean additional data about the pedagogy of NOS within the classroom. However, since the modification of questions affected all teachers, the overall depiction of NOS remained constant across the entire study. Finally, due to the nature of the study, we did not directly capture how NOS was performed in the classrooms and, therefore, we must rely on the teachers' self-reported practices, when given, in order to come to any conclusions about how a teachers' understanding of NOS may have effected pedagogy.

Chapter 4

Results

The purpose of this chapter is to present the results of the analyses conducted to examine the research questions proposed in chapters one and two. The data collection, subjects and measurement strategies and practice have been described in Chapter 3 wherein the research approach was reported. Thus, this chapter centers on three topics: an examination of the impact of induction group membership on NOS scores; an examination of the impacts of demographic and other background variables on NOS scores; and a review of changes in NOS score patterns over time. The principle goal in this chapter is to report and interpret findings. Chapter 5 will deal with the issues associated with the meaning of these findings for the broader study of NOS and for science education.

IMPACT OF INDUCTION GROUPS ON NOS SCORE

Our initial concern rests with Induction Group impact on NOS score. Table 1 shows Descriptive data for NOS score by Time of measurement and induction program. These descriptive statistics are initially presented for each of the four times measured. Within T1, the highest mean number of NOS references 9.5 (SD=10.6) for the INTERN group. The group means continue in descending order for ASIST (8.35, S.D.= 8.5), eMSS (7.41, S.D.=8.5), and GEN (5.37, S.D.= 6.7). Across all groups in T1, the mean number of NOS mentions was 7.38 (S.D.=8.3).

For T2, the INTERN group was again highest (10.9, S.D.=10.3), followed in descending order by ASIST, (10.7, S.D.=16.3), eMSS (7.24, S.D.=8.3), and

GEN (6.0, S.D.= 7.5). Across all groups in T2, the mean number of NOS mentions was 8.38 (S.D.=11). For T3, the INTERN group was again highest (8.90, S.D.=7), followed in descending order by ASIST, (6.82, S.D.= 7,2), eMSS (6.12, S.D.=7.4), and GEN (5.89, S.D.= 5). Across all groups in T3 the mean number of NOS mentions was 6.68 (S.D.=6.5). For T4, the ASIST group was highest (8.35, S.D.=8.6), followed in descending order by GEN, (7.47, S.D.= 5), INTERN (7.30, S.D.=7.6), and eMSS (5.59, S.D.= 4.5). Across all groups in the T4, the mean number of NOS mentions was 7.17 (S.D.=6.4).

TABLE 4.1.

NOS score by Induction Program and Time Measured

	Induction Program	Mean	Std. Deviation	N
NOS Score-T1	eMSS	7.41	8.515	17
	ASIST	8.35	8.500	19
	GEN	5.37	6.702	19
	INTERN	9.50	10.669	8
	Total	7.38	8.315	63
NOS Score-T2	eMSS	7.24	8.265	17
	ASIST	10.71	16.263	19
	GEN	6.00	7.476	19
	INTERN	10.90	10.268	8
	Total	8.38	11.046	63
NOS Score-T3	eMSS	6.12	7.398	17
	ASIST	6.82	7.178	19
	GEN	5.89	4.999	19
	INTERN	8.90	6.983	8
	Total	6.68	6.545	63
NOS Score-T4	eMSS	5.59	4.501	17
	ASIST	8.35	8.573	19
	GEN	7.47	5.092	19
	INTERN	7.30	7.558	8
	Total	7.17	6.412	63

An analysis of variance calculated on the data in Table 1 shows Huynh-feldt coefficients for the main effect of time to be not statistically significant

(F=1.0, p=.39) and the interaction effect of time with induction program is also not statistically significant (F=.57, p=.81). In these cases, there is a recognizable pattern in the substance of the data that shows the GEN group and the eMSS overall lower than either the INTERN group or the ASIST group. The absence of statistical significance in spite of the apparent pattern likely stems from the combination of small sample sizes within the cells and some induction group categories with large standard deviations.

Finally, there is a pattern that arises for the groups when observed over time. Figure 1 shows the average score for each of the four induction groups over the four time periods measured. Over the course of the three years of the study the mean scores of T1-T4 for all four groups tended to converge. This pattern of convergence, while not statistically significant, can be observed in the other analyses of the data.

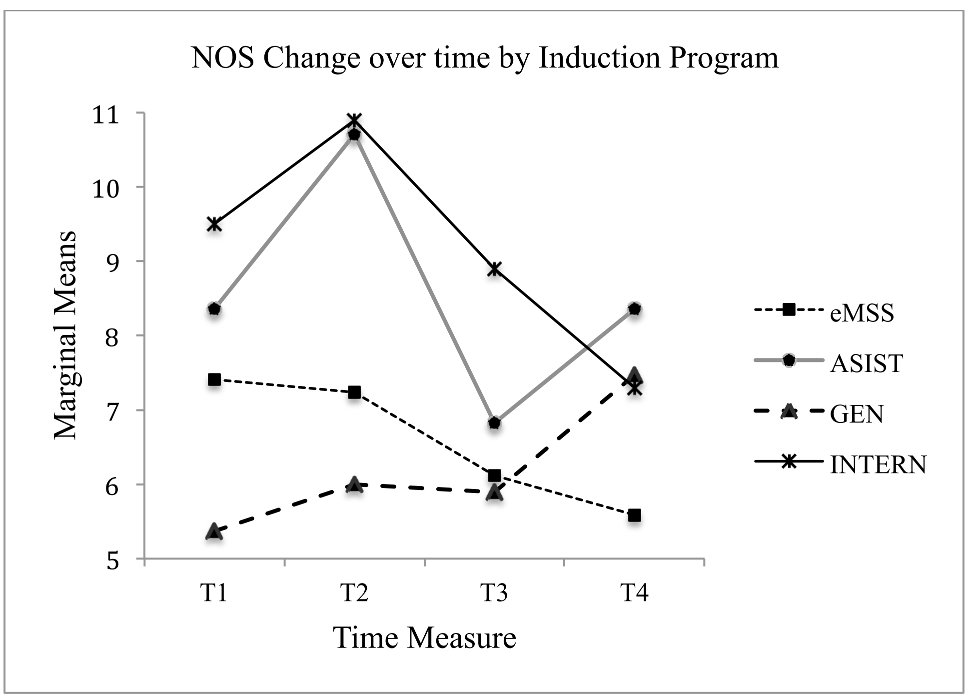

Figure 4.1. NOS score by induction program over time (T1-T4)

IMPACT OF HIGHEST DEGREE EARNED

Several demographic factors were examined in order to determine any effect on NOS over time; the first of these was the impact of the highest academic degree earned prior to beginning teaching. Table 2 shows Descriptive data for NOS score by Time of measurement and highest degree earned. Within T1, the highest mean number of NOS mentions is 24.0 (SD=0) for the PhD group. This group consists of only one participant, hence the standard deviation of 0. The group means continue in descending order for Science M.S. (22.0, S.D.= 2.8), M.S./M.Ed. (7.1, S.D.=6.7), and B.S. (6.47, S.D.= 6.5). Across all groups in T1, the mean number of NOS mentions was 7.38 (S.D.=8.3).

