Teaching the nature of science: Practices and associated factors

Benjamin C. Herman

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Teaching the nature of science: Practices and associated factors

by

Benjamin C. Herman

A dissertation submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Education

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Iowa State University
Ames, Iowa
2010

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DEDICATION

To my parents Richard and Vicki, for the love you have given and teaching me core values and a hard work ethic.

To my brother Travas, who has always been there to be a guiding and reassuring figure in my life.

To my sister Shae, whose undying optimism reminds me to never give up.

And finally, to Cecil, for the much needed distractions from this work.

To you all, thank for the support and many laughs.
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ABSTRACT

This exploratory study investigated the extent and manner that former ISU-STEP students implemented the nature of science (NOS), and potential factors associated with their varying levels of NOS implementation. Thirteen teachers from the ISU-STEP participated in this study. All of the participants completed the nature of science in science education course at ISU, and were in at least in their second year of professional practice. A naturalistic inquiry approach was employed in this study and data sources included teaching observations, classroom artifacts, questionnaires, and interviews.

Evidence from this study indicates factors associated with teachers’ NOS implementation levels include their implementation of reform-based practices, self reflection abilities, considerations of how people learn, understanding of NOS teaching, perceived utility value for NOS teaching, level of responsibility to implement reform-based and NOS teaching practices, and coping strategies in response to teaching constraints. Furthermore, teachers who implemented the NOS at moderate or high levels interacted with one another forming a kind of informal support network which resulted in a higher level of responsibility to accurately and effectively teach the NOS.

Recommendations for pre and inservice science teacher professional development include: (1) ensuring sufficient opportunities to understand and reflect upon the NOS and effective NOS teaching through focused coursework and practical experiences; (2) facilitating the internalization of the importance and utility value of NOS instruction; (3) explicitly addressing how to effectively cope with teaching constrains; and (4) facilitating the development of support networks and co-generated responsibility to teach the NOS.
CHAPTER 1: INTRODUCTION

The Nature of Science in Science Education

The phrase “nature of science” (NOS) is commonly used in science education to describe the integration of philosophy, history, sociology, and psychology of science in order to understand the core values and assumptions found in the development of scientific knowledge (Lederman & Zeidler 1987, McComas et al., 1998). More specifically, people study the NOS to understand what science is, how it works, the epistemological and ontological foundations of science, how scientists interact socially, and the reciprocal role between science and society (Clong, 2006).

For more than a century, the science education literature has noted the importance of the NOS in science literacy. In 1907, the scientific method was thought to be synonymous with an understanding of the NOS (Central Association for Science and Mathematics Teachers, 1907; Abd-El-Khalick & Lederman, 2000). In the 1960’s and 1970’s an increased emphasis on NOS themes such as inquiry, science process skills, and characteristics of scientific knowledge (e.g. science as tentative, public, a human endeavor, empirical) emerged in the literature base (Abd-El-Khalick & Lederman, 2000).

More recently, science education reform documents have placed increasing importance on accurate and explicit NOS instruction in the classroom. Most notably, the National Science Education Standards (NSES, 1996) and Project 2061 (AAAS 1990; 1993) argued for increased emphasis on an overarching conceptual understanding of the NOS and scientific inquiry in science classrooms (McComas & Olson, 1998). Science teacher
organization’s positions statements, such as the National Science Teachers Association (NSTA, 2009a), also urge attention to effective NOS instruction in science classrooms. For example:

All those involved with science teaching and learning should have a common, accurate view of the nature of science. Science is characterized by the systematic gathering of information through various forms of direct and indirect observations and the testing of this information by methods including, but not limited to, experimentation. The principal product of science is knowledge in the form of naturalistic concepts and the laws and theories related to those concepts. (NSTA, 2009a)

These and other efforts are, in part, a reaction to the significant NOS misconceptions held by science teachers, their students, policymakers and the general public (Lederman, 1992; Abd-El-Khalick & Lederman, 2000; Clough, 2006; Rudolph, 2007). This deplorable situation exists because the way school science is almost universally taught conveys persistently mistaken images of the NOS, whether or not teachers consciously choose to explicitly address the NOS (Clough & Olson, 2004; Clough, 2006). This is so because as Clough (2006) noted:

Teachers’ language (Zeidler & Lederman, 1989; Lederman, 1986b; Benson, 1984; Dibbs, 1982), cookbook laboratory activities, textbooks that report the end products of science without addressing how the knowledge was developed, misuse of important words having special meaning in a science setting, and traditional assessment strategies are just some of the ways students develop conceptions about the NOS. Ever present in science content and science teaching are implicit and explicit messages regarding the NOS. (p. 464)

The pervasive calls for improving NOS teaching and learning reflect the many important outcomes that have been argued will follow from such efforts. These include:
• Deeper understanding of science concepts (DeBoer, 1991; Matthews, 1994; McComas et al., 1998).

• Diminished resistance to particular science ideas (e.g. biological evolution, age of the Earth, and global climate change) that many people reject due to misunderstandings about the NOS (Clough, 1994 & 2006; McComas et al. 1998; McComas, 2004; Rudolph, 2007).

• Understanding that the durable yet tentative nature of science lends to the ability to know and understand the natural world in more valid ways (McComas, 2004; Clough, 2006).

• Understanding why many science ideas are counter-intuitive and do not follow from observation through the realization of the underlying ontological and epistemological assumptions of science, and the reasons for idealizing the natural world. (Matthews, 1994; Clough 2006).

• Increased ability to distinguish scientific from pseudoscientific claims (Matthews, 1994), thus encouraging the proficiency in making decisions regarding issues of wellness, health, and life.

• Fostering the ability to navigate the developments and products of science, and understand science ideas and socioscientific issues that face society (Driver et al., 1996; McComas et al. 1998; Rudolph and Stewart, 1998; Zeidler et al., 2002; Clough and Olson, 2004; McComas, 2004; Narguizian, 2004; Sadler, 2004; Rudolph, 2007; Clough et al., 2008; Herman, 2009).
What has emerged is a clear, compelling, and forceful unifying message that accurately understanding the NOS is crucial for effective science teaching, deep science learning, and responsible citizenship. Despite this consensus, from the primary grades through post-secondary school the NOS is rarely addressed in an accurate and effective manner (Duschl, 1985; King, 1991; Abd-El-Khalick et al., 1998; Clough, 2006), and is often devalued by science teachers and parents (Lakin & Wellington, 1994). Often, teachers do not see the NOS as a cognitive objective (Abd-El-Khalick et al. 1998; Lederman, 1998) and are discouraged from implementing it in their curriculum because they perceive doing so will detract from time spent on teaching science content they see as more important (Lakin & Wellington, 1994; Abd-El-Khalick et al., 1998; Clough & Olson, 2001; Lederman, 2007). This combined with the fact that NOS instruction appears to conflict with parents’ and societies’ expectations of science and science education further discourages teachers from actively teaching the NOS (Lakin & Wellington, 1994).

Much has been written about attempts by science teacher educators to facilitate and account for the transition of a NOS understanding into teaching practice (Abd-El-Khalick et al., 1998; Lederman, 1999; Abd-El-Khalick & Lederman, 2000; Bell et al. 2000; Shwartz & Lederman, 2002; Lederman, 2007). Initial attempts focused on teachers’ NOS understanding as a primary factor that influences whether or not they explicitly teach the NOS to their students (Abd-El-Khalick & Lederman, 2000). Research has made clear that a teacher’s understanding of the NOS is a necessary, but insufficient condition for accurate and effective NOS instruction (Abd-El-Khalick & Lederman, 2000; Clough, 2006; Lederman, 2007).
More recent research has emphasized that a more complex network of synergetic factors may be responsible for facilitating or impeding the development of teachers’ NOS understanding and its transition into practice (Abd-El-Khalick et al., 1998; Lederman, 1999; Abd-El-Khalick & Lederman, 2000; Bell et al., 2000; Khishfe & Abd-El-Khalick, 2002; Shwartz & Lederman, 2002; Abd-El-Khalick & Akerson, 2004; Lederman, 2007). Furthermore, much has been written on how effective NOS instruction falls within the synergy of effective science teaching as a whole (Clough, 2006; Clough et al., 2009). Because of the interconnectedness of the many factors associated with learning and teaching science and the NOS, teacher education programs must take a more holistic approach to facilitating teachers to achieve reform-based practices including implementing the NOS effectively (Clough et al., 2009).

The Iowa State University Science Teacher Education Program

The Iowa State University Science Teacher Education Program (ISU-STEP) was created to prepare science teachers to teach in a manner congruent with science education reform documents (NRC, 1996; AAAS, 1990, 1993) and the best available education research (Clough et al., 2009). Preparing secondary science teachers who will accurately and effectively teach the NOS is one crucial objective of this program. This highly cohesive program consists of multiple science methods courses (three for undergraduates and four for graduate licensure students) and a required Nature of Science and Science Education course. These courses, which are coupled with extensive practical field experiences, are directed at preparing science teachers who will effectively teach science, including the nature of science
and scientific inquiry. Faculty in this program consistently model the teaching practices they expect from their students, and accurately and effectively teaching the NOS is a consistent theme throughout the science education portion of the program. The ISU-STEP science education faculty always strives to improve the program, and they are well aware that efforts to promote NOS teaching have largely been disappointing. Having created a program that emphasized the importance of teaching and learning the NOS, they sought evidence regarding the extent to which graduates of this program do consistently, accurately, and effectively teach the NOS.

**Study Purpose and Research Questions**

The study reported here followed graduates from the Iowa State University Science Teacher Education Program (ISU-STEP) to observe their NOS teaching practices and determine factors that influence those practices. Accurately understanding the NOS, how to effectively teach it, and valuing it as an educational outcome are all crucial if teachers are to promote a deep and accurate NOS understanding among their students (Abd-El-Khalick & Lederman, 2000; Clough, 2006). Investigating the relationship between teachers’ NOS implementation and situational factors (e.g. institutional constraints, classroom management), characteristics of pre-service programs, and teachers’ personal qualities (e.g. motivation, self efficacy, cognitive characteristics) has potential to move forward efforts to accomplish this important objective (Abd-El-Khalick & Lederman, 2000; Schwartz &Lederman, 2002; Abd-El-Khalick & Akerson, 2004).
This study is directed at three primary purposes. This first is to investigate the extent and characteristics of former ISU-STEP graduates’ NOS teaching practices. The second is to investigate factors associated with any observed variation in NOS teaching practices among ISU-STEP graduates. Determining these factors would address an important gap in NOS research (Abd-El-Khalick & Lederman, 2000). Understanding the NOS implementation practices of former ISU-STEP graduates and the factors that influence those practices will permit achieving the third purpose of this study, making recommendations to improve the ISU-STEP. Specific research questions for this study fall under the following two categories:

1. NOS teaching practices exhibited by ISU-STEP graduates:
   a. To what extent do teachers explicitly teach the NOS?
   b. To what extent do teachers accurately convey the NOS?
   c. To what extent do teachers contextually and decontextually teach the NOS?
   d. To what extent do teachers explicitly scaffold along the decontextualized to contextualized NOS instruction continuum?

2. Factors associated with varying levels of NOS instruction by ISU-STEP graduates.
   a. To what extent is an understanding of the NOS associated with teachers’ implementation of the NOS in instruction?
   b. To what extent are classroom teaching practices associated with teachers’ implementation of the NOS in instruction?
   c. To what extent are cognitive factors (understanding of NOS teaching, orders of consciousness, considerations of how people learn, self reflection abilities) associated with teachers’ implementation of the NOS in instruction?
   d. To what extent are motivational factors (self efficacy, utility value) associated with teachers’ implementation of the NOS in instruction?
   e. To what extent is the affective factor of interest in the NOS associated with teachers’ implementation of the NOS in instruction?
   f. To what extent are teaching constraints (classroom and institutional constraints) associated with teachers’ implementation of the NOS in instruction?
   g. To what extent are other factors associated with teachers’ implementation of the NOS?
Methodology

Using both quantitative and qualitative methods and a naturalistic inquiry approach, this study investigated thirteen former ISU-STEP students who had completed at least one year of professional teaching service. These teachers were purposefully sampled because they all completed crucial components of their science teacher education preparation in the ISU-STEP. Twelve of the thirteen participants completed their entire pre-service teacher education in the ISU-STEP, whereas the last completed critical components of their science teacher education including science methods courses and the NOS course.

Classroom observations were conducted and extensive instructional artifacts were collected to determine teachers’ NOS and inquiry instructional practices, and classroom contextual factors associated with those practices. Classroom observations were scored using the LSC Classroom Observation Protocol (Horizon Research Inc., 2006) with a NOS instruction category added. Instructional artifacts were evaluated for their NOS accuracy, explicit referral to the NOS, and level of NOS contextualization (Clough, 2006).

A questionnaire was completed by teachers to assess their NOS understanding and perceptions on teaching and factors they perceive that affect teaching. The NOS evaluative portion of the questionnaire was an extended version of the SUSSI (Liang et al., 2009). This questionnaire was used as a framework for interviews with teachers to ascertain factors associated with their varying levels of NOS implementation. Interviews were analyzed using open and axial coding (Strauss & Corbin, 1998) to determine cognitive, motivational, professional, and other factors associated with teachers NOS implementation practices.
Assumptions

In conducting this study, several assumptions were made. Twelve out of thirteen teachers studied completed all portions of the ISU-STEP. These teachers represent approximately 16% of all students who have graduated from the ISU-STEP since it was restructured in fall 2003 to include the multiple science methods courses and a NOS course. Furthermore, the remaining participant had completed crucial components of the ISU-STEP (e.g. NOS and Advanced Pedagogy courses) prior to this study. Therefore, any conclusions and recommendations assume that the sampled subjects are representative of all ISU-STEP graduates. Second, the several observations and extensive data collection are assumed to have no significant impact on teachers’ implementation levels of the NOS or interview/questionnaire responses. Finally, this study assumes that the triangulation methods employed in this study sufficiently ensured the validity of the collected data.

Limitations

This study focuses only on teachers’ implementation of the nature of science, and factors associated with varying levels of implementation. Investigating factors that may be associated to teachers’ implementation of the NOS such as subject area taught, grade level taught, school demographic characteristics, and numbers of years teaching are beyond the scope of this study.
Delimitations

This study investigated former students of the ISU-STEP after the program was restructured in 2003. This population consists of 5 females and 8 males that are beyond their first year of teaching, teach in Iowa, are pre-dominantly Caucasian and Midwest natives, and range in age from the mid-20’s to late 40’s. Conclusions may be extrapolated to similar populations of teachers in the Midwest. However, due to the extensive nature of the ISU-STEP’s focus on reform-based practices to include NOS teaching as compared to other teacher education programs, it is not representative of teacher education programs across the nation. Therefore, caution must be taken when attempting to extrapolate results to teacher programs other than the ISU-STEP.

Definitions

ISU-STEP- The science teacher education program at Iowa State University that resulted from extensive restructuring in 2003 to be more congruent with reform-based teaching (NRC, 1996; AAAS, 1990; 1993). ISU-STEP graduates complete several science methods courses (three for undergraduates and four for graduate students), the Nature of Science and Science Education course, general education course requirements, and possess at least an undergraduate degree in a science discipline.

Research-Based Framework (RBF) - An approach to teacher education that demands students integrate all components in their science education program into a coherent view of science learning, teaching, and teacher decision-making illustrated in Figure 1. (Clough et al., 2009)
Reform-Based Instruction - Approach to science teaching and learning consistent with that promoted in Project 2061 (AAAS, 1989 & 1993), the National Science Education Standards (NRC, 1996), and contemporary education research (Clough et al., 2009).

Motivational Factors - A compilation of factors including interest, perceived level of importance (utility value), personal goals, and one’s self-efficacy that together influence the level of success at task completion (Pintrich et al., 1993).

Cognitive Factors - Factors that account for the processing ability pertaining to a certain domains of knowledge. This includes the ability to accurately and deeply reflect on that domain of knowledge.

Orders of Consciousness - Constructive-developmental theory of development that focuses on an individual’s understanding of reality and the progression to more complex levels over time through experiences and conceptual growth. (Kegan 1985; 1992; Lahey et al., 1988)

Teaching Constraints - Factors that impede teachers’ implementation of reform-based teaching practices (e.g. administrators and colleagues, resistant students and parents, district policies, professional developmental requirements, time constraints, additional duties, and inadequate materials and resources) (Desimone, 2006).
Figure 1. Framework illustrating teacher decisions and their interactions.
CHAPTER 2: A REVIEW OF THE LITERATURE

The Nature of Science in Science Education

The nature of science (NOS) refers to what science is, how it works, the epistemological and ontological foundations of science, the general characteristics of scientists and how they interact, and the reciprocal impact between science and society (Lederman & Zeidler, 1987; McComas et al., 1998; Clough, 2003; Clough, 2006). The importance of the NOS in science education has been greatly stressed in recent reform documents (AAAS, 1990, 1993; NSES, 1996). To fully understand the NOS, knowledge from the disciplines of philosophy, history, sociology, and psychology of science are integrated (McComas, et al., 1998; McComas & Olson, 1998). For science educators, the importance of studying the NOS is to help them promote an accurate portrayal of science.

Historical Summary of the NOS in Science Education

Implicit evidence of the NOS in science education can be found in literature that is well over 200 years old. In the following example that clearly articulates how theory precedes observation, the role of prior knowledge in accounting for the natural world, and how scientific thinking must disregard supernatural explanations, Rousseau (1762, p. 173) explains how he primed his student to develop a naturalistic explanation.

One day we go to the fair; a magician attracts a wax duck floating in a tub of water with a piece of bread. Although we are quite surprised, we nevertheless do not say “He is a sorcerer,” for we do not know what a sorcerer is. Constantly struck by effects whose causes we do not know, we are in no hurry to make any judgments, and we remain at rest in our ignorance until we happen to find the occasion to escape it.
Rousseau then proceeds to explain how he scaffolds his student to test this phenomenon through using a magnet in a wax duck under similar conditions. Clearly, Rousseau emphasized in *Emile* how to teach the sciences in a manner that does not emphasize the knowledge of scientific facts, but the importance of having students develop a way of understanding the natural world through scientific thinking.

Approximately 150 years later, literature more explicitly emphasized the role and importance of the NOS in science education. In 1907, an understanding the scientific method was seen as synonymous with an understanding of the NOS (Central Association for Science and Mathematics Teachers, 1907; Abd-El-Khalick & Lederman, 2000). Nine years later, Dewey (1916) presented an argument that understanding scientific method was more important than the acquisition of scientific fact (Dewey, 1916; Hodson, 1991; McComas et al., 1998). Dewey advocated that education should prepare children not for a pre-set of situations through a recipe check list curriculum, but for them to be self-sufficient through their own judgment to problem solve under the conditions they may find themselves in (Dewey, 1897; 1916). This position is evident through his view that education should be the “reconstructing or reorganizing of experience which adds to the meaning of experience, and which increases the ability to direct the course of subsequent experience…..No one can carry around with him a museum of all the things whose properties will assist the conduct of thought.”(Dewey, 1916, pp. 77, 157).

Through the mid-1900’s the importance of addressing the NOS in science education became more apparent. Eventually, the National Society for the Study of Education explicitly emphasized students should understand not only scientific knowledge, but also the
nature of the scientific enterprise (Hurd, 1960). Seemingly, this work placed understanding the NOS on an equal footing with understanding science content as evident through the following quote:

There are two major aims of science-teaching; one is knowledge, and the other is enterprise. (Hurd, 1960, p.34)

Significant transitions occurred during the 1960’s through the 1980’s in understanding what science is and how it works. Much of this change in thinking reflected movements in the areas of philosophy, sociology, and history of science, influenced by Kuhn’s (1962) *Structure of Scientific Revolutions* (Giere, 1998; Abd-El-Khalick & Lederman, 2000). Abd-El-Khalick & Lederman (2000) explain that prior to Kuhn’s highly influential book, logical empiricists disregarded descriptive explanations of how science works in favor of justifications for science claims. Because of this, psychological and sociological foundations were not included in the epistemological foundations of science.

With the publication of Kuhn’s (1962) *Structure of Scientific Revolutions*, historians and philosophers of science began to integrate psychological and socio-cultural elements into describing the way science works. Soon thereafter, Herron (1969) pointed out no set and distinct articulation of the NOS exists. This was followed by efforts during the 70’s and 80’s that attempted to characterize how science works through sociological explanations. As Abd-El-Khalick & Lederman (2000 p. 667) explain, the “[H]allmark of post-Kuhnian philosophy of science was a preoccupation with reconciling accounts of science with ‘actual’ scientific practice.” Collectively, the efforts during this period encouraged the placing of science within cultural and social contexts.
During this time frame, scientific knowledge became viewed as public, tentative, dynamic, probabilistic, based in history, empirical, holistic and internally consistent, and a human endeavor (Abd-El-Khalick & Lederman, 2000; The Center of Unified Science Education at Ohio State University, 1974). Subsequently, psychological considerations played a great role in the science education community’s view of the NOS in the 1980’s (Abd-El-Khalick & Lederman, 2000).

Currently, the importance of the NOS in science education has been clearly articulated for science teaching practitioners. Reform documents have placed an ever increasing importance on the presence of accurate and explicit NOS instruction in the science classroom. Most notable of these are the National Science Education Standards (NSES, 1996) and Project 2061 (AAAS, 1990; 1993) which call for increased emphasis on an overarching conceptual understanding of the NOS and scientific inquiry in classrooms, and a reduction in “mile wide and inch deep instruction”. Positions statements of leading science education organizations such as the National Science Teachers Association (NSTA, 2009a) reflect reform documents’ calls for an increase in effective NOS instruction in science classrooms. For example:

All those involved with science teaching and learning should have a common, accurate view of the nature of science. Science is characterized by the systematic gathering of information through various forms of direct and indirect observations and the testing of this information by methods including, but not limited to, experimentation. The principal product of science is knowledge in the form of naturalistic concepts and the laws and theories related to those concepts. (NSTA, 2009b)
Consensus Views of the NOS in Science Education

Because the NOS draws from many highly specialized fields of study and is influenced by historical and disciplinary contexts, science educators continue to discuss what NOS themes all students should learn in K-12 science classrooms (Matthews, 1994; Smith et al., 1997; McComas et al., 1998; Clough, 2007). Additionally, debate has occurred pertaining to the extent those views reflect the ones held by contemporary philosophers of science. In the mid to late 1990s, a consensus regarding NOS ideas appropriate to teach K-12 students appeared to emerge. These have come in various forms, but do appear to coalesce among a few key NOS ideas. The most popular list is the seven NOS tenets presented by Abd-El-Khalick et al., (1998). The first five are characteristics of science and include science is: (1) tentative; (2) empirically based; (3) subjective; (4) steeped in imagination, human inference, and creativity; and (5) socially and culturally embedded. The last two aspects address (6) differences between observations and inferences and (7) the relationship between scientific data and theories. McComas & Olson (1998) presented fourteen tenets from an analysis of international science education standards and documents. Eflin et al. (1999) presented appropriate K-12 NOS tenets as: (1) the main purpose of science is to acquire knowledge of the physical world; (2) an underlying order exists in the natural world that science attempts to understand and describe in the simplest means possible; (3) science is tentative and ever changing; and (4) no single scientific method exists.

Not all science educators are in agreement with these tenets. Alters (1997) attempted to study whether current philosophers of science agreed with the fundamental tenets of science put forth by science educators. Alters noted that philosophers of science held varying
positions regarding fundamental aspects of the NOS. Because of this, Alters claimed a set philosophical base for the NOS in science education did not exist and recommended a reconsideration of the basic tenets of the NOS established by science educators.

Smith et al. (1997) directly criticized Alters’ (1997) study on several grounds. They argued that design flaws in Alters’ study wrongly resulted in the appearance that philosophers of science disagree with the NOS tenets more than they actually do. They also pointed out that the very nature of philosophical discourse is to argue important, yet subtle, points. Therefore, one could intuitively predict there would be dissidence between the positions taken by professional philosophers of science and science educators about the NOS tenets.

Philosophers of science continue to debate important nuances surrounding the NOS, yet, for the most part, these issues are inappropriate for inclusion in K-12 science classrooms (Eflin et al., 1999). Furthermore, a generally agreed upon consensus between philosophers of science and science educators of K-12 appropriate NOS tenets had existed at the time of Alter’s (1997) study and continues to this day (Matthews, 1994; Smith et al., 1997; Abd El Kalick et al., 1998; McComas & Olson, 1998; McComas, et al., 1998; Eflin et al., 1999; Clough, 2006; Clough, 2007). For example, Abd-El-Khalick et al., (1998, p. 418) states:

The disagreements that continue to exist among philosophers, historians, and science educators are far too abstract for K-12 students to understand and far too esoteric to be of immediate consequence to their daily lives. . . There is, however, an acceptable level of generality regarding the NOS that is accessible to K-12 students and also relevant to their daily lives. At this level of generality we can see clear connections between students’/citizens’ knowledge about science and decisions made regarding scientific claims. Also, at this level of generality, virtually no disagreement exists among historians, philosophers, and science educators.
However, disagreement with the often-cited NOS tenets is not simply a matter of their content. Clough (2007) acknowledged that some NOS ideas are to a great extent uncontroversial, but reframing tenets as questions would better address the contextual nature of the NOS, and promote more effective teaching of the NOS. His rational was tenets presented as statements may give the wrong impression that characteristics of the NOS are distinct and simply a list to be transmitted and memorized. By viewing tenets as questions, researchers, teachers, and students can more accurately understand NOS ideas. This is because they are forced to wrestle with deeper conceptual considerations (such as how NOS ideas are interrelated or how science is durable even though it is tentative) inherent to philosophical NOS ideas. Clough’s (2007) position of how to consider NOS ideas is shared by Eflin et al. (1999, p. 112):

Just as science educators stress that science is more than a collection of facts, we emphasize that a philosophical position about the nature of science is more than a list of tenets.

Undeniably, in order to effectively teach the NOS, science teachers’ understanding of the NOS must go well beyond a trite acknowledgement of the agreed upon tenets. Clough (2006) noted that:

[T]eachers must understand and notice [NOS] issues entangled in science content and its development, and then effectively incorporate [those] with content instruction. (pp. 487-488)

**Rationales for Including the NOS in Science Education**

Significant justifications for emphasizing the NOS in science classrooms exist in current literature. These include justifications immediate to and transcending students’ classroom experiences. These justifications are presented below.
Teachers’ and Students’ Misconceptions

The most obvious justification for accurately, explicitly, and reflectively teaching the NOS is the wealth of inaccurate and simplistic views students and teachers hold about the NOS. These misconceptions include the following (Behnke, 1950; Carey & Stauss, 1968; Broadhurst, 1970; Carey & Stauss, 1970; Mackay, 1971; Aikenhead, 1973; Rubba, 1977; Rubba et al., 1981; Lederman & O’Mally, 1990; Tamir & Zohar, 1991; Aikenhead & Ryan, 1992; Lederman, 1992; Abd-El-Khalick & Lederman, 2000; Clough, 2006): (1) science can be based on the assumption of an interfering supernatural explanation; (2) science ideas are simply discovered and not acknowledging the inventive side of knowledge generation; (3) science models are exact copies of reality; (4) a set scientific method exists; (5) observation precedes theory; (6) science ideas progress in validity from hypothesis to theory to law; (7) science ideas when well tested can be proven; (8) science ideas are unchanging; (9) science when well done is objective with no influence from individual or cultural biases; (10) science is a collection of facts and not a process of knowledge seeking; (11) science and technology are the same or science exists solely to serve technology. Without a fundamental understanding of the NOS these misconceptions will persist among students and citizens.

The Perpetual Teaching of the NOS

The very manner that teachers structure their courses and teach science content conveys an image of the NOS, whether or not they consciously intend to do so (Clough & Olson, 2004; Clough, 2006). Instructional practices, cookbook labs and activities, assignments and assessments (Clough, 2006), teachers use of language (Dibbs, 1982;
Lederman, 1986; Zeidler & Lederman, 1989), and chosen content constantly send implicit and explicit messages about the NOS. Often these convey teachers’ NOS misconceptions to their students (Dibbs, 1982). However, even teachers who themselves have a more accurate NOS understanding may easily convey inaccurate views through their instructional practices unless they vigilantly reflect on what they are communicating about the NOS. Thus, given that the NOS is conveyed in science education regardless of intent, an obligation exists to accurately portray the NOS.

**Encouraging Students to Engage in and Understand Science Ideas**

Tobias (1990) as presented in McComas et al. (1998, p. 13) “[M]aintains a number of potential university science students-those they call the second tier-lament that science classes ignore the historical, philosophical, and sociological foundations of science.”

Through becoming informed of the social, creative, imaginative, and human nature of science, student interest in the sciences may be peaked because they no longer see science as a “sterile” endeavor (Clough, 2009). Intuitively, this higher mental engagement in science would logically lead to a better understanding of science content. Additionally, students may be persuaded to pursue further study in the sciences (McComas et al., 1998; Clough, 2009).

Research conducted by Clough et al., (2010) supports the contention that student interest in the science can be garnered through teaching the history and nature of science. In this study, undergraduate biology majors’ introductory biology course was augmented with five historical science short stories (available at [http://www.storybehindthescience.org](http://www.storybehindthescience.org)) that focused on the development of important science ideas (e.g. age of the earth, Darwin’s theory of natural selection, and Mendel’s ideas on heredity). These stories and the questions within
them explicitly address important NOS ideas (e.g. imagination, creativity, collaboration in science). After completing the story set students demonstrated a significantly increased understanding of the NOS. Additionally, all students (N = 85) reported these stories increased their interest and understanding of the content they were learning in their biology course.