For T2, the Science M.S. group was the highest (32.5, S.D.=46), followed in descending order by PhD., (16.0, S.D.=0), M.S./M.Ed. (8.8, S.D.=8.8), and B.S. (7.0, S.D.= 7.0). Across all groups in T2, the mean number of NOS mentions was 8.38 (S.D.=11). For T3, the Science M.S. group was again highest (14.5, S.D.=14.8), followed in descending order by B.S., (6.6, S.D.= 6.6), M.S./M.Ed. (6.33, S.D.=5.3), and PhD., (2.0, S.D.= 0). Across all groups in T3 the mean number of NOS mentions was 6.68 (S.D.=6.5). For T4, the Science M.S. group was highest (9.50, S.D.=7.8), followed in descending order by M.S./M.Ed., (8.47, S.D.= 5.7), B.S. (6.78, S.D.=6.7), and PhD., (1.0, S.D.= 4.5). Across all groups in the T4, the mean number of NOS mentions was 7.17 (S.D.=6.4).

TABLE 4.2:

NOS score by Highest Degree Achieved

	Highest Degree Earned	Mean	Std. Deviation	N
NOS Score-T1	B.S.	6.47	8.131	45
	Science M.S.	22.00	2.828	2
	M.S./M.Ed.	7.07	6.692	15
	PhD or EdD	24.00	.	1
	Total	7.38	8.315	63
NOS Score-T2	B.S.	7.00	8.337	45
	Science M.S.	32.50	45.962	2
	M.S./M.Ed.	8.80	8.801	15
	PhD or EdD	16.00	0	1
	Total	8.38	11.046	63
NOS Score-T3	B.S.	6.56	6.570	45
	Science M.S.	14.50	14.849	2
	M.S./M.Ed.	6.33	5.273	15
	PhD or EdD	2.00	0	1
	Total	6.68	6.545	63
NOS Score-T4	B.S.	6.78	6.664	45
	Science M.S.	9.50	7.778	2
	M.S./M.Ed.	8.47	5.693	15
	PhD or EdD	1.00	0	1
	Total	7.17	6.412	63

An analysis of variance calculated on the data in Table 2 shows Huynh-feldt coefficients for the main effect of time to be statistically significant ($F=7.8$, $p=.000$) and the interaction effect of time with induction program is also statistically significant ($F=7.79$, $p=.000$). In these cases, there is a recognizable pattern in the substance of the data that shows the B.S. group and the M.S./M.Ed. overall lower than the Science M.S. group. There is an interesting pattern that arises for the groups when observed over time. Figure 2 shows the average score for each of the four groups over the four time periods measured. Similar to the results found within the induction group data, over the course of the three years of the study the mean scores of T1-T4 for all four groups tended to converge.

However in the case of the highest degree obtained, this data is statistically significant. The outlier in this set is the PhD., which represents a single individual.

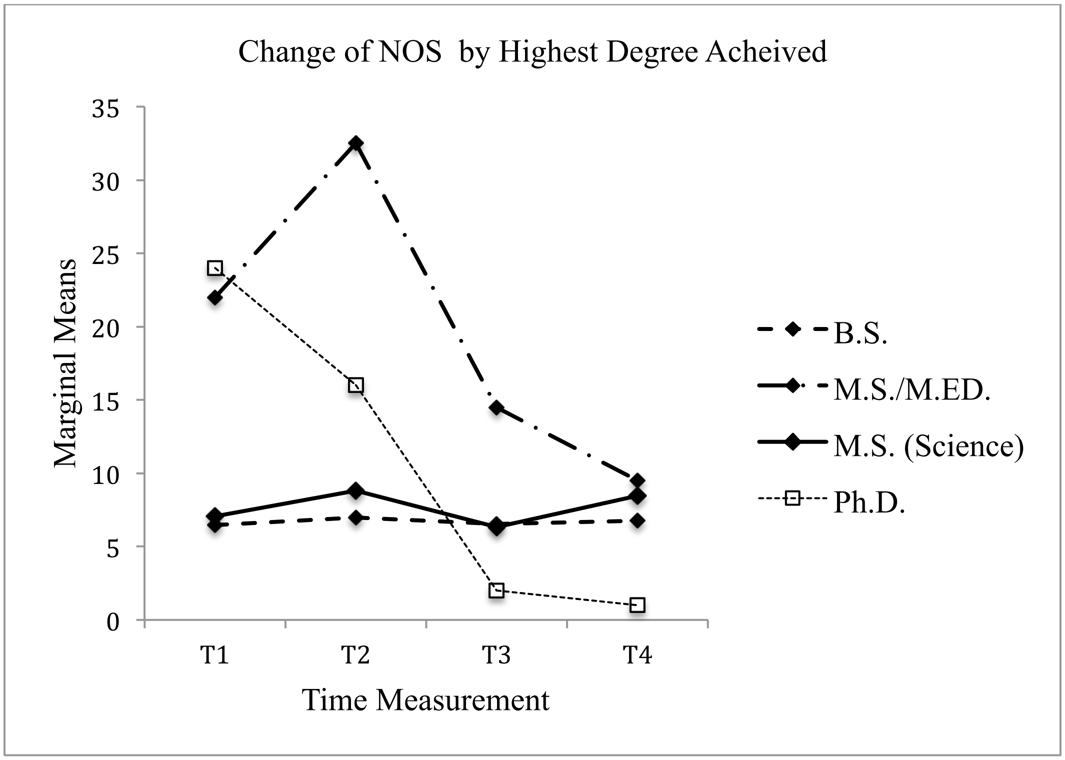

FIGURE4.2. NOS Score by Highest Degree Earned over time (T1-T4)

IMPACT OF DEGREE MAJOR

In addition to the level of degree achieved prior to teaching, the degree major was also examined. Table 3 shows Descriptive data for NOS score by Time of measurement and degree major. Within T1, the highest mean number of NOS references is 9.67 (SD=12.5) for Physics majors. The group means continue in descending order for Chemistry majors (9.18, S.D.= 10.1), Life Science majors (8.0, S.D.=8.9), Other Science majors (6.14, S.D.=6), Earth Science majors (5.2, S.D.=5.2) Non-Science majors (4.29, S.D.=5.6) and Engineering majors (4.0, S.D.= 0). Across all groups in T1, the mean number of NOS mentions was 7.38 (S.D.=8.3).