Beyond increasing interest in science, teaching the NOS helps students become open to learning science ideas they mistakenly think conflict with their religious beliefs (Clough, 1994 & 2006; McComas et al., 1998; McComas, 2004). For instance, students should come to understand science is limited to accounting for the natural world through methodological naturalism. Methodological naturalism refers to the guiding epistemological principle in a scientific approach to understanding the natural world, that is, within the context of scientific inquiry, scientists are obligated to explain all phenomena and events through naturalistic causes and events (Forrest, 2000). Through students understanding this important concept they may become more open to ideas they may have previously perceived as conflicting with their supernatural belief systems.

McComas et al. (1998) note that when science is wrongly seen as an immutable set of facts, and when a previously accepted fact comes into question, students are apt to wrongly question all that is associated with that fact under scrutiny. Furthermore, science ideas are often counterintuitive, and if students do not come to understand why that is the case, they may acknowledge those ideas in school science, but reject them outside of that context (Wolpert, 1992; Matthews, 1994; Clough, 2009). Deeply understanding why scientific knowledge appears counter-intuitive with our everyday experience demands, at least in part,
understanding the rationale behind many science ideas being dependent upon unobtainable idealizations of phenomena (Matthews, 1994; Clough, 2009). Understanding the underlying ontological and epistemological assumptions of science, and the reasons for idealizing the natural world, students will better understand science ideas that are clearly counter to everyday observation (Matthews, 1994; Clough, 2006; 2009). Through teaching these NOS themes, students will more deeply understand scientific knowledge, and that when scientific knowledge changes, it does so for good reasons.

**Students’ Participation in a Democratic Society**

Dewey’s works addressing subjects such as society, philosophy, and education had science as the central theme which is illustrated through Dewey’s quote “ultimately and philosophically science is the organ of general social progress.” (Dewey, 1916, p. 230). Dewey, also claims education through experiences provides the renewal of social group and the “social continuity of life” (Dewey, 1916, p. 2). Thus, through Dewey’s writings, one can infer that social progress is dependent upon students receiving an effective science education that includes the NOS. Reflecting Dewey’s thinking, much has been recently written on the role of the NOS in facilitating students’ understanding how to navigate and solve issues in society related to science. Several important rationales exist why students must possess a deep understanding of the NOS that transcends from classroom into society. Included in this list is the NOS facilitates people and the public to:

1. Demarcate the difference between science and pseudoscience (Matthews, 1994).
2. Conceptualize the science and navigate technology they encounter in their lives (Ryan & Aikenhead, 1992; Driver et al., 1996).

3. Understand how science plays a major role in contemporary culture (Driver et al., 1996).

4. Understand and make decisions pertaining to socio-scientific issues (Driver et al., 1996; McComas et al., 1998; Zeidler et al., 2002; Sadler, 2004; Rudolph, 2007).

Matthews (1994) describes the role of rationality as a central focus in the philosophy of science that must be present in science education. Matthews (1994, p. 93) defines rationality in science to be:

A sphere of rational inquiry and rational appraisal of competing beliefs; and that where there are departures from rational thinking in science, such departures are criticized as regrettable aberrations.

Matthews proceeds to describe the important role of rational thought in science teaching that could, if effectively addressed when teaching science, transfer beyond the science classroom and schooling to everyday situations in life.

Rudolph (2007) specifically discusses how the general public wrongly thinks that good science derives exclusively from controlled experiments, and valid scientific conclusions are those that are “proven”. This narrow view of the nature of science results in well-supported fundamental science ideas (e.g. the age of Earth, biological evolution, global climate change, astronomy) being cast aside because they rely on methodologies that go beyond repeatable control-treatment experiments. Sadly, this ignorance of the way science
works has been used by special interest groups, politicians, and corporations to cast doubt about these well supported ideas so that these group’s economic, social, and personal interests may be preserved. For example in the case of global climate change Rudolph (2007, p. 2) states:

The situation with global warming is a telling case in point. Given that the majority of the public hold an oversimplified view of science—as an activity that is capable of producing verifiable knowledge by means of a carefully prescribed experimental method—it’s not surprising that those who seek to undermine public faith in the claims made by climatologists have highlighted the uncertainties in their work. This is a not-so-subtle way of implying that scientists have yet to hit the nail on the head with respect to global warming, with the upshot being that, since definitive evidence hasn’t been found to link human activity to global temperature increases, then we really don’t know for sure what’s going on, and, they argue with a wink, it clearly wouldn’t be prudent to take any rash actions at this point—certainly not any that might put a cramp in American economic growth or corporate profits.

Rudolph recommends that a proper science education would make clear that many valid methods in science exist and are utilized to construct valid knowledge of the natural world. Without this approach to science education he warns society is sure to face “grave consequences” in the future.

Effective NOS Instruction

Clough et al. (2009) argued that effective reform-based science teaching is highly complex, and demands attention to many synergistic decisions in a holistic fashion. They put forth and elaborated upon a teacher decision-making framework (Figure 1) that must simultaneously be based on desired science education goals for students and how people learn. They noted that the science education goals for students are interactive and
complimentary in nature. Therefore, achieving a deep understanding of science content and the NOS demands significant concomitant attention to all other goals as well.

As noted previously, reform documents and science education literature stress it is crucial for teachers to promote the goal of students developing a deep and robust understanding of the NOS. If Clough et al. (2009) are correct in their assertion that the promotion of this goal is intertwined with others, then a solid foundation of reform-based practices may be a necessary condition for effective NOS instruction. Clough (2006, p. 465) articulates this very point when he stated, “Planning and implementing effective lessons are complex acts, and this applies equally to traditional science content as well as accurately conveying the NOS.” Similarly, Khishfe & Abd-El-Khalick (2002, p. 573) articulate “attempts to teach about NOS should be contextualized and woven into inquiry activities and teaching about science content and process skills”.

Despite the many NOS ideas worth teaching in science education, and the many science disciplines in which such instruction should take place, several general recommendations have been put forward for effective NOS instruction. For instance, research supports that to be effective, the NOS must be an explicit objective in a lesson and be taught explicitly and in a manner that requires students to reflect upon identified NOS ideas (Ackerson et. al., 2000; Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2006). Additionally, Clough (2006) noted the context in which NOS instruction takes place is crucial and argued for extensive scaffolding between a variety of NOS experiences. These recommendations will be addressed in the preceding paragraphs.
Implicit vs. Explicit/Reflective NOS Instruction

Many times, teachers will either overlook the importance of NOS instruction and/or believe students will inherently pick up implicit NOS messages through inquiry activities or readings (Abd-El-Khalick et al., 1998; Bell et al., 2000; Clough, 2006). Although this is the case, extensive science education literature condemns this approach of teachers letting students “figure the NOS out for themselves” through classroom experiences (Lederman, 1992; Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Clough, 2006). This is because throughout their lives students have been bombarded with inaccurate portrayals of the NOS that have, over time, resulted in their developing deeply held, yet mistaken views of the NOS. Therefore, implicit NOS instruction has been shown to be insufficient to facilitate conceptual change toward more accurate views of the NOS (Khishfe & Abd-El-Khalick, 2002; Clough, 2006).

Recent literature has advocated a proactive explicit/reflective approach must be undertaken in science classrooms to help students achieve an accurate understanding of the NOS. In regards to being explicit, literature states teachers must plan in advance to design lessons so students may be directly attended to NOS themes. Of course, in light of Matthews (1994) recommendations, effective explicit NOS instruction should not be an indoctrination of the teacher’s ideology of the NOS. Instead, NOS instruction should be a consequence of sufficient planning before lessons and also recognizing opportunities to address key NOS ideas as they unfold in the classroom.

The second component of effective NOS instruction requires teachers facilitate their students to reflect on NOS ideas that have been explicitly identified. This involves effective
pedagogical practices such as asking engaging questions, requiring journaling, student discussion, or other activities that force students to deeply wrestle with identified NOS themes. By requiring students to reflect on NOS issues in this manner they are better able to make connections between their classroom activities and the way science works (Clough, 2006).

Empirical research supports an explicit/reflective approach is more effective in promoting gains in students’ understanding of NOS themes (Akerson et al., 2000; Khishfe & Lederman, 2006) than an implicit approach (Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002). Khishfe & Abd-El-Khalick (2002) conducted a study investigating the impact of implicit-inquiry oriented vs. explicit reflective approaches on two groups of sixth graders’ conceptualizations of the NOS. In this study both groups completed the same inquiry based activities under the same conditions (e.g. time, materials). However, the explicit/reflective group was required to engage in explicit guided discussions on predetermined NOS themes (e.g. tentative, empirical, inferential, and imaginative and creative aspects of NOS) inherent in the activities. The other group did not engage in discussions on the NOS themes present in the inquiry based activities. At the conclusion of this study, students in the explicit/reflective group significantly improved their understanding in regards to all of the NOS themes. In fact, 31 to 46 percent more students achieved an informed understanding of these NOS themes. Conversely, students in the implicit-inquiry group did not improve their understanding of these NOS ideas.

The findings of this study are congruent with several others preceding it. Abd-El-Khalick & Lederman (2000) presented in their review nine studies in which gains in NOS
understanding were achieved through explicit approaches. One of the studies took a qualitative approach whereas the others a quantitative approach using paper and pencil instruments to measure NOS understanding. In all eight quantitative studies statistically significant gains were realized in participants’ understanding of the NOS. More specifically, NOS understanding of participants increased between 3 and 11% as measured by NOS instruments such as the Wisconsin Inventory of Science Process (WISP), Nature of Science Scale (NOSS), Test on Understanding Science (TOUS), and Nature of Science Test (NOST). Important to note, Abd-El-Khalick & Lederman (2000) indicated the practicality of these results may be subject to speculation given the small gains in percentages, thus weakening the claim explicit instruction impacts NOS understanding. Although this is the case, four additional studies were described in their review employing implicit approaches, but showed no significant change in participants’ understanding of the NOS using the same instruments.

**Decontextualized to Highly Contextualized Continuum**

Clough (2006) noted the NOS should be taught outside and within the context of scientific inquiry, science ideas, and historical accounts for science. Support for contextualizing the NOS within science instruction is evident in several studies (Driver *et al.*, 1996; Ryder *et al.*, 1999; and Brickhouse *et al.*, 2000). Khishfe and Abd-El-Khalick (2002) reported that sixth graders’ ability to discuss the NOS was different depending on the content and context in which the NOS was discussed. More specifically, the students in this study were able to make sense of targeted NOS concepts when they were presented in more concrete, relevant, and interesting science contexts. Consequently, Khishfe & Abd-El-Khalick (2002, p. 573) provided the following recommendation: “It is the researchers’ belief
that attempts to teach about NOS should be contextualized and woven into inquiry activities and teaching about science content and process skills.” Conclusively, the NOS understanding students develop partially depends on the science content that frames the NOS discussion.

Clough (2006) builds on researchers’ prior recommendations and emphasizes NOS instruction should be explicit/reflective and also range from decontextualized to moderately and highly contextualized with extensive scaffolds back and forth along this continuum. Decontextualized activities attend students to the nature of science in a concrete fashion in the absence of science content. These activities are traditionally thought of as “black box” and puzzle solving activities often found in science education literature (Clough, 1997; Clough & Olson, 2001; Lederman & Abd-El-Khalick, 1998). Decontextualized activities are extremely important from a conceptual change standpoint as they provide opportunities for teachers to confront and initiate students’ dissatisfaction with their misconceptions of the NOS. Additionally, they provide an excellent scaffolding point into more abstract NOS ideas that may be intertwined within science content.

Because decontextualized NOS activities are largely absent of science content, they alone are not sufficient for students to develop a proficient scientific literacy. (Clough & Olson, 2001; Clough, 2006). Additionally, if exclusively used to portray the NOS in science classrooms, students will likely note that such activities are not science. Therefore, students will probably disregard these activities simply as “puzzle solving” if they are not augmented with NOS experiences that are more contextualized within science content.

Moderately contextualized NOS instruction is reflective of that presented in studies such as Khishfe & Abd-El-Khalick (2002) where students are explicitly and reflectively
taught the NOS in the context of inquiry and science ideas. These types of activities are important for directly facilitating students to consider how their classroom experiences are like science.

Much like decontextualized lessons, Clough (2006) points out that moderately contextualized NOS experiences alone are insufficient to fully facilitate conceptual change away from NOS misconceptions to fully accurate ones. He writes:

This is made evident in efforts to persuade students how decontextualized and moderately decontextualized NOS activities are like doing science. This suggests that the activities may easily create two conceptions of the NOS – that illustrated by these sorts of activities and an alternate view associated with their perceptions of authentic science. (p. 473)

Often, students are able to compartmentalize these activities as something that is “like doing science” yet still hold on to their erroneous views of how the scientific enterprise works. Consequently, they may carry dual notions of the nature of science-that which is associated with the activities they completed in classroom and a different view of the NOS associated with the scientific enterprise.

In addition to decontextualized and moderately contextualized activities, teachers must explicitly and reflectively teach the NOS through highly contextualized examples. Through explicit/reflective highly contextualized NOS instruction teachers can overtly draw students’ attention to the NOS through a focus on how the science ideas presented in classroom content were developed. By instructing in this manner the NOS and science content are intertwined, seamless, and complimentary. This reduces students’ abilities to see the NOS as something divorced from science content. More importantly, dismissing those NOS ideas as not reflecting authentic science is far more difficult.
Clough (2006) recommends teachers explicitly require students to reflectively link decontextualized and moderately contextualized NOS experiences with highly contextualized NOS examples. For instance, decontextualized activities such as the tube lab outlined in Lederman and Abd-El-Khalick (1998) can be reintroduced when students are completing moderately contextualized lessons on evolution through the teacher asking questions such as “What are some reasons why we did not use supernatural explanations to account for what was inside the tube? What are some reasons why we don’t use supernatural explanations to account for the adaptations these organisms exhibit?” Teachers can then effectively scaffold those NOS ideas into highly contextualized NOS instruction of Darwin, his ideas, and the use of naturalistic explanations. Additionally, teachers can scaffold from this example of highly contextualized NOS instruction back to less contextualized experiences by asking: “In what ways did your curiosity of the mechanisms behind the way the tube worked compare to the curiosity Darwin had with the mechanisms behind adaptations in species?”