For T2, Physics majors continued to be the highest (16.0, S.D.=14.4), followed in descending order by Chemistry majors, (11.73, S.D.=19.9), Earth Science majors (9.40, S.D.=5.7), Life Science majors (7.4, S.D.=8.8), Non-science majors (6.86, S.D.=6.5), Other science majors (5.71, S.D.=5.9), and Engineering majors (1.0, S.D.= 0). Across all groups in T2, the mean number of NOS mentions was 8.38 (S.D.=11). For T3, the Chemistry majors were highest (9.09, S.D.=10.4), followed in descending order by Earth Science majors, (8.40, S.D.= 4.9), Physics majors (6.67, S.D.=1.6), Life science majors (6.24, S.D.=6.2), Other science majors (6.14, S.D.=5), Non-science majors (4.86, S.D.=3.3), and Engineering majors, (1.0, S.D.= 0). Across all groups in T3 the mean number of NOS mentions was 6.68 (S.D.=6.5). For T4, Physics majors were the highest (18.67, S.D.=12.2), followed in descending order by Other Science majors (7.14, S.D.= 6.5), Chemistry majors (7.09, S.D.=6.5), Earth Science majors (7.0, S.D.=3.5), Life Science majors (6.72, S.D.=6.0) Non-Science majors (4.86, S.D.=3.3), and Engineering majors, (1.0, S.D.=0). Across all groups in the T4, the mean number of NOS mentions was 7.17 (S.D.=6.4).

An analysis of variance calculated on the data in Table 3 shows Huynh-feldt coefficients for the main effect of time to be not statistically significant (F=.763, p=.493) and the interaction effect of time with induction program is also not statistically significant (F=.668, p=..832). In these cases, there is a recognizable pattern in the substance of the data that shows the Engineering majors, Non-science majors, and Other Science majors overall lower than

TABLE 4.3

NOS score by Degree Subject

	Background Demographics -	Mean	Std. Deviation	N
NOS Score -T1	Life Science	8.00	8.992	29
	Chemistry	9.18	10.147	11
	Physics	9.67	12.503	3
	Earth Science	5.20	5.167	5
	Other Science	6.14	5.956	7
	Engineering	4.00	.	1
	Non-science	4.29	5.559	7
	Total	7.38	8.315	63
NOS Score -T2	Life Science	7.41	8.777	29
	Chemistry	11.73	19.875	11
	Physics	16.00	14.422	3
	Earth Science	9.40	5.683	5
	Other Science	5.71	5.880	7
	Engineering	1.00	.	1
	Non-science	6.86	6.517	7
	Total	8.38	11.046	63
NOS Score -T3	Life Science	6.24	6.226	29
	Chemistry	9.09	10.406	11
	Physics	6.67	1.155	3
	Earth Science	8.40	4.930	5
	Other Science	6.14	4.981	7
	Engineering	1.00	.	1
	Non-science	4.86	4.018	7
	Total	6.68	6.545	63
NOS Score -T4	Life Science	6.72	6.017	29
	Chemistry	7.09	6.472	11
	Physics	18.67	12.220	3
	Earth Science	7.00	3.464	5
	Other Science	7.14	6.492	7
	Engineering	4.00	.	1
	Non-science	4.86	3.338	7
	Total	7.17	6.412	63

Chemistry majors. Earth Science majors start lower than most other groups, but by T4 are essentially equal to Life Science majors, Other Science majors, and Chemistry majors. Physics majors have the greatest change, starting highest, increasing, decreasing below Chemistry majors and Earth Science majors, and then greatly increasing above all other groups. There is an interesting pattern that arises for the groups when observed over time. Figure 2 shows the average score for each of the four groups over the four time periods measured. Similar to the results found within the induction group data, over the course of the three years of the study the mean scores of T1-T4 for all majors (except for Physics majors) tended to converge. The outliers in this set are the Physics majors that by the end of three years are higher than all other majors.

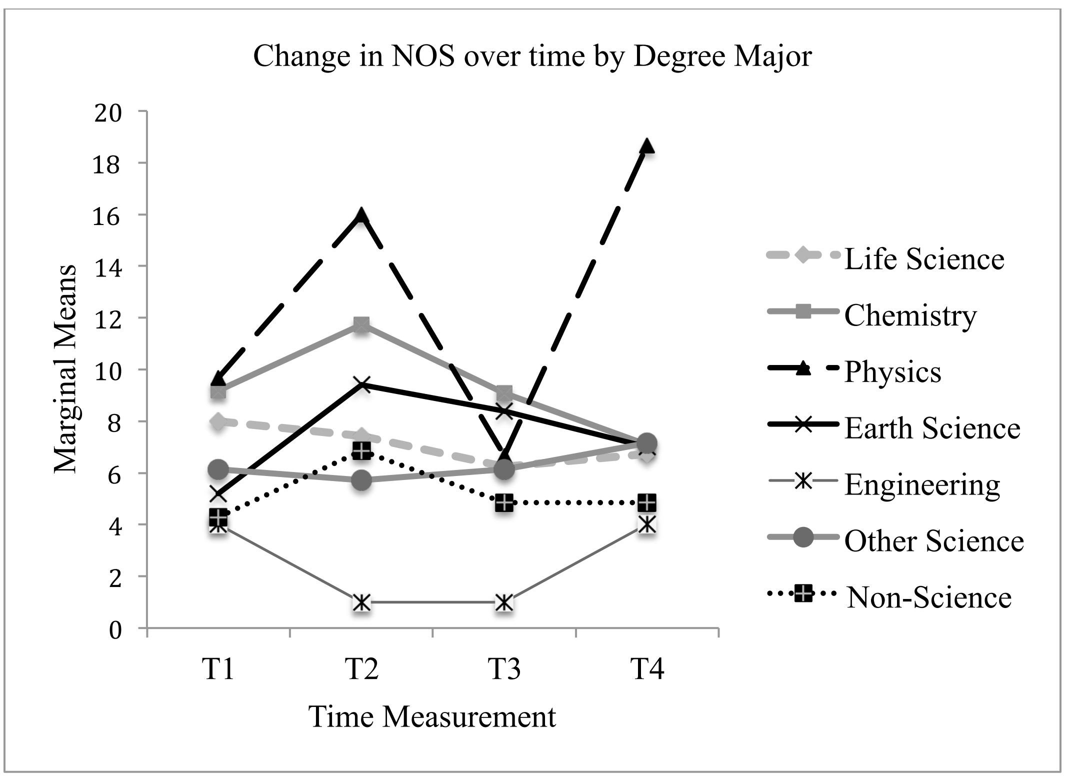

FIGURE 4.3. NOS Score by Degree Major earned over time (T1-T4)

IMPACT OF CERTIFICATION PROGRAM

As part of the examination of demographics the certification program from which the teachers graduated was also investigated. Table 4 shows Descriptive data for NOS score by Time of measurement and certification program. Within T1, the highest mean number of NOS mentions was 17.0 (SD=14.1) for teachers who held no certification at the beginning of their careers. The group means continue in descending order for teachers who were certified through a Master's program (9.44, S.D.=7.9), through an 'Other' programs (8.75, S.D.=10.4), Post-Baccalaureate programs (4.4, S.D.=4.6), and an Undergraduate programs (4.1, S.D.=6.3). Across all groups in T1, the mean number of NOS mentions was 7.38 (S.D.=8.3).

For T2, teachers without a teaching certification continued to be the highest (13.33, S.D.=15), followed in descending order by teachers categorized as 'Other' in terms of certification program, (11.0, S.D.=6), Master's certification programs (10.37, S.D.=14.6), Undergraduate programs (7.29, S.D.=7.5), and Post-Baccalaureate programs (4.13, S.D.=3.9). Across all groups in T2, the mean number of NOS mentions was 8.38 (S.D.=11). For T3, teachers without a teaching certification continued to be the highest (11.33, S.D.=10), followed in descending order by teachers from Master's certification programs (7.93, S.D.=7.3), teachers categorized as 'Other' in terms of certification program, (7.75, S.D.=6.2), Undergraduate programs (6.07, S.D.=5.9), and Post-Baccalaureate programs (3.80, S.D.=4.3). Across all groups in T3 the mean number of NOS mentions was 6.68 (S.D.=6.5). For T4, from Master's certification programs were the highest (8.44, S.D.=7.5), followed by teachers without a teaching certification (8.33, S.D.=10.2), followed in descending order by teachers categorized as 'Other' in terms of certification program, (6.25, S.D.=6.6), Undergraduate programs (8.07, S.D.=5.9), and Post-Baccalaureate programs (4.07, S.D.=3.6). Across all groups in the T4, the mean number of NOS mentions was 7.17 (S.D.=6.4).

TABLE 4.4.

NOS score by Certification Program

	Certification program	Mean	Std. Deviation	N
NOS Score-T1	Undergraduate	4.14	6.347	14
	Post-bacc	4.40	4.626	15
	Masters	9.44	8.907	27
	Other	8.75	10.372	4
	None	17.00	14.107	3
	Total	7.38	8.315	63
NOS Score-T2	Undergraduate	7.29	7.518	14
	Post-bacc	4.13	3.944	15
	Masters	10.37	14.642	27
	Other	11.00	5.598	4
	None	13.33	14.978	3
	Total	8.38	11.046	63
NOS Score-T3	Undergraduate	6.07	5.916	14
	Post-bacc	3.80	4.280	15
	Masters	7.93	7.301	27
	Other	7.75	6.238	4
	None	11.33	10.017	3
	Total	6.68	6.545	63
NOS Score-T4	Undergraduate	8.07	5.298	14
	Post-bacc	4.07	3.595	15
	Masters	8.44	7.480	27
	Other	6.25	6.652	4
	None	8.33	10.214	3
	Total	7.17	6.412	63

An analysis of variance calculated on the data in Table 4 shows Huynh-feldt coefficients for the main effect of time to be not statistically significant ($F=1.005$, $p=.389$) and the interaction effect of time with induction program is also not statistically significant ($F=.664$, $p=.775$). In these cases, there is a recognizable pattern in the substance of the data that shows teachers who graduated from Post-Baccalaureate certification programs scored, overall, lower than other certification programs and had the least amount of change over time. Teachers from Undergraduate certification programs increase over time and by T4 essentially the same as teachers from Master's programs and those how do not have a certification. Those without certification have the greatest change dropping rapidly to meet in the same general area as the other programs in terms of NOS score. There is an interesting pattern that arises for the groups when observed over time. Figure 2 shows the average score for each of the four groups over the four time periods measured. Similar to the results found within the induction group data, over the course of the three years of the study the mean scores of T1-T4 for all certification programs tended to converge.

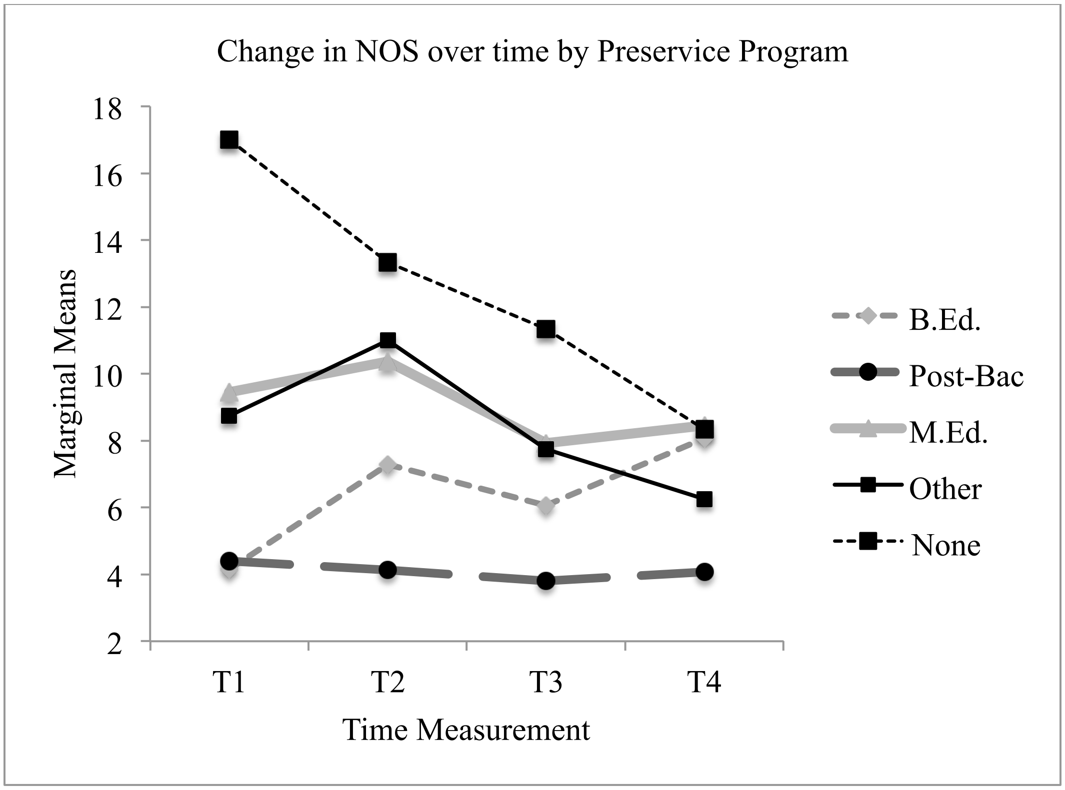

FIGURE 4.4. NOS Score by Certification Program over time (T1-T4)

IMPACT OF HISTORY AND PHILOSOPHY OF SCIENCE CLASSES

Table 5 shows Descriptive data for NOS score by Time of measurement and number of History and Philosophy of Science (HPS) classes. Within T1, the highest mean number of NOS mentions was 13.0 (SD=10.2) for teachers took more than one HPS class. The group means continue in descending order for teachers who took only one HPS class (6.91, S.D.=5.9), and those that took no HPS classes (6.0, S.D.=7.8). Across all groups in T1, the mean number of NOS mentions was 7.38 (S.D.=8.3).

TABLE 4.5.