Recent research has indicated explicit/reflective highly contextualized NOS instruction significantly improved post-secondary students’ conceptions of the NOS and attitudes toward science (Clough, et al., 2010). In this study, five historical stories addressing fundamental biology ideas were implemented in an introductory biology major’s course. In each story, comments and questions appear that explicitly draw readers’ attention to important NOS ideas. After completing the story set students demonstrated an increased understanding of scientific laws compared to theories, imagination and creativity in science, methodology of scientific investigations, social interaction among scientists, and the relationship between science and religion. In fact, across all of these NOS ideas, mean post
scores of these components were approximately 20 to 30 percent higher than their respective pre-scores as measured on the Student Understanding of Science and Scientific Inquiry (SUSSI) questionnaire (Liang et al., 2008) and additional SUSSI-like items.

**Current State of NOS Instruction**

Despite science education reform documents and literature emphasizing the importance of NOS instruction, and extensive research indicating how to effectively achieve this desired end, teachers still fail to accurately, explicitly, and reflectively teach the NOS (Lederman, 1992; Abd-El-Khalick et al., 1998; Clough, 2006). As indicated before, whether teachers intend to or not, the NOS will always be portrayed in science classrooms (Clough & Olson, 2004; Clough, 2006). Unfortunately, this portrayal is most always erroneous (Duschl & Wright, 1989; Brickhouse, 1990; DeBoer, 1991; Clough & Olson, 2004; Clough, 2006). This dismal reality was pointed out by Eccles (2005) in a speech based on decades of research when she stated:

> We as a culture do a very bad job of telling our children what scientists do. Young people have an image of scientists as eccentric old men with wild hair, smoking cigars, deep in thought, alone. Basically, they think of Einstein. We need to change that image and give our children a much richer, nuanced view of who scientists are, what scientists do and how they work.

Sadly, science textbooks often determine the image students and teachers develop of the NOS. This is a phenomenon noted long ago by Kuhn (1962, p.143) when he stated

> “[m]ore than any other single aspect of science, [the textbook] has determined our image of the nature of science and of the role of discovery and invention in its advance.” Beyond the textbook, erroneous implicit and explicit messages of the NOS are conveyed to students
through cookbook labs, lecture, and language used by teachers (Zeidler & Lederman, 1989; Clough & Olson, 2004; Clough, 2006).

These mediums often convey an image of the NOS similar to what Finley (1983) reported is promoted in science classrooms. Finley (1983) reported that in 1965 Gagne had proposed a position to the American Association for the Advancement of Science (AAAS) promoting scientific inquiry as the “terminal objective” of science education. Gagne’s (1963, p. 145) position on scientific inquiry is described as:

A set of activities characterized by a problem-solving approach in which each newly encountered phenomena becomes a challenge for thinking. Such thinking begins with a careful set of systematic observations, proceeds to design the measurements required, clearly distinguish between what is observed and what is inferred, invents interpretations which are under ideal circumstances brilliant leaps, but always testable, and draws reasonable conclusions (Gagne, 1963, p. 145).

Finley then described how many science educators adopted Gagne’s views and used inductive empiricism to frame instructional decisions. Because of this, students developed a simplistic view of science such as methodological unitarianism—that is, all scientists utilize the same processes of highly controlled experimentation beginning with observations and ending with infallible results. Furthermore, Finley (1983) claimed that without a shift in teachers’ understanding and portrayal of the NOS, a naïve inductive discovery approach to science education will fail at helping students understand even the most rudimentary of science ideas. This reflects the earlier NOS idea that science concepts do not follow simply from observation.
Factors that Impede Accurate and Effective NOS Instruction

Considering the broader context of science education over the past three decades, the current state of nature of science instruction is not surprising. Because of the way science is taught, a reduced value of NOS instruction is present among parents and students (Lakin & Wellington, 1994). Poor NOS instruction is just one symptom of science education lacking a unifying theme of what science is and how it should be taught. Contributing to NOS instructional deficiencies, many classrooms are characterized by very little interaction, collaboration, speculation, investigation, interpretation, and questioning (Goodlad, 1983; Schmidt et al., 1999).

Recommendations and efforts to understand and improve teachers’ understanding and implementation of NOS instruction (Kimball, 1967; Carey & Strauss, 1968; 1970; Ogunniyi, 1983; Akindehin, 1988; Matthews, 1989; 1990; 1994; King, 1991; Loving, 1991; Mc Comas et al, 1998) appeared often well before Abd-El-Khalick & Lederman’s (2000) review. Science education research had established that NOS conceptions held by teachers were many times insufficient, and could be preemptively improved through instruction in pre-service programs (Carey & Strauss 1968, 1970; Ogunniyi, 1983; Akindehin, 1988; Abd-El-Khalick & Lederman, 2000).

This research assumed that improving teachers’ NOS understanding would translate into their classroom practice (Lederman, 1992). However, most of these studies analyzed the impact of NOS instruction on preservice teachers’ NOS understanding within preservice science teaching methods courses or classes that ranged over short periods of time. Given the inability to focus explicitly and solely on the NOS in these instructional situations, a question
arose whether a sufficient understanding of the NOS was achieved so that it could be transferred into the classroom (Abd-El-Khalick & Lederman, 2000). Despite this criticism, the science education community consensus is that an accurate NOS understanding possessed by the teacher is the “necessary but insufficient condition” for effective NOS instruction to take place (Abd-El-Khalick & Lederman, 2000; McComas et al, 1998). That understanding the NOS is a necessary, yet insufficient, condition for influencing NOS instruction means that other factors must be at play.

Earlier research has also indicated factors other than the teacher’s understanding of the NOS that may explain why teachers fail to effectively and accurately implement NOS instruction. One of the most common reasons is that science teachers do not consider the NOS an important part of a science curriculum (King, 1991). Other potential factors impacting teachers’ implementation of NOS instruction include classroom management concerns (Lantz & Kass, 1987; Hodson, 1993), pressure to cover science content (Duschl & Wright, 1989; Hodson 1993), teaching experience (Brickhouse & Bodner, 1992), concerns for student abilities and motivation (Brickhouse & Bodner, 1992; Duschl & Wright, 1989;), and institutional constraints (Brickhouse & Bodner, 1992). Important to note, most of the aforementioned constraints were inferred by the researchers and not directly articulated by the participants (Abd-El-Khalick et al., 1998; Bell et al., 2000).

Several studies were completed in the late 1990’s to early 2000’s to more aggressively account for the transference of NOS understanding into practice to include factors that may impede it. One of the more well known studies from this time period was conducted by Abd-El-Khalick et al. (1998). This study analyzed the actual and intended NOS
teaching practices of fourteen preservice teachers during their MAT program, and factors impeding those practices. Data collected on NOS instructional practices included analyses of classroom teaching during a twelve week internship, and lesson plans and portfolios completed by the preservice teachers.

In this study the participants had recently completed NOS coursework with the majority of NOS instruction embedded in the second of two science methods courses. More specifically, the teaching of the NOS occurred through approximately 15 decontextualized and contextualized activities. Ensuring the necessary but insufficient condition was met; researchers first determined that the participants possessed a proficient understanding of the NOS. Although preservice teachers understood several crucial aspects of the NOS (e.g. empirical tentative nature of science, distinction between observation and inference) and saw great utility value in teaching the NOS (e.g. make science more interesting, the NOS is interwoven with the content) they rarely employed explicit/reflective NOS instruction in their practice. More specifically, only 3 of the 14 participants had planned to teach the NOS explicitly. Despite not being observed to extensively teach the NOS, when asked whether they felt they taught the NOS, 12 out of 14 claimed they did. Additionally, all of the participants indicated they were unsure if their students learned anything about the NOS—a finding congruent with the fact none of them formally assessed students’ NOS understanding.

When asked why they had neglected teaching the NOS, the participants in this study directly and indirectly indicated several reasons including constraints from the cooperating teacher, classroom management concerns, discomfort with their understanding of the NOS,
insufficient experience and resources, lack of planning time, and they viewed the NOS as unimportant as other instructional objectives. Not all of these reasons were uniformly given by all of the participants. Furthermore, these reasons were given only after the researcher called attention to the preservice teachers’ neglect of the NOS in their instruction. Additionally, while simultaneously describing their students doing activities, these preservice teachers had indicated they felt they had taught the NOS. Therefore, Abd-El-Khalick et al. (1998) concluded these participants were still framing effective NOS teaching from the views that students could learn the NOS implicitly. Consequently, the researchers stated:

In the case of many participants, whether this implicit teaching approach was an intentional choice in opposition to an explicit approach is not clear. However, this view appears to represent an intricate interaction between participants’ perspectives on the NOS, pedagogy, and instructional outcomes. The complexity and interrelatedness of these perspectives cannot be over emphasized. Consequently, although we have attempted to disentangle these views related to NOS, pedagogy, and instructional outcomes for purposes of discussion, it will become evident that the quotations employed to support the specific assertions that follow could easily be used interchangeably across assertions…… So perhaps the preservice teachers conflated a process or inquiry oriented teaching approach with an attempt to promote what they believed to be an atypical cognitive outcome (i.e., the NOS). (p. 430, 433)

Abd-El-Khalick et al. (1998) proceeded to say these distinctions are artificially constructed in their explanation to provide clarity of the complex dynamics associated with the transition of NOS understanding into classroom practice. The fact that students could not accurately determine the difference between their inquiry based activities and effective NOS instruction may result from an inability to self assess those practices. More research is needed to understand the interplay of participants’ perspectives on the NOS, pedagogy, and instructional outcomes (Abd-El-Khalick et al., 1998). Without understanding the variables
involved in this interplay and to what degree(s) they affect transference of a NOS understanding to teaching, pre and inservice teachers may never be fully prepared to implement the NOS in practice.

Abd-El-Khalick et al. (1998) give several potential explanations why the participants failed to transfer their NOS education into practice. Many of these are associated with the participants’ preservice status. Specifically, they explain the combination of the preservice teachers just learning the NOS and having to apply it to a classroom setting in which they had no concrete experiences or functional knowledge of may have influenced the participants’ NOS teaching practices. Another possibility Abd-El-Khalick et al. (1998 p. 433) presented was that the preservice teachers may have needed to have “constant one-to-one correspondence between the content of education courses and actual teaching situations” to effectively implement the NOS. Lastly, Abd-El-Khalick et al. (1998 p. 433) suggests temporally separating preservice teachers’ learning the NOS and NOS pedagogy, and that their learning NOS pedagogy should wait until they have had teaching experiences.

One year later, Lederman (1999) published a study that investigated inservice teachers’ NOS understanding and factors that affect the transference of that understanding into practice. In this study five high school biology teachers’ practices were analyzed over the course of one academic year using data sources including teaching observations, open-ended questionnaires, interviews, and classroom artifacts (e.g. lesson plans, assignments). Although all five teachers had diverse backgrounds, all received instruction on the NOS and NOS pedagogy from the researcher. Consequently, the researcher purposefully sampled these teachers because he perceived they all possessed a view of the NOS consistent with reform-
based documents (AAAS, 1993; NRC, 1996). Furthermore, all of the teachers were able to choose their curriculum within districts that had clearly articulated NOS objectives and no imposed formal/informal assessment requirements (Lederman, 1999). Because of this one could infer institutional constraints from these sources were minimized.

When analyzing practice, Lederman (1999) found the two teachers who were more experienced (over five year’s experience) implemented instructional practices (e.g. inquiry based activities) consistent with their views of the NOS more so than inexperienced teachers. Interestingly, neither teacher indicated through their interview responses or lesson plans they deliberately considered the NOS when planning. The two least experienced teachers did not teach in a manner consistent with their views of science and cited instructional management as a significant concern. Additionally, both of these teachers indicated a discomfort with teaching the NOS, but were interested in doing so - a response Lederman (1999) pointed out was an attempt by participants to answer in a manner they felt was desired by the researcher.

The last teacher with considerable experience was vastly different than the other more experienced teachers as she did not teach in a manner consistent with her views of science. Instead, she felt the NOS was “too abstract” for 10th graders and focused on students developing “foundational knowledge” of biology (Lederman, 1999, p. 924). Lederman (1999) interpreted this participant’s commitment to students achieving only an understanding foundational knowledge of biological content may be attributed to the wealth of experiences she possessed in the subject matter.

Lederman (1999) derived several conclusions from this study. First, teachers’ understandings of the NOS do not automatically influence their teaching. Second, experience
may play a part in teachers making their practice congruent with their NOS conceptions - a finding Lederman (1999, p. 925) dubs “most superficial”. Third, the intentions, goals, and perceptions of students held by the teacher influence their NOS implementation in the classroom.

In regards to the last point, Lederman (1999) noted that the two more experienced teachers expressed instructional aims of making the students feel good and successful through reform-based practices. Notably, Lederman (1999, p. 925) points out the intertwined nature of effective reform-based and NOS teaching, and teachers’ beliefs and instructional intentions through the following statement:

In short, although the aforementioned instructional approaches could be used to teach the nature of science in a manner consistent with the reforms and the views of the teachers in this investigation, the same activities could also be used to promote success, positive attitudes, and relevancy in science. Consequently, John and Mary’s instructional behaviors can just as easily be used to lend further support for the idea that teachers’ intentions are of paramount importance when trying to ascertain the relationship between teachers’ beliefs about science and classroom practice.

Lederman concluded that the impact of teachers’ beliefs on NOS implementation needs further research. Additionally, he recommends “systematic and concerted” efforts in teacher education that facilitate teachers to transfer their understanding of the NOS to instruction must be implemented and researched. Included in these efforts would be facilitating teachers to adopt the notion the NOS is an important instructional objective. Additionally, teachers may be better prepared to implement the NOS in practice if they are facilitated to develop proficient pedagogical knowledge and methods for dealing with the management of instruction (e.g. classroom management).
Bell et al. (2000) also researched factors impacting transference of preservice teachers’ NOS understanding into instructional planning and science teaching. This study built upon Abd-El-Khalick et al.’s (1998) by attempting to determine the influence of temporally separating preservice teachers’ learning the NOS and learning to teach the NOS to students. Outside of having three fewer participants studied, the only other difference between this study and Abd-El-Khalick et al.’s (1998) was the temporal difference of when students were taught the NOS and NOS pedagogy. More specifically, preservice teachers were taught the NOS prior to the fall part time teaching internship, which was followed by them learning NOS pedagogy. Additionally, Bell et al. (2000) ensured that in their NOS teaching course they (1) afforded concerted efforts from faculty to address the preservice teachers’ concerns about NOS teaching; and (2) taught extensively the importance of explicit/reflective NOS instruction and the NOS as a cognitive objective for students.

The results of this study differed from Abd-El-Khalick et al. (1998) in several ways. First, preservice teachers frequently noted the NOS as an important instructional objective with 45% of them including it as one of their primary goals. This was without being influenced by researchers’ comments. Additionally, three of the participants integrated in their answer the importance of teaching with less memorization and more emphasis on science themes including the NOS. Second, the implementation of explicit NOS instruction by 9 of 11 participants was substantiated by researchers.

Some similarities between this study and Abd-El-Khalick et al. (1998) did exist. Participants in both studies generally failed to include explicit NOS objectives in lesson plans and assess their students’ NOS understanding. Findings also similar in this study to those in
Abd-El-Khalick et al. (1998) were the constraints to teaching the NOS reported by preservice teachers. Included in these were perceived conflicts between teaching science content and the NOS, time and the inability to keep the same instructional pace as their cooperating teacher or other teachers, lack of comfort with their own NOS understanding, and feeling overwhelmed by the student teaching experience.

Bell et al. (2000) concluded the impact of temporal separation between NOS and NOS pedagogy instruction was promising as it appeared to help preservice teachers not conflate the NOS with scientific processes. Furthermore, preservice teachers either taught and/or emphasized the importance of teaching the NOS explicitly and reflectively. Bell et al. (2000) claimed no evidence existed these preservice teachers internalized the importance of the NOS in teaching. They point out this is an important consideration considering teachers’ intentions to teach the NOS are closely linked to classroom practice (Lederman, 1999). A final conclusion considered here is that Bell et al.’s (2000) acknowledged preservice teachers may not be the most beneficial group to study to move science teaching toward reform-based and NOS teaching. They make this point clear by stating:

The nature of science continues to be one of the most difficult constructs to teach to K-12 students. Expecting novice teachers, whose primary concerns are necessarily classroom management, rapport with students, instructional organization, etc., to effectively internalize the primacy of the nature of science and to consistently address it as a curricular theme is an expectation that may well be developmentally inappropriate. (p. 577)

This implication raises the question of whether we should be studying those fresh to the teaching field to determine factors associated with NOS instruction.

Shwartz & Lederman (2002) noted a full exploration of factors and the relationships between them associated with the level in which teachers implement the NOS had not been
conducted. They recommend the investigation of these factors and the relationships between them so teacher education programs could understand the limitations and needs of preservice teachers in constructing their understanding of the NOS and NOS pedagogy. Consequently, they investigated two beginning teachers (Rich and Laura) during their student teaching and first year of inservice practice as they learned the NOS and attempted to implement it into teaching. The goal of this study was to determine how the intentions and knowledge of the NOS and NOS pedagogy these two teachers possessed were associated with their practice.

During the two teachers’ initial efforts to learn the NOS they struggled, but not in the same ways. Rich had an extensive past in science and recognized his own dissidence in the way he viewed science as compared with that promoted in his preservice program. Because of this, Schwartz and Lederman (2002) insinuated he was able to autonomously recognize persistent NOS themes in his preservice program and integrate newly understood NOS examples into his own view. Conversely, Laura was very uncomfortable and insecure with her views of the NOS to the extent she sought an external authority to inform her of the “right” answers regarding the NOS and NOS teaching. Additionally, her views were slow to progress beyond those provided to her in MAT courses.

In respect to NOS teaching, both of these teachers initially struggled to implement the NOS with Rich teaching the NOS implicitly and Laura didactically. Additionally, the participants struggled with reflecting how the NOS fit into teaching. As the two participants progressed through student teaching, Schwartz & Lederman (2002) compared the teachers’ approaches to teaching, personal knowledge, experiences, and self-perceptions of their teaching practices. This afforded the researchers insights about the fruition of the
participants’ pedagogical content knowledge (PCK) of the NOS. Rich was able to implement the NOS spontaneously, autonomously, and seamlessly, where as Laura struggled to teach it in any other way than in a scripted manner often provided to her through activities gained in her preservice program. This difference reflected their views of the NOS where Rich saw it intertwined and complimentary with science content and Laura struggled by seeing the two as distinct. Schwartz & Lederman (2002) point out this demarcation between the two participants continued into their first year of teaching.

Overall, the results of this study indicated depth of NOS and subject matter understanding and the perceived relationship between the two affected the learning and teaching of the NOS by these individuals. Schwartz and Lederman (2002, p. 230) more specifically pointed out:

For Rich and Laura reflection on science in general and reflection on how their own NOS knowledge fit within that context were essential for their progression in NOS learning, and in turn, teaching.

Additionally, conclusions in this study indicated these teachers maintained interest and intentions to teach the NOS despite the presence of constraints (e.g. time, classroom management), and were successful in varying degrees in doing so during their first year. Also, the development of pedagogical content knowledge (PCK) was linked to teachers’ views of NOS teaching, knowledge of NOS, and knowledge of science content. Laura’s pedagogical approach was to rely heavily on NOS activities provided to her in preservice program. Additionally, her lack of a deep understanding of the NOS prohibited her from applying the content in these NOS activities to other contexts. Conversely, Rich’s pedagogical approach demonstrated how he augmented his integration of the NOS in varied
teaching contexts through his understanding of the NOS, scientific research, and ecology.

Conclusively, Schwartz and Lederman (2002, p. 231) state:

Views of the NOS pedagogy were seen here to connect to knowledge of NOS as well as knowledge of science subject matter as part of a teacher’s developing PCK. As such, simply providing a packet of activities will not suffice to enhance their PCK for NOS.

Included in the conclusions specifically in regards to Rich’s PCK, Schwartz and Lederman (2002, p. 230) indicated explicit NOS instruction is possible in the absence of inquiry, thus leading them to say:

Inquiry may be a method of providing context for student learning of NOS, but inquiry alone is not sufficient nor is inquiry necessarily a prerequisite for weaving NOS concepts into traditional science content.

From their study Schwartz and Lederman (2002) provide several implications for further research. These include investigating how knowledge of NOS and subject matter interact with knowledge of history of science, scientific inquiry, and associated teaching methods for the NOS. Schwartz and Lederman (2002) also indicate the exploration of the impact of teachers’ knowledge and intentions on their developing an understanding of the NOS and teaching it is in its primacy. Additionally, they point to their participants’ indicated beliefs in students’ abilities to learn the NOS and their differentiated beliefs in their own proficiency in teaching the NOS. Consequently, Schwartz and Lederman (2002) call for further research on how teachers’ beliefs about NOS instruction are connected to teaching approaches, and how to improve.

Important to note is the apparent difference in self directedness between the participants presented in Schwartz and Lederman’s study (2002) to diagnose their own conceptual state about understanding the NOS and NOS teaching practices, and ability to
autonomously reflect upon these understandings according to new perspectives and contexts. These characteristics reflect Kegan’s (1994) orders of consciousness. Orders of consciousness is a measure of adult cognitive development that examines how people make meaning and construct reality. A central feature of an “order of consciousness” is what an individual feels ownership over (“object”) and what they feel powerless to control (“subject”).

For third order individuals, the opinions and expectations of others have a high degree of influence over how an individual thinks, behaves, and frames and solves problems. These individuals and their professional decision making tend to be “owned” by their work and workplace. Because of this, the institution in which the individual works often serves as their fourth order decision making entity by framing problems and providing solutions for them (Kegan, 1994). In the case of teachers, the school and district often serves this role. For instance, a teacher may not be implementing the NOS because their colleagues don’t, and the teacher feels compelled to do exactly as their colleagues do. Conversely, a teacher could be implementing the NOS at a high level because they are framing decisions to do so almost entirely from a different institution they feel accountable to—they may have freedom in their work setting (e.g. the only science teacher, no required curriculum) and rely upon their preservice program to define what NOS teaching should look like.

Teachers operating from a fourth order consciousness are not subject to the opinions and expectations of others and institutions in which they find themselves. Because of this they can take the expectations of others as object (something over which they have control) while simultaneously framing and solving problems from their own meaning making (Kegan,
Additionally, these individuals may become offended and set boundaries with others that try to impose meaning making upon them. In a sense, these individuals truly own their own work. A teacher could be rated at fourth order and implement the NOS at a low level because they have constructed a value system around the decision of whether or not to teach the NOS, and have chosen not to do so. Conversely, a teacher could be rated as fourth order and implement the NOS at a high level because they have self-generated a value system to do so independent of the institution in which they find themselves.

Individuals can also be between third and fourth order consciousness. These individuals could be viewed as transitional between being directed by a surrounding culture, such as the school, and self-directedness. In other words, these individuals would frame and solve problems by alternating between their own way of knowing and borrowing ways of knowing from other sources. These individuals often become torn when two conflicting ideologies for framing and solving problems are present. For instance, a reform-based teacher who implements the NOS operating from this order may regulate relationships with traditional colleagues by not talking to them about practice. This would be a fourth order approach. Conversely, the same teacher can exhibit third order operation by longing for their practice to be defined by an outside authority, potentially even the colleagues they avoid talking to. Additionally, these teachers may blame their traditional colleagues for any resentment they possess for not having support to implement reform-based and NOS teaching.

Seemingly, based on Schwartz and Lederman’s (2002, p. 228) descriptions, one of the participants was able to be self directed to “take on a new eye” to reflect on prior experiences
in the sciences from a new philosophical perspective. To take ones’ entire conceptions, prior knowledge, and epistemology as object and autonomously adjust it in this manner is reflective of the fourth order way of thinking presented in Kegan (1994). The other individual out of discomfort sought out and relied on an external authority to inform her of the “right” answers and methodologies regarding the NOS and NOS teaching. This indicates this individual may very well have been operating more toward a third order of consciousness (Kegan, 1994). Perhaps contributing to the differences between these teachers’ practices are their ability to be self directed in their understanding and implementing the NOS based on the order of consciousness they operate from.

In 2004 Abd-El-Khalick and Akerson conducted a study analyzing elementary science methods students’ learning ecologies and how a conceptual change approach to explicit/reflective NOS instruction impacted their NOS understanding. Although this study did not look specifically at factors that may impede transfer of teachers’ NOS knowledge to practice, several important results and implications for science education research were realized. Generally, Abd-El-Khalick and Akerson (2004) were able to show through studying 28 elementary preservice teachers that substantial shifts in NOS understanding could be realized from employing a conceptual change approach. Additionally, through analyzing a smaller focus group of six of these participants, they indicated shifts in NOS understanding were impacted by cognitive, motivational, and worldview attributes.

Abd-El-Khalick and Akerson (2004, p. 806) identified in the focus group and tentatively put forth three properties associated with cultural, cognitive, and motivational domains that impact the development of an accurate understanding of the NOS. First,
members of their focus group who had deeper processing orientations were better able to
develop more sophisticated NOS views. More specifically, Abd-El-Khalick and Akerson
(2004, p. 806) state those “who sought to clarify the meanings of key NOS terms and
concepts and use such meanings and concepts consistently across contexts, and who
monitored changes in their NOS ideas, developed more informed views.”

Second, those that had high degrees of utility value for the NOS and importance
placed on NOS teaching also developed a better understanding of the NOS. This utility value
stemmed mainly from preservice teachers learning they had been taught wrongly about the
NOS. Therefore, they wanted to dispel the wrong messages for their students in their future
classrooms. Because of this, Abd-El-Khalick and Akerson (2004) indicate teachers should be
taught the importance of instructing the NOS. This may even include informing them of the
more compelling arguments why the NOS is valuable for students (e.g. democratic,
utilitarian, pedagogical, moral). Furthermore, Abd-El-Khalick and Akerson (2004) claim
much more empirical research is needed to determine through evidence if indeed
justifications for teaching the NOS include these more compelling theoretical arguments
often used by science educators.

Third, the authors of this study claim effective NOS instruction must help preservice
teachers develop the notion science and religion are two valid ways of knowing.
Furthermore, preservice teachers must be led to the idea that one way of knowing is not
inherently better than the other.

Abd-El-Khalick and Akerson (2004) point out it is not fully known if any of these
cultural, cognitive, and motivational factors are prerequisite to one another. They do propose
several scenarios for later research to determine if they are associated with teachers implementing the NOS. Armed with previous research from Abd-El-Khalick et al. (1998) which indicated an internal importance for NOS teaching was necessary for preservice teachers to instruct the NOS, they discuss the usefulness to science teacher educators if research was able to determine if an ordered relationship (if any) exists between one’s approach to understanding and learning, views of how science and religion are separate ways of knowing, and utility value for NOS teaching. By understand these factors and the order in which they occur, science teacher educators can better facilitate the transition of NOS knowledge into practice.

After the study by Abd-El-Khalick and Akerson (2004), little research has addressed factors that may impact preservice or inservice teachers’ implementation of NOS teaching. Schwartz et al. (2004) conducted a study on the development of inservice teachers’ NOS understanding throughout the course of a science internship. In this study they found interns who took a reflective approach advanced their NOS knowledge to a greater extent than those maintaining a “scientist’s identity”. Trumball et al. (2006) conducted a study spanning three years that analyzed the practices and conceptions of two teachers implementing inquiry. These researchers found a less than expected link between NOS views and implementation of inquiry. Additionally, they supported the position that learning about inquiry and/or the NOS does not mean they will be transferred into teaching practice.
Basis for the Present Study

Lederman (2007) outlined several generalizations derived from reviewing 50 years of research related to teaching and learning the NOS. Included in these generalizations are (1) teachers’ NOS understanding is not guaranteed to be transferred into their science teaching; and (2) teachers do not equate NOS instruction as important as other “traditional” science education objectives. In addition, he presents several areas warranting further research on NOS teaching and learning. Specifically, he asks: How do teachers develop PCK of the NOS and value NOS teaching to an extent equal to or greater than “traditional” science subject matter?

Lederman notes that whether one should take a pessimistic or optimistic stance of teaching the NOS can only be determined through further research, teaching, and learning about the NOS. Given the inherent educational value and the more compelling reasons that justify NOS teaching, perhaps the question that should be asked is: Why isn’t the NOS being taught? As articulated above, recent studies have provided to a greater or lesser degree some indication of factors that affect the characteristics of NOS implementation in the classroom. These include:

- Constraining factors (e.g. classroom management, pressure from cooperating teachers) (Abd-El- Khalick et al., 1998; Bell et al., 2000).
- Teacher held intentions, goals, and perceptions of students (Lederman, 1999).
- Teachers’ views of the NOS, pedagogy, and perceived teaching outcomes (Abd-El- Khalick et al., 1998; Bell et al., 2000; Schwartz & Lederman, 2002).
- Teachers’ depth of subject matter and NOS understanding, the relationship between them, and the development and demonstration of NOS PCK (Schwartz & Lederman 2002).

- The degree one relies on an external authority for the development of an understanding of the NOS and decisions of how to teach it (Schwartz and Lederman, 2002).

- Teachers’ depth of cognitive processing orientation and utility value to develop NOS understanding, which may impact NOS instruction (Abd-El-Khalick and Ackerson, 2004).