NOS score by Number of History and Philosophy of Science classes

	Number of History & Philosophy of Science courses	Mean	Std. Deviation	N
NOS Score-T1	No HPS	6.00	7.842	41
	One HPS	6.91	5.924	11
	More than One HPS	13.00	10.237	11
	Total	7.38	8.315	63
NOS Score-T2	No HPS	7.66	7.952	41
	One HPS	4.09	4.908	11
	More than One HPS	15.36	20.086	11
	Total	8.38	11.046	63
NOS Score-T3	No HPS	6.15	6.002	41
	One HPS	5.00	3.521	11
	More than One HPS	10.36	9.479	11
	Total	6.68	6.545	63
NOS Score-T4	No HPS	7.22	5.850	41
	One HPS	4.91	3.780	11
	More than One HPS	9.27	9.655	11
	Total	7.17	6.412	63

For T2, teachers who took more than one HPS class continued to be the highest (15.36, S.D.=20), followed in descending order those that took no HPS classes (6.15, S.D.=6.0) and by teachers who took only one HPS class (4.09, S.D.=4.9). Across all groups in T2, the mean number of NOS mentions was 8.38 (S.D.=11). For T3, teachers who took more than one HPS class were highest (10.36, S.D.=9.5), followed in descending order by teachers who took no HPS classes (6.15, S.D.=6.0), and who took one HPS class (5.0, S.D.=3.5). Across all groups in T3 the mean number of NOS mentions was 6.68 (S.D.=6.5). For T4, teachers who took more than one HPS class remained highest (9.27, S.D.=9.7), followed in descending order by teachers who took no HPS classes (7.22, S.D.=5.9), and who took one HPS class (4.91, S.D.=3.8). Across all groups in the T4, the mean number of NOS mentions was 7.17 (S.D.=6.4).

An analysis of variance calculated on the data in Table 5 shows Huynh-feldt coefficients for the main effect of time to be not statistically significant (F=1.20, p=.311) and the interaction effect of time with the number of HPS classes is also not statistically significant (F=1.310, p=..259). In these cases, there is a recognizable pattern in the substance of the data that shows who had more that one HPS classes consistently higher than those that had one or none. However, interestingly, except for at T1 those teachers who had no HPS classes scored higher than those that had only one. There is an interesting pattern that arises for the groups when observed over time. Figure 5 shows the average score for each of the four groups over the four time periods measured. Similar to the results found within all the other analyses over the course of the three years of the study the mean scores of T1-T4 for all groups tended to converge.

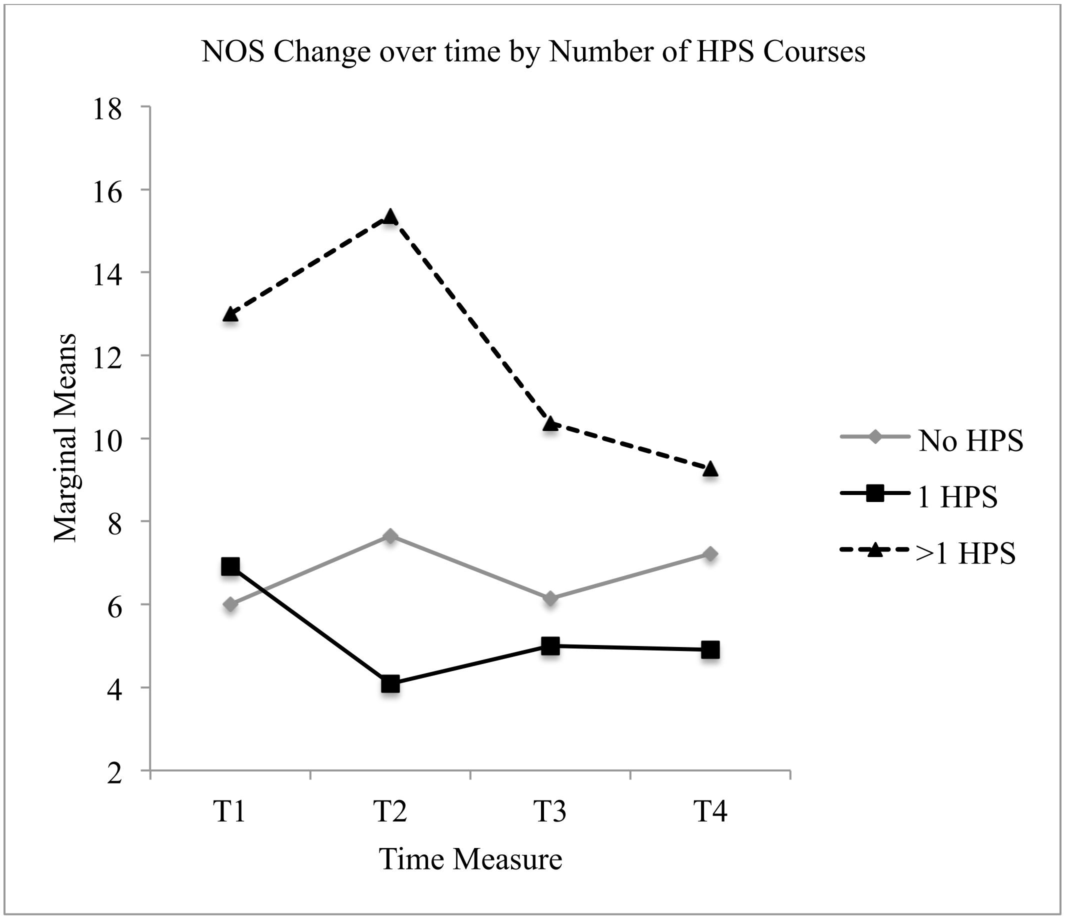

FIGURE 4.5: NOS Score by number of HPS classes over time (T1-T4)

IMPACT OF GENDER

Table 6 shows Descriptive data for NOS score by Time of measurement and number of Gender. Within T1, the higher mean number of NOS mentions was 9.56 (SD=8.9) for male teachers. Female teachers' mean score was (5.75, S.D.=7.5). Across both groups in T1, the mean number of NOS mentions was 7.38 (S.D.=8.3).

For T2, the mean number of NOS mentions was higher for female teachers (8.83, S.D.=12.3), than male teachers (7.78, S.D.=9.3. Across all groups in T2, the mean number of NOS mentions was 8.38 (S.D.=11). During T3, the mean for male teachers was again higher (7.04, S.D.=6.6) than female teachers (6.42, S.D.=6.6) Across all groups in T3 the mean number of NOS mentions was 6.68 (S.D.=6.5). For T4, male teachers continued to be higher (7.44, S.D.=7.6) than female teachers (6.97, 5.4). Across all groups in the T4, the mean number of NOS mentions was 7.17 (S.D.=6.4).

TABLE 4.6.

NOS score by Gender

	Gender	Mean	Std. Deviation	N
NOS Score-T1	Female	5.75	7.527	36
	Male	9.56	8.946	27
	Total	7.38	8.315	63
NOS Score-T2	Female	8.83	12.288	36
	Male	7.78	9.329	27
	Total	8.38	11.046	63
NOS Score-T3	Female	6.42	6.592	36
	Male	7.04	6.590	27
	Total	6.68	6.545	63
NOS Score-T4	Female	6.97	5.448	36
	Male	7.44	7.612	27
	Total	7.17	6.412	63

An analysis of variance calculated on the data in Table 5 shows Huynh-feldt coefficients for the main effect of time to be not statistically significant (F=.788, p=.49) and the interaction effect of time with gender is also not statistically significant (F=1.823, p=.259.151. There is an interesting pattern that arises for the groups when observed over time. Figure 6 shows the average score for both genders over the four time periods measured. Similar to the results found within all the other analyses over the course of the three years of the study the mean scores of T1-T4 for both males and females tends to converge over time.

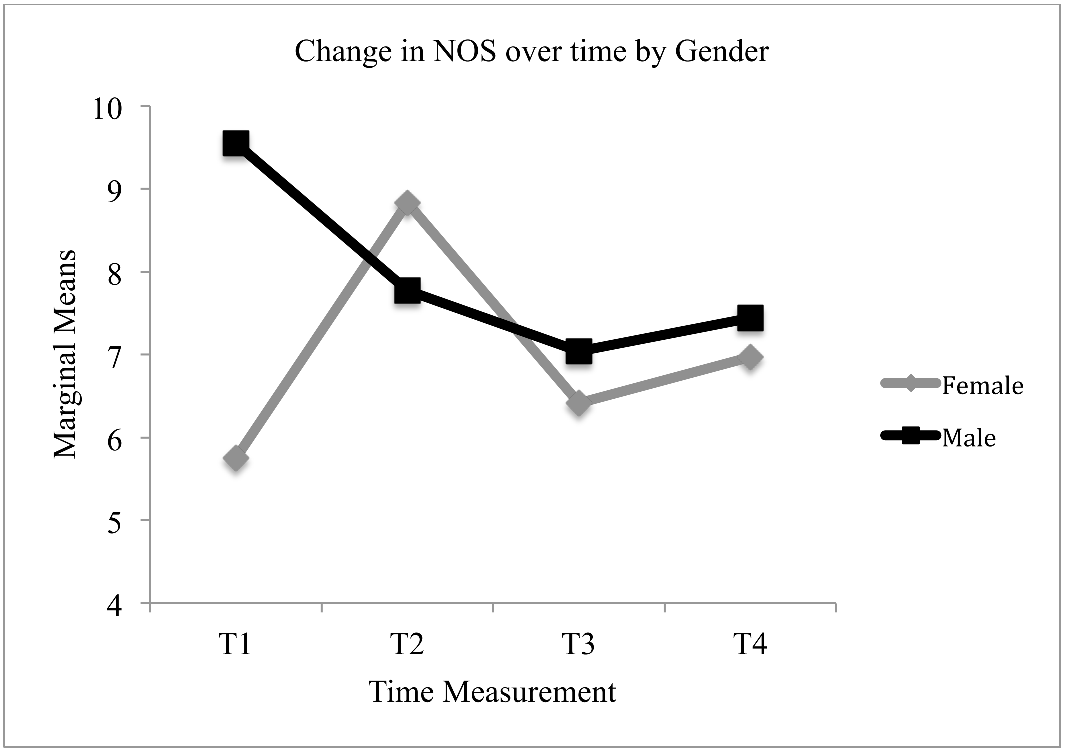

FIGURE 4.6: NOS Score by gender over time (T1-T4)

NOS CLASSIFICATION

Overall the majority population of the study was considered Naïve across the four measurements of NOS (see Figure 7). Only at T2 was there one teacher who would be considered having a Knowledgeable rating of NOS. This rating seemed to be an anomaly not only in terms of the other teachers' understanding of NOS, but also in regards to the individual who before and after T3 had a much lower score. There was some change over time, however, to a more Emerging category as the group as a whole converged to a more middle ground of understanding of NOS. At the same time there was a reduction in the number of teachers that would be considered Developing. These two factors combine to indicate that there was a process over time that moved the understanding of NOS amongst the population to a more homogenous area.

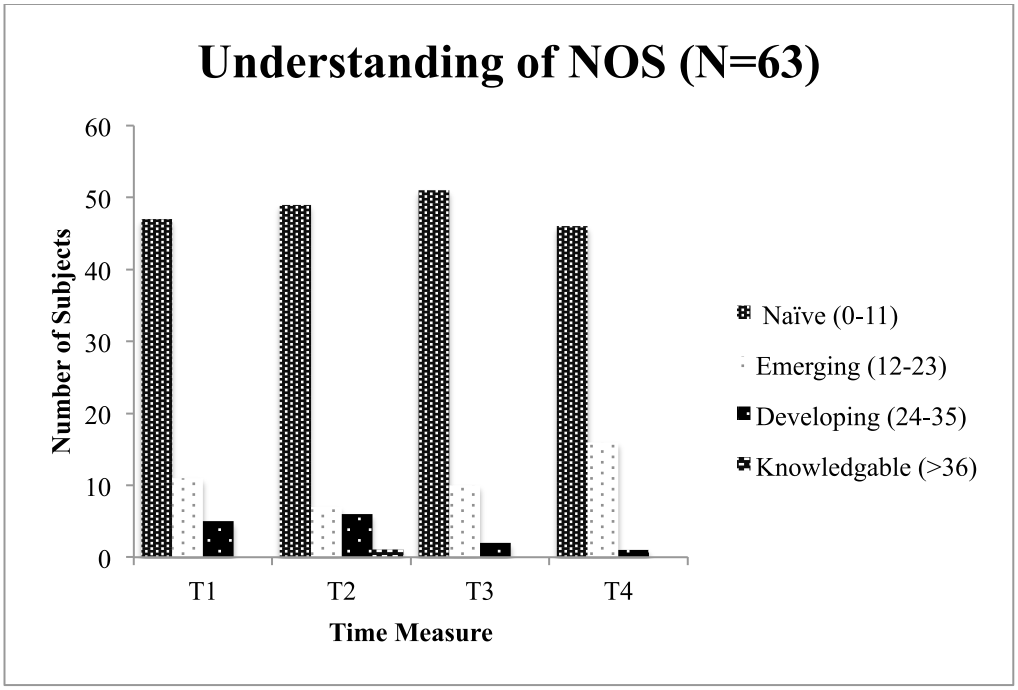

Figure 4.7: Understanding of NOS categories by time measurement (T1-T4)

INDIVIDUAL NOS FACETS OVER TIME ACROSS GROUPS

An examination of the individual Facets of NOS reveals that some facets remained constant over time while others resulted in the changes seen with in the other reported data (see Table 7). Specifically, Facet 1: Observations vs. Inferences remain low or non-existent across all T1-T4. The reason for this was that there were no questions directly related to that Facet contained within the semi-structured interview. Any references to Facet 1 were in response to questions that were not concerning Observations and Inferences and were, therefore, very rare. In contrast to this, the teachers referred to Facet 6 almost universally throughout T1-4. This was mainly the result of a question within the semi-structured interview that directly asked the teachers their opinion on this matter. Across the four round of interviews the highest average reference to the facet was T2.

The greatest increase in the number of positive references of facets concerned Facet 4 (Personal Bias). This Facet increased from an average response of 0.46 in T1 to 0.65 during T4. Facet 5 (Cultural Contexts) also increased from T1-T4, but to a lesser degree. Facets 2 (Laws and Theories) decreased somewhat over the course of the four measurements and was, overall, had the lowest reference rate of any Facet that was directly referred to the within the interview. Facet 3 (Creativity) decreased the most over time from 0.43 in T1 to 0.25 in T4.

Table 4.7.