Notably, with the exception of Lederman’s study (1999), the participants in the studies outlined in this list were either preservice or first year teachers. Noted in these studies were several issues with researching novice teachers and their transition of NOS knowledge into practice. Abd-El-Khalick et al. (1998) pointed out the combination of the novel status of the preservice teachers’ NOS knowledge and lack of classroom experience may have influenced their NOS teaching practices. He also indicated the reliance on correspondence between education courses and actual teaching may be needed to effectively implement the NOS. Bell et. al (2000) indicated expecting novice teachers to internalize the NOS as an important educational objective and significantly implement it in practice may be developmentally inappropriate. This is due to the complexities associated with understanding and teaching the NOS and the concerns novice teachers bring to practice (e.g. classroom management, instructional organization).
Important to note is the teachers in Lederman’s (1999) study were experienced. However, they were able to choose their curriculum within districts that had clearly articulated NOS objectives and no imposed formal/informal assessment requirements. Because of this, one could infer institutional constraints in these teaching environments were minimized in relation to teaching the NOS. This may have created a situation in which most teachers may not find themselves in. Hence, there is a need to study the NOS implementation practices of experienced teachers that face common institutional constraints.

Although a wealth of knowledge has been gained through previous studies, several areas for further research into factors that facilitate or impede teachers effectively implementing the NOS exist including teachers’:

- Internalization of the importance, utility value, and intentions to effectively teach the NOS by teachers (Lederman, 1999; Schwartz & Lederman, 2002; Abd-El-Khalick & Ackerson, 2004; Lederman, 2007).

- Depth of cognitive processing orientation in relation to NOS learning and teaching (Abd-El-Khalick & Ackerson, 2004).

- Beliefs about NOS instruction and self efficacy to teach the NOS. (Schwartz & Lederman, 2002).

- Outcome expectations for teaching and perceptions of students’ abilities to learn the NOS (Lederman, 1999; Schwartz & Lederman, 2002).

- Knowledge of science content, the NOS, and pedagogical approaches for teaching the NOS, and how they interact in developing NOS PCK (Schwartz & Lederman, 2002; Lederman, 2007)
Ability to learn the NOS in different contexts (Bell et al. 2000; Schwartz & Lederman, 2002).

Self directedness, based on their order of consciousness, to transfer NOS knowledge into various contexts of science teaching practice (Schwartz & Lederman, 2002; Kegan, 1994).

Development of strategies for dealing with the management of instruction (Lederman, 1999).

Furthermore, research must focus on experienced teachers beyond their preservice and first year of teaching experiences. This would allow researchers to study teachers who are embedded in, and familiar with, typical teaching environments that are potentially fraught with constraints.

A holistic approach to NOS teaching research is needed given the multifaceted complex relationship between teachers’ conceptions and their classroom practice. Recent literature has articulated the many synergetic factors involved in effective reform-based and NOS teaching (Craven & Penick, 2001; Clough, 2003; Backhus & Thompson, 2006; Clough, 2006; Clough et al., 2009). Gess-Newsome and Lederman (1995) found the transfer of secondary science teachers’ conceptions of their subject matter may be mediated by their autonomy, intent, content knowledge, pedagogical knowledge, students’ requirements, and time.

Recent NOS research has also recognized the need to focus on the interconnectedness many factors that potentially either facilitate or impede NOS understanding and instruction (Schwartz & Lederman, 2002; Abd-El-Khalick & Ackerson, 2004; Lederman, 2007). This
study takes this holistic approach. The first objective of this study is to determine the effectiveness of NOS teaching practices of teachers who are in at least their second year of professional practice. This ensures the novelty of being a preservice or new teacher unfamiliar to the teaching landscape does not confound with other factors that may be associated with teachers’ NOS implementation practices. The second objective of this study is to determine factors, and their interconnectedness, associated with these teachers’ NOS implementation practices. More specifically, in partial response to the existing gap in the research outlined above, this study aims to determine the extent the following factors are associated with teachers’ NOS implementation:

- NOS understanding.
- Teachers’ classroom practices.
- Cognitive factors (understanding of NOS teaching, considerations of how people learn, self reflection, orders of consciousness).
- Motivational factors (self efficacy and utility value).
- Interest in the NOS.
- Teaching constraints (classroom and institutional constraints)
- Other factors.
CHAPTER 3: METHODOLOGY

Summary of Purpose of Study

John Dewey eloquently claimed the “net conclusion is that the final reality of educational science is not found in books, nor in experimental laboratories, nor in the classrooms where it is taught, but in the minds of those directing educational activities.” (Dewey, 1929, p. 32). The ISU-STEP reflects Dewey’s ideology by striving to prepare future teachers to become proficient with research based teaching strategies and decision making through extensive coursework and clinical experiences coupled with practical classroom experiences (Clough et al., 2009). Through preparing teachers in this fashion, the ISU-STEP recognizes successful teachers are not guided by a recipe checklist curriculum structured for a pre-determined set of situations. Instead, successful teachers self sufficiently identify and solve problems and make decisions under the conditions in which they may find themselves (Dewey, 1916; 1929).

The implementation of NOS instruction is embedded within decision making processes teachers must employ in effective science teaching. Consequently, failures or successes in consciously and accurately portraying the NOS results from a collective set of decisions made by the teacher and factors affecting those decisions. Because so much of effective NOS instruction stems from teacher decision making, an optimal way to determine reasons associated with why teachers vary in their NOS instruction is to analyze their thinking, perceived experiences, rationales and practices.
Following the framework of Clough (2006), the ISU-STEP and this study asserts effective NOS instruction must be explicit and scaffold along a decontextualized to highly contextualized continuum (Clough, 2006). For example, teachers that effectively teach the NOS may begin the year with a mystery tube activity (Lederman & Abd-El-Khalick, 1998) sans contextualized science instruction to explicitly attend students to key NOS ideas in a more concrete fashion. Teachers may then draw upon this activity later in a highly contextualized fashion by requiring students to compare their tube activity experiences with those of Darwin’s when they read historical accounts of how he developed his ideas on evolution. Of course to teach in this fashion, teachers must first fulfill the necessary but insufficient condition—that is possess a deep understanding of the NOS (Abd-El-Khalick & Lederman, 2000).

Teaching the NOS explicitly and effectively is also congruent with achieving a wider context of science education goals through reform-based teaching (Penick, 1986; Yager, 1988; Clough et al., 2009). Abd-El-Khalick & Lederman (2000) and Lederman (1999) echoes this claim by stating a proficiency in general pedagogy (i.e. classroom management abilities, teacher behaviors, questioning skills) must also be present to teach certain subjects such as the NOS. More specifically, teachers’ NOS pedagogical content knowledge (PCK) has been cited as a factor that may determine NOS teaching effectiveness (Shulman 1986; 1987; Wilson et al. 1987; Abd-El-Khalick & Lederman, 2000; Clough, 2006, Lederman, 2007). Effective NOS PCK is characterized by the integration of effective pedagogical practices with strategically placed effective NOS instruction—that is, the teacher would know when, how, and why to teach particular aspects of the NOS so they are more accessible to
students. In addition, the teacher’s decision making while teaching the NOS would reflect the goals they have for students and how students learn (Clough et. al 2009).

This study is designed to compare reasons, beyond teachers’ possession of accurate NOS knowledge (Abd-El-Khalick & Lederman, 2000), associated with why teachers effectively or ineffectively teach the NOS, to include factors of context and the degree to which teachers promote other goals through reform-based practice. To accomplish this, this study looks at the characteristics of, and reasons for differences in, NOS instructional practices of thirteen teachers that stem from the ISU-STEP. Following recommendations present in the literature base, this study controls for deficiencies and concerns present in previous studies in four ways. First, twelve of the thirteen teachers in this study have completed their entire preservice program in the ISU-STEP. The remaining teacher completed crucial components of the ISU-STEP (Restructuring Science Activities, Advanced Pedagogy). This ensures all participants have been educated to implement reform-based practices. Second, all teachers in this study have taken a NOS in science education course, and ten out of the thirteen completed a restructuring science activities course. Furthermore, the science teaching methods courses ISU-STEP students take includes NOS teaching methods within general science teaching methods. These factors ensure the participants in this study have had sufficient opportunities to develop an accurate understanding of the NOS and NOS pedagogy that may transition to practice. Third, the NOS understanding of the teachers in this study will be evaluated a-priori to the investigation of other factors that may influence their NOS instructional practices. Fourth, all teachers in this study are in at least their second year of professional teaching. Therefore, they have had sufficient opportunities
to become familiar with their teaching environments. Evidence collected in this study to
determine NOS teaching practices, and reasons for differences in those practices, include
classroom observations, instructional artifacts, a questionnaire, and interviews.

**Review of Research Questions**

**Research Questions**

This study addressed the following research questions:

1. NOS teaching practices exhibited by ISU-STEP graduates:
   a. To what extent do teachers explicitly and reflectively teach the NOS?
   b. To what extent do teachers accurately convey the NOS?
   c. To what extent do teachers contextually and decontextually teach the NOS?
   d. To what extent do teachers explicitly scaffold along the decontextualized to contextualized NOS instruction continuum?

2. Factors associated with varying levels of NOS instruction by ISU-STEP graduates.
   a. To what extent is an understanding of the NOS associated with teachers’ implementation of the NOS in instruction?
   b. To what extent are classroom teaching practices associated with teachers’ implementation of the NOS in instruction?
   c. To what extent are cognitive factors (understanding of NOS teaching, orders of consciousness, considerations of how people learn, self reflection) associated with teachers’ implementation of the NOS in instruction?
   d. To what extent are motivational factors (self efficacy, utility value) associated with teachers’ implementation of the NOS in instruction?
   e. To what extent is the affective factor of interest in the NOS associated with teachers’ implementation of the NOS in instruction?
   f. To what extent are teaching constraints (classroom and institutional constraints) associated with teachers’ implementation of the NOS in instruction?
   g. To what extent are other factors associated with teachers’ implementation of the NOS?
Participants

The ISU-STEP

Between 2003 and 2009, over 75 individuals have completed the ISU-STEP. After the 2003 program restructuring, the ISU-STEP required all preservice teachers to complete science content, general education courses, and three to four secondary science teaching methods courses; the prior program had required only one science methods course. This extensive science education methods sequence sets the ISU-STEP apart from many preservice programs. In addition, all preservice teachers in this program are required to take a nature of science in science education course. Specifically, the course description from this requirement reads as follows:

The intersection of issues in the history, philosophy, sociology, and psychology of science and their application to and impact on science teaching and learning, science teacher education, and science education research. (ISU 2009-2010 course catalogue)

The ISU-STEP also offers an optional Restructuring Science Activities course. The description of this course is as follows:

Modification of laboratory activities and other everyday science activities so they are more congruent with how students learn, the nature of science, and the National Science Education Standards. (ISU 2009-2010 course catalogue)

The structure of the ISU-STEP creates seamless transitions between the science teaching methods and NOS courses and field experiences. The courses are currently taught by the same professor and promote reform-based teaching through the instructors’ own pedagogy and teacher decision making (Clough et al., 2009). The NOS and science teaching methods courses not only address themes, historical contexts, and examples dealing with the
NOS, but also model for teachers how to implement these NOS components into their own instruction. Specifically, students are taught how to implement inquiry-based activities, historical and contemporary NOS examples, and explicit scaffolds along a decontextualized to highly contextualized continuum in order to make the NOS more accessible for their own students (Clough, 2006; Herman & Clough, 2010).

**Participant Characteristics**

The ISU-STEP provides ample opportunities for all its preservice teachers to understand the NOS and effective NOS instruction. This creates an optimum situation where ISU-STEP preservice teachers should be able to implement the NOS in professional practice. All thirteen participants in this study are former ISU-STEP students and have a highly similar teacher education preparation including the completion of the NOS in science education course. Twelve of the participants completed all portions of the ISU-STEP, whereas the other one completed critical components of the program to include advanced pedagogy and science teaching methods courses. Furthermore, ten of the participants took the optional restructuring science activities course.

Eleven of the thirteen participants had the same professor for their NOS in science education course. This professor also taught the restructuring science activities course that ten of the participants completed. Additionally, this professor instructed all of the science teaching methods courses for ten out of the twelve participants who completed the entire ISU-STEP. The remaining two participants had this professor for all of their science teaching methods courses with the exception of the second methods and NOS in science education courses during the fall of 2006. An adjunct professor of science education and a Ph.D.
student instructed these courses under close supervision from the professor who instructed the other ten participants.

Table 1. Study participants’ professional information.

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Years of Experience</th>
<th>Years at Current School</th>
<th>Science Discipline Taught</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>3-5</td>
<td>3-5</td>
<td>Physical Science</td>
</tr>
<tr>
<td>H2</td>
<td>3-5</td>
<td>1-2</td>
<td>Physical &amp; Life Sciences</td>
</tr>
<tr>
<td>H3</td>
<td>1-2</td>
<td>1-2</td>
<td>Physical Science</td>
</tr>
<tr>
<td>H4</td>
<td>1-2</td>
<td>1-2</td>
<td>Physical &amp; Life Sciences</td>
</tr>
<tr>
<td>H5</td>
<td>5+</td>
<td>5+</td>
<td>Physical Science</td>
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<tr>
<td>H6</td>
<td>1-2</td>
<td>1-2</td>
<td>Life Science</td>
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<tr>
<td>H7</td>
<td>3-5</td>
<td>3-5</td>
<td>Physical Science</td>
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<tr>
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<td>3-5</td>
<td>3-5</td>
<td>Life Science</td>
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<tr>
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<td>1-2</td>
<td>Physical &amp; Life Sciences</td>
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<tr>
<td>H10</td>
<td>1-2</td>
<td>1-2</td>
<td>Physical &amp; Life Sciences</td>
</tr>
<tr>
<td>H11</td>
<td>3-5</td>
<td>3-5</td>
<td>Physical &amp; Life Sciences</td>
</tr>
<tr>
<td>H12</td>
<td>3-5</td>
<td>3-5</td>
<td>Physical &amp; Life Sciences</td>
</tr>
<tr>
<td>H13</td>
<td>3-5</td>
<td>3-5</td>
<td>Physical Sciences</td>
</tr>
</tbody>
</table>

Table 1 shows the participants’ professional information. To ensure participants’ anonymity, information about them insignificant to the purposes, findings, and conclusions
of this study was omitted (i.e. gender and age). Furthermore, gender neutral language was used when describing participants in this final product. For instance, instead of using he or she, participants were referred to as s/he. Participants in this study ranged from two to fourteen years of teaching experience and taught 9th to 12th grade life and physical sciences in suburban and urban schools in Iowa. Demographics of the participants included ranging in age from mid-20’s to late 40’s and originating from the Midwestern United States.