Change in NOS Facets over Time

	Facet 1	Facet 2	Facet 3	Facet 4	Facet 5	Facet 6
Time Measurem ent	Observation & Inference	Laws and Theories	Creativity	Personal Bias	Cultural Contexts	Science Changes
T1	0.00	0.25	0.43	0.43	0.35	1.11
T2	0.02	0.27	0.40	0.56	0.38	1.22
T3	0.02	0.22	0.38	0.46	0.32	1.13
T4	0.00	0.21	0.25	0.65	0.40	1.13

SUMMARY

Overall the understanding of NOS converged between the beginning of the study and the end. Teachers across groups started from more widely spaced understanding of NOS and over time their understanding became more similar and often lower. Several factors were shown to affect the NOS score of the participants. The most profound effect was seen between teachers with a M.S. in science and a B.S. or B.A. In addition, the number of History and Philosophy of

Science classes also acted as a strong determining factor. This was seen especially between teachers who did not take any History and Philosophy of Science classes and those who took more than one. Content major, induction program, and degree certification program played lesser roles in the differences of NOS, while Gender did not have any overall effect.

Chapter 5

DISCUSSION AND IMPLICATIONS

This study set out to answer two questions regarding the understanding of NOS of beginning secondary science teachers:

1. What demographic factors influence how beginning secondary science teachers' understand the nature of science?
2. Do these factors contribute to significant change in beginning science teachers' understanding of the nature of science over time?

Using the analysis model discussed in chapter 3, I identified several demographic factors that influence how beginning secondary science teachers' initially understand NOS. However, the data also showed that the influence of these factors wanes over time. Within the first three years in the classroom, differences between groups of teachers based upon factors such as degree program, highest degree achieved, certification program, number of History and Philosophy of Science classes, type of induction program, and gender, diminished as the culture of school affected the teachers' understanding and beliefs about NOS.

Impact of Demographic Factors

Of the demographic factors studied, the most profound and significant effect on a teacher's understanding of NOS is created by the level of education attained and the content of the degree major completed prior to entering the classroom. This finding is important because it can be used to inform teacher educators on what qualities of a preservice program might be necessary in order to improve NOS amongst beginning secondary science teachers. Specifically, what qualities do programs such as M.S. degrees in science give to their students that are not found in students with other types of degrees?

In answer to this question, there are three factors to consider. First, M.S. students take different classes—usually with more science and quantitative emphases--than B.S. or B.A. students. There may be some quality to these classes that is absent in undergraduate classes that informs students in terms of NOS. Or there maybe some experience that M.S. students are more likely to be exposed to, such as reading scientific journals, engaging individually with research faculty, and conducting or assisting in science research, that B.S. or B.A. students do not engage in or engage in a more limited fashion. Second, the additional length of time that students are engaged in an M.S. program may also be a factor in their development of NOS. Typically, students with M.S. degrees have already earned a B.S. in the same field and this additional amount of time studying a particular aspect of science may be a factor in their development of NOS understanding. That is, the time provides for added exposure to faculty with potentially higher and more sophisticated levels of understanding that is passed along, as well as a longer period for the students themselves to become more comfortable with NOS. Finally, the science community itself may be a factor. The engagement in the above activities (more classes and working on research projects) plus working with faculty and other graduate students within a particular field may act to enculturate students into a more advanced understanding of NOS. This last point aligns well with Symbolic Interactionism (the theoretical framework of this study) in that the beginning teachers have developed their beliefs and understanding of

NOS in order to align with the academic community in which they were formerly involved.

Other demographic factors such as the number of History and Philosophy of Science classes seem to also have an effect, albeit a lesser one. In terms of the number of HPS classes, the difference lies not between taking one class versus taking no classes, but between taking multiple classes versus no classes. This also indicates that it is not necessarily the information that is imparted during a particular class, but the act of taking multiple classes and of working with the material over time that changes a teacher's views of NOS. This suggests, like the case of M.S. degrees versus B.S./B.A. degrees, that a determining factor may be the environment inside the HPS class and the reinforcement of NOS knowledge over time as much as the material itself that effects change.

In contrast to this, participation in preservice programs initially had the opposite effect than that of encouraging the development of NOS. Teachers who had not experienced a preservice program had much higher NOS scores than those that had participated. Specifically, the scores were much higher than those of students whose preservice program was part of their B.Ed. or who had gone through a Post-Baccalaureate program for their certification. In this case it seems that the experience of taking education classes through a certification program had the opposite effect on teachers' understanding of NOS.

Impact of Enculturation

Of equal importance is that the effect of particular demographic factors wane over time. The analysis of the data revealed that while there were initially large differences between groups on a variety of the demographic and other background scales, these differences diminished greatly over the course of the first three years in the classroom. All demographic factors (induction program, highest degree achieved, degree major, certification program, number of HPS classes, and gender) that originally showed large differences (and in some cases statistically significant differences) seem to converge over time. This finding is in alignment with the theoretical framework of Symbolic Interactionism. As the teachers leave their past educational and preservice experiences behind they transition from one community to another. This new community acts to enculturate the new teachers' into the standards and norms of the teaching profession. According to Symbolic Interactionism, while the teachers were working towards earning their college degrees they took on the behaviors, beliefs, and cultural knowledge of the communities in which they were involved. This is reflected in the variety of different NOS scores that different groups had initially prior to beginning teaching. As they spent more time as teachers in their schools and classrooms their beliefs and understandings about NOS (and probably about other aspects of education and science) changed to more reflect the norms of the school environment.

Symbolic Interactionism (Blumer. 1969) describes this process as both conscious, wherein the teachers actively modify their behavior in order to meet the explicit needs and expectations of their school, and unconscious, whereby the teachers subconsciously adapt their behavior to more reflect the implicit expectations and explicit actions of their new community. As Blumer (1969) argues, individuals seek to accommodate viewpoints and behaviors shared by others in their work group as a means of demonstrating belonging and commitment, and to locate their observable performance within the group definition of competence.

This convergence is significant in that it runs contrary to conclusions drawn from current literature about NOS. Specifically, Lederman (1999; 2007) maintains that nothing influences teachers' understanding of NOS except for direct instruction. If this were the case then the teachers in this study would not have started at a variety of different levels of understanding of NOS based upon their various demographic factors. All teachers, except for those that had received direct instruction of NOS, should have been indistinguishable from each other. Instead, several factors seemed to have a large effect upon teachers understanding of NOS. In addition, if the observations made by Lederman and others (Lederman, 1999; Lederman 2007; Akerson, Abd-El-Khalick, & Lederman, 2000; etc.) about direct instruction singular role in affecting on NOS were correct, there should have been no change over the duration of the study. However, during the three years of the study the teachers' understanding of NOS did change. Overall, the teachers started off with a much wider range of their conceptions of NOS. This range, over time, constricted as teachers' understanding of NOS seemed to become more homogenous due to factors that were not related to direct instruction of NOS.

Implications

The implications of this study on preservice teacher certification programs and induction support for new teachers are profound. In terms of preservice, the study demonstrates that there are significant experiences that new teachers bring with them prior to beginning teaching that effect their understanding of NOS. These experiences seem to stem from the type of science communities in which they were engaged prior to joining preservice certification programs. This runs counter to the prevailing notion (Lederman, 2007) that demographic aspects of preservice teachers have no impact upon their understanding of NOS.

This finding informs research into preservice teachers in two ways. First, it indicates that there are experiences that occur within certain types of non-educational degree programs that may enhance future teachers' understanding of NOS. At the same time there may be some aspects of preservice training that act to impede development of NOS. This impediment could stem from the type and number of classes or experiences that typically make up a preservice program. Or it could also be a result of enculturation into the roles expected of teachers in schools. By examining both non-education and preservice programs, future researchers might be able to glean what it is within each type of program that impacts teachers' understanding of NOS. This data could then be used to include aspects of the non-education and M.S. science programs that foster NOS understanding and reduce aspects from current preservice programs that act to limit NOS understanding.

Second, it indicates that there may be aspects of preservice programs that could both enhance and constrain understanding of NOS. There seems to be a clear relationship between taking multiple HPS classes and an increase in the understanding of NOS. In designing preservice certification programs for secondary science teachers, it seems clear that the more HPS classes that a teacher can be exposed to, the better their understanding of NOS. This aligns with arguments presented by Lederman (1999; 2007) that support the policy of direct instruction in NOS. However, as with all cases within this study, the effect of the number of HPS classes diminishes over time. Multiple HPS classes, advanced, degrees, and other previous experience is not enough to counteract the impact of the school environment. Other support in terms of ongoing professional development concerning NOS and induction programs that have a NOS component are needed to maintain the higher level of NOS fostered by particular previous experiences of beginning secondary science teachers.

In terms of induction program design, it seems that current induction designs are not sufficient to increase or even maintain teachers' understanding of NOS. Other recent research by Glazerman (2011) indicates that induction has no impact upon beginning teachers' beliefs or understanding of NOS. In terms of Symbolic Interactionism this makes sense. Typically, induction programs support teachers periodically throughout their first couple of years in the classroom. Teachers meet with mentors who, quite often, are not within the same science discipline, grade level, or are not even science teachers. Often teachers turn to other sources of support within their school such as the teacher next door (Luft, 2000). While well intentioned, induction programs support a model of teaching that is quickly overwhelmed by the omnipresent culture of the school in which beginning teachers find themselves. This local environment promotes different norms that are often at odds with the goals and agendas of more socially distant preservice and induction support. For example, although mentors may periodically emphasize the use of particular NOS principles in teaching, the inexperienced teacher may be more likely to structure class material in terms similar to that of experienced local teachers ("next door") who have gone through evaluations previously and presumably know what teacher behaviors are rewarded and respected. The pressure on a new teacher is both to teach effectively and to demonstrate that they understand the school environment and that they are capable of being a positive colleague. Rapidly, beginning teachers change in order to more align with these norms in the new environment in which they find themselves.

In order to fight this trend to adapt locally first, induction programs are going to have to change how they support teachers in terms of the amount and type of contact during the first couple of years in the classroom and the length of time in which they actively engage in support. Currently, induction programs are limited in the amount of time that they spend with teachers and do not often expose new teachers to more than one or two 'experts' in science teaching during their course. One solution may be to create a 'counter-community' of teachers that supports more desirable, in terms of NOS, practices, beliefs, and science teaching concepts for beginning teachers. This 'counter-community' would actively support beginning science teachers over the course of several years and would have its own set of norms, expectations, and ideals that would act to counter-balance the norms of the school environment that are detrimental to NOS understanding. In addition, by the creation of such a 'counter-community', beginning secondary science teachers could be exposed to a variety of different science teachers at various levels of experience and therefore be able to more readily identify with a community of teachers that is separate from the teachers that are local to their school.

Overall, this study emphasizes the need for further NOS research. Recently, there has been much discussion within the Science Education community as to whether the study of NOS is a valid and viable pursuit (Lederman, 2007). This discussion has centered on the argument that if nothing affects the understanding of NOS among science teachers, then we should not spend money and effort on research. In addition, if there is little to no transfer from a teachers understanding of NOS to the student then the level of NOS understanding of the teacher is immaterial. However, this study indicates that, at least, the first assumption is flawed. There does seem to be additional factors that affect NOS understanding. These factors may be identifiable and, therefore could be used to improve preservice, induction, and professional development programs that do not explicitly teach NOS, but may be able to improve NOS understanding. Finally, if the new assessment measure is able to identify changes in NOS understanding not seen before in teachers, then perhaps their students are changing their understanding of NOS in ways that heretofore have not been identified.

Future Directions of Research

This dissertation is drawn from a large NSF funded study that followed beginning secondary science teachers through their first five years of the study. In order to fully understand the trajectory that beginning teachers travel in terms of their understanding of NOS, further analysis could be done upon the fourth and fifth years of data that was collected. This additional analysis would help to further shed light on the effect of teacher demographics on their understanding of NOS and how their school, community, and experiences may further influence this understanding over time.

Along with this further analysis of teachers is an opportunity to continue to refine the new analysis technique that was created for this study. As referenced in Chapter 2, the majority of assessments of the NOS of preservice and working teachers involves small pools of subjects and is difficult to quantify in a meaningful manner. Within this study, I have been able to create a quick, more quantifiable assessment that can be used to more accurately compare individuals and groups of teachers with each other in terms of their overall understanding of NOS. The scale that was developed in order to describe various levels of NOS understanding is based upon the assumption that a single mention of each NOS facet within an interview was an indication of someone who was ‘knowledgeable’ in their understanding of NOS. While I consider this a sound basis to create categories for the modified VNOS-C used in this study and for this population of beginning secondary science teachers, additional calibration of this scale is necessary in order to more accurately link the facets of NOS to other semi-structured interviews and to different populations of teachers.

Further work on this scale will entail additional assessments of different populations across different demographic and teaching factors. This work will continue with the larger sample set of from the NSF funded study along with additional demographic factors that are available through the study. In addition, to this the scale will be used to assess different levels of teachers (elementary and middle school) as well as differing levels of students (elementary, middle, and college) in order to determine if the scale can be used more universally and if there is an affect on students' understanding of NOS in relation to other factors than direct NOS instruction.

Finally, the larger NSF funded study from which this dissertation is derived contains several other vectors that could be used to assess NOS knowledge and to assess the use and instruction of NOS within the classroom. Specifically, practice data from monthly lesson plans and interviews plus bimonthly observations could act to help answer questions of how teachers' conception of NOS may translate into practice. These interviews could also enlighten researchers as to other factors within the teaching community that may be affecting the individual teachers' understanding of NOS.

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APPENDIX A

MODIFIED VNOS-C SEMI-STRUCTURED INTERVIEW

NOS Questions

1a. How is the discipline of science represented in your teaching?

1b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction?

1c. You just talked about how the scientific method is done in your classroom, how is that related to how science is done outside the classroom?

Scientific Advancement

2. Can scientific knowledge change over time? If so, how does this happen? If not, why?

3a. What is the role of experimentation in science?

3b. What characterizes experiments in science?

3c. Are experiments necessary?

4a. What are the roles of theories and laws in science?

5a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? Would they have gone through the same processes to get those conclusions?

5b. If they disagree, what happens?