**Study Design**

**Recruitment**

Recruitment of participants began after Institutional Review Board Approval was procured for this study. Participants were purposely selected from e-mail lists of students that were enrolled in the ISU-STEP after the 2003 restructuring. Participants were also selected based on geographic location in respect to convenience for the researcher and level of perceived NOS implementation (low, medium, or high) based on conversations with the NOS/methods professor. His perceptions were informed by his continued contact with graduates to provide support during their early years of teaching. Participants were mailed letters outlining the study protocol that asked for their voluntary participation (*Appendix A*). To minimize impact on instruction, classroom observations, artifact collections, and interview times were determined by the participants.
Data Collection

Effective teaching is synergetic in nature (Clough et al., 2009), yet many prior studies related to NOS teaching empirically examine at most a few variables and their impact on practice (Abd-El-Khalick et al., 1998; Lederman, 1999; Abd-El Khalick & Lederman, 2000; Schwartz & Lederman, 2002; Lederman, 2007). In order to determine former ISU-STEP students’ decision making in relation to NOS implementation and factors that affect that decision making, several aspects of practice must be analyzed and examined as a coherent whole. For the purpose of this study, variables include: the teacher’s actions in the classroom, assignments given, rationales for instructional decisions, perceptions of practice, and experiences in the teaching profession. Specific data sources included classroom observations, classroom artifacts, questionnaires about NOS understanding and perceptions of teaching practice, and semi-structured interviews.

This study followed a naturalistic inquiry approach with emergent design flexibility and participant validation to develop rich data with a high degree of validity (Maxwell, 2005). This approach is warranted because to categorize differing levels of NOS and scientific inquiry instruction and understand reasons why these phenomena happen, classroom teaching must be studied, to the greatest extent possible, as it occurs naturally and without outside manipulation. In addition, because of the dynamic nature of teaching, the factors that affect it, and the need for a deep understanding of these phenomena based on empirical evidence, inquiry methodologies such as interview protocols and questionnaires must be adaptable (Patton, 1990).
Classroom Observations

Participants were observed at their convenience for 3 to 5 forty-five minute class periods. When possible, observation times occurred when the maximum amount of instruction could be witnessed with little interruption (i.e. fire drill, assembly, shortened period, work day). During observations, the researcher did not interact with participants or students and classroom instruction was not interrupted.

The ISU-STEP promotes effective reform-based teaching as a decision making process with the end goal of students achieving well defined goals to include a fundamental understanding of the NOS (Clough et al. 2009). The rationale behind conducting classroom observations was to witness firsthand the extent to which teachers employ reform-based instruction-particularly their implementation of the NOS. In addition, situational, classroom contextual, and instructional factors associated with differing levels of NOS instruction could also observed, thus providing context to teachers’ perceptions of factors that influence their practice.

Field notes were taken during observations and annotations included the general layout of the room, lesson characteristics (i.e. tasks, activities, and assignments), and general characteristics of practice (i.e. use of inquiry, and wait time). After each observation, a Local Systematic Change (LSC) Classroom Observation Protocol (LSC-COP; Appendix B) (Banilower, 2005; HRI, 2006) was completed in conjunction with field notes. This instrument aids in data reduction and provides a standardized way of measuring teachers’ classroom practice (Krathwohl, 1998). A NOS section was added to the LSC-COP to specifically account for participants’ levels of NOS instruction (NOS-COP; Appendix B).
This section was structured much like the four already existing sections of the LSC-COP with measurements of NOS instruction to include levels of accuracy, explicitness, reflectivity, and scaffolding along the decontextualized to highly contextualized continuum (Clough, 2006).

**Modified Local Systematic Change Classroom Observation Protocol**

The Local Systematic Change Classroom Observation Protocol (LSC-COP) was developed because the NSF-required evaluation of LSC grants between the years of 1998-2004. This instrument is extensively used in science education research, and is a rating tool for assessing the extent to which science lessons are congruent with NSES standards for reform-based teaching (NRC, 1996). Measurement of instruction occurs on a scale of 1 (not reflective of NSES standards) to 5 (extremely reflective of NSES standards) within four categories (design, implementation, science content, and classroom culture).

An overall capsule rating of instruction is then developed based on the lesson as a whole (not simply an average of the individual categories), with 8 possible ratings ranging from ineffective instruction (i.e. “passive learning” and “activity for activity’s sake”) to exemplary instruction most in line with reform documents and science education research (i.e. instruction that requires students to be engaged, construct knowledge, and enhance their understanding to “do” science) (NRC, 1996; AAAS, 1990; 1993; Clough et al., 2009).

To ensure data validity and reliability, the researcher completed LSC-COP training consisting of evaluating several videotaped teaching scenarios with a faculty member who had training on this instrument at NSF under the supervision of the Horizon Research Institute. Evaluations of videotapes were completed until the researcher accomplished a
proficiency rating of over 90% based on an inter coder agreement of at least 90% between the researcher and faculty member.

As mentioned above, a fifth category measuring NOS instruction was added for this study. The coding scheme for this section was the same as those in the original LSC-COP with the exception of scores being reflective of the conceptual framework presented in Clough (2006) and NSES standards (NRC, 1996) of NOS instruction. The conceptual framework presented in Clough (2006) is a culmination of, and addition to, many years of NOS research (Lederman, 1992; Lederman, 1999; Clough, 2004; McComas, 1998; Abd-El-Khalick & Lederman, 2000; Akerson et al., 2000; Bell et al., 2000; Khishfe & Abd-El-Khalick, 2002) and provides guidelines for the level of accuracy, explicitness, reflectivity, and scaffolding along the decontextualized to highly contextualized continuum for effective NOS instruction. To avoid conflation of NOS practices with reform-based teaching this category was considered and analyzed independently of the LSC-COP.

**Classroom Artifacts**

Classroom artifacts were collected because the researcher could not be physically present on a daily basis to complete observations. Artifacts served a valuable role in determining the extent to which students were being accurately and effectively taught NOS concepts throughout the course, whether they were assessed on NOS ideas, and the congruency between ISU-STEP NOS emphases (both content and pedagogy) and those occurring longitudinally in the classroom. Artifacts from participants’ classes included assignments, readings, activities, labs, and lesson plans. These were collected on a bi-weekly
basis and collectively were evaluated using the NOS-COP to record the level of accuracy, explicitness, reflectivity, and scaffolding along the decontextualized to highly contextualized continuum (Clough, 2006) present in participants’ NOS instruction. Through using the NOS-COP as a data reduction and analysis tool for the artifacts, they can be compared with classroom observations on identical scales of measurement. This aids in the triangulation process, thus providing a higher degree of validity.

**Views on Science, Scientific Inquiry, and Science Teaching (VASSIST)**

Participants individually completed the Views on Science, Scientific Inquiry, and Science Teaching (VASSIST) questionnaire *(Appendix C).* To ensure this questionnaire did not influence participants’ NOS teaching practices, it was distributed after all classroom observations and artifacts were collected. Participants were given approximately two weeks to complete the VASSIST and asked not to use outside resources when completing answers. The purpose of the questionnaire is three fold. First, the instrument gives a uniform measure that will be comparable between all participants. Second, responses participants provide on the questionnaire were used to tailor interview protocols. Third, the questionnaire provided triangulation and clarity to interview responses.

The VASSIST consists of two sections. The first consists of 10 items that measure an understanding of the nature of science. Items 1-6 originated from the Student Understanding of Science and Scientific Inquiry (SUSSI) questionnaire (Liang *et al*., 2008) for use with undergraduate students. During development, the SUSSI was extensively tested and retested to ensure validity and reliability and has a high degree of efficacy due to the various internal ways to check for authenticity of the data. In addition, this instrument has been used in
several studies including those measuring pre and inservice teachers’ views on the NOS (Saderholm, 2007; Liang et al., 2008; Clough et al., 2010). Four additional SUSSI-like items (items 7-10) were developed, structured, and evaluated by six science education researchers in order to ensure they achieved congruency with the original SUSSI components. These SUSSI-like items have been used in conjunction with the original SUSSI components with great success in studies dealing with post-secondary science students’ understanding of the NOS (Clough et al., 2010). The instrument measures the following NOS constructs:

- Item 1 – Observations and Inferences
- Item 2 – Scientific Theories
- Item 3 – Scientific Laws compared to Theories
- Item 4 – Social and Cultural Influences on Science
- Item 5 – Imagination and Creativity in Scientific investigations
- Item 6 – Methodology of Scientific Investigations
- Item 7 – Social Interaction among Scientific Researchers
- Item 8 – Science and Religion
- Item 9 – Development and Acceptance of Science Ideas
- Item 10 – Discovery and Invention.

These NOS issues are quantitatively evaluated through four Likert sub-scale items that include the most common naïve and informed NOS views for each component. Each component is accompanied with a qualitative prompt that requests participants to further explain their NOS understanding. The SUSSI attempts to achieve “credibility, trustworthiness, and authenticity of the data” stemming from the ability to cross compare quantitative and qualitative responses, and the qualitative perspective from which it was derived (Liang et al., 2008). Therefore, this instrument should be equally effective with large or small scale studies (Liang et al., 2008).

The second section of the VASSIST measures teachers’ perceptions of their practice and factors affecting that practice. The components for this section were developed for this
study and address themes such as institutional factors, parental and student influences, collegiality, self efficacy, motivation, and self directedness. Each component contains 4 to 5 Likert items that are quantitatively evaluated and collectively reflect the views of the teacher in respect to the issue the component is addressing. The researcher acknowledges the threats to validity that arise when developing instruments. However, instrument development was necessary due to the lack of published instruments that assess the NOS pedagogy emphasized by the ISU-STEP, and factors that may affect that pedagogy. Face validity was established between the researcher and a NOS expert to ensure the instrument corresponded with NOS concepts taught to the students. Because of threats to construct and content validity, results of the instrument were triangulated with interview data, classroom observations, and artifacts.

Interviews

Informal interviews were conducted throughout the study when participants volunteered information. Additionally, during January and February, after all other forms of data were collected, a one and a half hour formal interview was conducted. All interviews took place in person, in the participants’ school, with the exception of one participant who teaches several hours away. Interviews with this individual were conducted via video chat. This allowed the researcher to not only derive meaning from verbal responses, but from non-verbal responses as well.

Interviews were semi-structured and previous measures (i.e. questionnaires, artifacts, and observations) guided question formulation. Because the interview was semi-structured, participants were asked the same questions based on an interview protocol (Appendix D), but flexibility was retained to probe further into responses of particular interest (Reinharz, 1992;
Patton, 1990; Esterberg, 2002). By employing this level of flexibility, interviews become more open-ended and are better able to provide data that meets the objectives of the study. In addition, emergent themes of significant phenomena are more readily uncovered (Patton, 1990).

Interviews addressed themes organized around study variables, such as teachers’ perceptions of their NOS teaching practices and factors that affect those practices. Specifically, questions were tailored to elicit responses that provide information on themes such as the participants’ orders of consciousness, self reflection abilities, self efficacy, perceptions of institutional factors, ability to cope with teaching constraints, and utility value for teaching the NOS. Due to emergent design flexibility, themes beyond the initial scope of this study were also investigated through interviews. Emergent themes included a personal sense of responsibility to implement reform-based and NOS teaching practices, and the source from which teachers obtained support for their teaching decision making and practices.

Data Analysis

Qualitative methodologies were framed from social constructionist epistemology with a theoretical perspective of phenomenology (Crotty, 1998). This approach to research “requires us to engage with phenomena in our world and make sense of them directly and immediately” (Crotty, 1998, p. 79). Data reduction and analysis followed a grounded theory approach and where possible, quasi-statistics were used to support claims and evidence through derived numerical results of the data (Becker, 1970; Crotty, 1998; Maxwell, 2005). During data collection and analysis for each participant, data sources were triangulated to
ensure conclusions were valid and a high degree of internal generalizability was achieved (Miles & Huberman, 1994; Crotty, 1998; Maxwell, 2005). Collectively, these data sources provide a holistic view of participants’ NOS teaching practices and factors that affect those practices.

The VASSIST, LSC-COP, and NOS-COP were not used for inferential statistical analyses due to low sample sizes. Although this is the case, the twelve participants in this study who completed the entire ISU-STEP make up approximately 16% of the total ISU-STEP graduates from the post-2003 restructuring to 2009. This creates a situation in which descriptive statistics (i.e. means and frequencies) may be generalized to all ISU-STEP graduates who completed the program in this time frame.

Interviews were coded and analyzed using the computer program ATLAS.ti Version 6 (ATLAS.ti GmbH, 2009). Transcriptions of teacher interviews were coded and categorized using open, axial, and pattern coding procedures (Strauss & Corbin, 1998; Miles & Huberman, 1994). Coding aligned with variables derived from the research questions and those that were considered emergent themes that became apparent during data collection.

**NOS Teaching Practices**

Research questions 1a. through 1d. pertaining to participants’ NOS teaching practices were addressed through analyzing, coding, and cross comparing classroom observations and artifacts. A LSC-COP like NOS section (NOS-COP) was used to facilitate the data reduction, coding, and triangulation of these data sources (Appendix B). The NOS-COP follows the same format as the original LSC-COP with scores on sub-items ranging from 1-5, representing the degree to which the observation or artifact reflected effective NOS
instruction. Specifically, a score of 1 on a sub-item would mean the lesson or artifacts were not reflective of NOS instruction outlined in NSES standards (NRC, 1996) and Clough (2006), where as a score of 5 would mean it was extremely reflective of NOS instruction outlined in NSES standards (NRC, 1996) and Clough (2006).

The first two sub-items of the NOS-COP were used to measure the extent in which inquiry and/or historical/contemporary accurate examples of science were present and afforded opportunities to effectively address the NOS in a single lesson or all artifacts collectively from a course. Sub-items 3 through 8 were used to measure the extent in which the NOS was actually implemented by the teacher through a lesson or all NOS-related artifacts collectively for a course. Specifically, these sub-items measured the accuracy, explicitness, reflectivity, and scaffolding along the decontextualized to highly contextualized continuum present in participants’ NOS instruction.

For each teaching observation sub-items 3-8 were averaged to develop a NOS implementation score. For each participant, these lesson scores were then averaged to develop a mean NOS observation implementation score. A mean NOS artifact implementation score was also calculated by averaging sub-items 3-8 for each participant’s NOS-related artifacts as a whole. Finally, a composite NOS implementation score for each participant was calculated by averaging their mean NOS observation and mean NOS artifact implementation scores.

Each teacher’s levels of NOS implementation based on mean classroom observation, artifact, and composite NOS implementation scores were rated as high, medium, and low. The cutoff values for NOS implementation levels were: 1 to below 2.3 = low; 2.3 to below
3.6 = medium; above 3.6 = high. The rationale for parsing the three levels along a 5 point scale, starting at 1 and increasing in approximate increments of 1.3, was to retain congruency with the NOS-COP and LSC-COP scales. Guidelines for NOS implementation ratings are discussed further in Chapter 4.

Factors Associated with NOS Teaching Practices

Teachers’ NOS Understanding

Research question 2a. pertaining to participants’ NOS understanding was addressed through employing the Student Understanding of Science and Scientific Inquiry (SUSSI) Questionnaire (Liang et al., 2008; Appendix C) and four additional SUSSI-like items. Each item on this instrument addressed a NOS construct through 4 Likert sub-items. Responses to Likert sub-items were given numerical values with 5 being the most informed and 1 being the least informed view of the NOS. These were summed to give a score ranging from 4 to 20 for each NOS construct. A score indicating each participant’s holistic NOS understanding was then calculated by adding their scores for each NOS construct. To ensure “credibility, trustworthiness, and authenticity of the data”, each participant’s qualitative and quantitative responses were compared for each NOS construct (Liang et al., 2008).

Teaching Practices

Research question 2b. was addressed through analyzing participants’ teaching practices using the LSC-COP. This instrument was used to assess the extent to which science lessons were congruent with NSES standards for reform-based teaching (NRC, 1996). Measurement of participants’ instruction was rated on a scale of 1 (not reflective of NSES
standards) to 5 (extremely reflective of NSES standards) within four categories (design, implementation, science content, and classroom culture).

An overall capsule rating of instruction was then developed based on the observed lesson as a whole (not simply an average of the individual categories), with 8 possible ratings ranging from ineffective instruction (i.e. “passive learning” and “activity for activity’s sake”) to exemplary instruction most in line with reform documents and science education research (i.e. instruction that requires students to be engaged, construct knowledge, and enhance their understanding to “do” science (NRC, 1996; AAAS, 1990; 1993; Clough et al., 2009).

**Cognitive Factors**

To address research question 2c., participants’ VASSIST and interview responses were analyzed to determine if cognitive factors (considerations of how people learn, self reflection abilities, understanding of NOS teaching, and orders of consciousness) were associated with NOS implementation. The following coding schemes were used to analyze interviews and determine the association between NOS implementation and cognitive factors.

**Considerations of How People Learn**

Teachers’ interviews were analyzed to determine if they considered how people learn in their teaching decision making in a manner that is reflective of the ISU-STEP. Considerations of how people learn were coded as being consistent or inconsistent with what preservice teachers are expected to develop in the ISU-STEP.
Consistent considerations of how people learn were often described by teachers directly or interwoven in reflections about classroom teaching. These descriptions contained several elements of the learning theories (i.e. social, constructivist, behavioral, and developmental) and how they informed the teacher’s practice. For instance, teachers may describe their role in scaffolding students from concrete to abstract concepts by referring to an inquiry-based NOS activity they implemented in the classroom. These teachers may also convey they consider the developmental level of students when planning lessons. Furthermore, these teachers may also advocate students could construct a deep understanding of fundamental science and NOS ideas in a manner promoted by the ISU-STEP.

Often evident in these teachers’ statements were themes from conceptual change and ecologies research. For instance, they may describe how true learning requires dissatisfaction, dissonance with current concepts, intellectual risks, epistemological and/or conceptual shifts, application to novel situations, and transcends many situations inside and outside the science classroom. Also often demonstrated in statements rated as consistent would be a holistic view of what a conceptual understanding is. For instance, teachers may describe how a student’s understanding is composed of many networks and layers of concepts-some of which are incorrect, correct, and partially correct. Lastly, these statements may also demonstrate that the teacher understands students will learn better if they have an accurate view of what learning is.

Teachers rated as inconsistent often neglected to acknowledge important considerations of how people learn (e.g. learning theories) in their reflections of teaching and learning. Additionally, statements related to how people learn that were rated as inconsistent
shared little to nothing with the themes taught in the ISU-STEP. In fact, these statements were often contradictory with what the ISU-STEP promotes that teachers, when engaged in instructional decision making, should consider about how people learn. Teachers’ statements rated as inconsistent referred to learning as the acquisition of skills, definitions, and content knowledge. Statements may also insinuate that learning is promoted through the transmission of knowledge (e.g. lectures, Power Point presentations, etc.) rather than developed by the student through facilitation from the teacher. Additionally, statements from these teachers may indicate students are incapable of constructing a deep and robust conceptual understanding of science and NOS ideas as promoted by the ISU-STEP. For instance, teachers may state students should just get an overview of science ideas, the type of learning advocated in the ISU-STEP is “too ideal” and unachievable for their students, and/or students are only capable of understanding shallow aspects of the NOS, such as how science relates to their everyday lives.

**Self Reflection**

Teachers’ interviews were analyzed for accuracy and depth of self reflection about general and NOS teaching practices. Accuracy and depth of self reflections for general and NOS teaching practices were coded as high, medium, and low. Analysis of general teaching reflections also included reflections made about NOS teaching. To determine if differences were present in NOS teaching reflections specifically, they were analyzed separately from the reflections of overall teaching practice.

Accuracy of self reflection about teaching practices was determined by comparing interview responses to collected observations and artifacts. Reflective responses could be
about specific examples of classroom practice or strengths and weaknesses and ways to improve teaching practice. A rating of high accuracy was assigned if reflections of teaching practices were highly congruent with observations and/or artifacts. For instance, a teacher may accurately state they used a great deal of inquiry in their practice and/or used decontextualized NOS activities to make the NOS more concrete for students.

Teachers whose reflections were somewhat congruent with observations and/or artifacts were rated as moderately accurate. These descriptions may have minor inconsistencies with observed practice or artifacts such as a minor exaggeration of the amount of inquiry or use of effective questioning. For instance, a teacher may state they use highly effective questioning strategies to scaffold NOS instruction but are observed implementing a mix of lecture, yes/no and/or short answer questions and a few effective questions.

Participants received low accuracy ratings if descriptions of teaching practices and associated strengths and weaknesses were not congruent with observations and/or artifacts. For instance, these teachers may have claimed they taught using inquiry and the NOS extensively whereas lecture-based practices with little to no NOS were present in observations and artifacts. Another example warranting a low rating would be failure to articulate areas in dire need of improvement when specifically asked about aspects of teaching they should improve. For instance, teachers may have been observed using very ineffective interaction patterns that were detrimental to students’ learning, but provide insignificant areas of improvement such as needing a quicker turnaround time on grading or organization skills.
A rating of high depth of self reflection was given if teachers described and reflected upon their teaching practices with great detail. These teachers provided reflections that are meaningful, include research based statements, and hold significant implications for practice (e.g. using effective questioning to improve the self efficacy of students, or considering prior knowledge to help them engage students). Furthermore, these reflections may link several aspects of teaching (e.g. how effective questioning strategies link inquiry and the NOS) through concrete examples drawn from the teacher’s own practice.

Teachers’ reflections were rated as demonstrating medium depth if they contained a fair amount of detail. These descriptions include what the reflection or practice is, but may or may not include how it is important or how it should change. These teachers’ reflections are somewhat meaningful and draw from the research base, but are spoken through generalities and tend to lack specific context and examples from their own classrooms (e.g. “My questioning needs work so students provide more in depth answers;” “I implemented my lessons to move from concrete to abstract and use historical NOS stories”). What characterizes these reflections is the appropriate use of educational terms learned in the program, but a lack of explanation or application to illustrate that the participant knows what these terms mean, despite questions from the interviewer that sought this information. This is what Abell et al. (1998) called “noises that sound pedagogical”. Additionally, links may be shallow or not evident between several aspects of teaching.

A rating of low depth was given to teachers if they reflected on their teaching practice in a shallow manner and with little detail. These teachers’ reflections lack direct links to the research base and resemble generic statements most teachers could provide. Additionally,
these reflections lack significant implications and recommendations for improvement (e.g. “I need to get homework graded sooner,” “My greatest strength is making students feel comfortable,” “I make students ‘find the answer on their own’ to help them understand the NOS”). Lastly, links between several aspects of teaching are rarely evident.

**Understanding of NOS Teaching**

Interviews were analyzed to determine the extent teachers understood how to teach the NOS. Understanding of NOS teaching was coded as *informed*, *transitional*, or *naïve*. Teachers with a fully functional understanding of NOS teaching were rated as informed. These teachers often indicated they knew how to teach the NOS and spoke of effective NOS instruction directly or in the context of their classroom lessons. Furthermore, descriptions these teachers gave were highly congruent with themes present in the ISU-STEP and NOS literature (Clough, 2006). For instance, teachers in this category may describe how they used moderately contextualized activities to explicitly and reflectively draw students’ attention to the NOS. These teachers may also demonstrate an understanding of how effective NOS teaching is embedded within effective teaching and learning as a whole. For instance, they may draw from conceptual change research to describe how students tenaciously hang onto their NOS misconceptions because they are embedded within a number of other incorrect and correct concepts.

Teachers rated as having a transitional understanding of NOS instruction may describe their limitations directly. For instance, they may openly discuss how they have not “put all the pieces” of effective NOS instruction together (e.g. NOS understanding, questioning strategies, NOS ideas being developmentally appropriate, etc.) and therefore are
not able to fully implement it into the classroom. Descriptions of classroom practice may also indicate that they understand some aspects of effective NOS instruction, but not others. For instance, they may accurately understand what the NOS is and how to implement it in the classroom, but confuse aspects of NOS instruction with inquiry and/or modeling in their descriptions.

Teachers possessing a naïve understanding of NOS teaching presented statements that are incongruent with the concepts taught in the ISU-STEP and NOS literature. For instance, these teachers may believe students will learn the NOS implicitly through inquiry-based activities or through traditional methods such as lecturing or vocabulary. Teachers with a naïve understanding may also attempt to pass nondescript conjectures as teachings of the NOS. For instance, they may believe they are teaching the NOS through presenting facts about the scientists or their lives without explicitly articulating any of the NOS concepts taught in the program.

Orders of Consciousness

Orders of consciousness is a measure of adult cognitive development that examines how people make meaning and construct reality. A central feature of an “order of consciousness” is what an individual feels ownership over (“object”) and what they feel powerless to control (“subject”). The determination of teachers’ orders of consciousness was completed through analyzing statements made in interviews and informed by Lahey et al., (1988). Exemplars for 3rd, between 3rd and 4th, and 4th orders of consciousness are sequentially presented as follows:
When it comes down to it, if you [the administrators] tell me that this is how you want it and that [which I was doing] was wrong. And then I go to make adjustments and I'm still not doing it right but I did what you told me to, that's saying I didn't do anything. Or telling me just what I did wrong and never that I did something right. The focus is on what was wrong but nothing on this was what was good. That is hard. And what you're saying is everything that I do is bad. No one ever wants to hear that… I don't think there's ever completely bad in everything you do, but there's something that is usually good but the bad part over rules the good. But you [the administrators] have to let me know I'm doing something good. Because if I know from [you that I am] doing a little bit of something good, I'm more likely to change the next thing and the next thing. (H2, 18:43: 3rd order statement)

If there are certain things that are required of the district, if I've specifically been asked by a superior to do something, I will definitely adhere to the policy within reason. They have never asked me to do anything that I felt was unreasonable. There may have been times where they asked me to do something or I would question the way that they were asking me to do it if that is in the best interests of my students. But if that is something that is asked of me I will comply. I'm trying to find that happy medium between doing what I feel is best, and doing what I learned in practice is the right thing to do for students. But I recognize that that is not the mindset that everyone else holds. We don't share similar philosophical views. So, how do I maintain and keep the ship going in my classroom but also maintain a professional level of integrity and professionalism. How do I, especially as a new kid not rock the boat too much. (H4, 2:17: between 3rd and 4th order statement)

[Having objectives on the board] is one of the expectations here. I do have objectives on the board and I told you what my objectives were. But notice how big the objectives are: become better learners; understand how science works; and now the [content] objective is understand weathering processes. So my objective is not: learn the definition of weathering and mechanically come up with [a definition of] weathering. So, I can still convince my principal that I have the objectives on the board. So, I would say [it comes down to:] to what extent can I work within the rules where I can convince my principal or my colleagues or whatever that I'm doing what they want me to do, while still doing what I know is best for kids. At the same time at this point my career I would not be afraid to say, “You know what, I don't need to fight these battles. I'm going to go someplace else.” If it was that bad, if the principal was consistently saying, “No, you’re not doing this right; now you’re not doing this right.” I would just leave. (H13, 17:23: 4th order statement)

I realized as long as I had a rationale for what I was doing, it didn't matter if my colleagues respected my decisions. They could not argue with what I was
doing academically and I thought that was cool because it really empowered me. (H10, 25:28: 4th order statement)

**Motivational Factors**

To address research question 2d. participants’ VASSIST and interview responses were analyzed to determine if motivational factors (self efficacy and utility value) were associated with NOS implementation. The following coding schemes were used to analyze interviews and determine the association between NOS implementation and motivational factors.

**Self Efficacy**

Teachers’ self efficacy to teach the NOS was classified as high, medium, or low based upon their interviews. Teachers with a high self efficacy express they are able to teach the NOS with little difficulty or room for improvement. These teachers cite very few operational problems that prevent them from accurately and explicitly teaching the NOS. Those with a medium self efficacy express they are able to effectively teach the NOS but have some difficulty in doing so. For instance, these teachers may state they are unable to help students make conceptual links between science content and the NOS through questioning, and may end up telling students what they want them to know. If teachers express they are limited in their NOS instruction by their understanding of the NOS, this is also considered a medium level of self efficacy. Teachers with a low self efficacy express they have significant problems implementing the NOS. For instance, these teachers may state they are unable to teach the NOS proficiently because they are severely deficient in their understanding of the NOS or how to implement it into their classroom instruction.
Utility Value

Teachers were rated on the level of utility value (high, medium, or low) they expressed during the interviews to teach the NOS. Teachers’ utility value for NOS teaching was also evaluated for the level of congruency (high or low) it had with the ISU-STEP and NOS literature.

Teachers rated as having a high utility value perceived that teaching the NOS has significant importance for students. For instance, teachers may express NOS instruction is crucial for students to accomplish long term goals (e.g. successfully completing a science course, seeing how science relates to everyday life, and/or understanding socio-scientific issues). Those expressing a medium utility value see the NOS as beneficial and somewhat useful for students. However, these teachers do not consider the NOS as a crucial component of science instruction. For instance, they may express the NOS is “a nice thing to know” for students to better understand a particular concept such as evolution, or they may indicate the NOS is important but lacks the utility possessed by science content. Teachers with a low utility value view teaching the NOS as completely unimportant for students. These teachers may state this directly or demonstrate it by not showing evidence the NOS is one of the goals they have for students.

Teachers possessing a utility value that is highly congruent with the ISU-STEP and NOS literature provide deep and compelling reasons to teach the NOS. These teachers effortlessly give more commonly-cited reasons why the NOS should be taught (e.g. NOS instruction helps students understand the content and its relevance). They will also often provide reasons for teaching the NOS that transcend students’ classroom experiences. For
instance, these teachers will provide examples of how teaching the NOS prepares students to participate in a democratic society to solve issues related to science, or they teach the NOS so their students are able to critically evaluate between science and pseudoscience now and later in life. These teachers may also indicate that effectively teaching the NOS promotes student learning about what real knowledge development and learning involves. Additionally, these teachers often provide concrete examples from their own practice and articulate how they achieve the reasons for teaching the NOS mentioned above.

Teachers that express a low congruency in utility value with the ISU-STEP and NOS literature at best provide shallow reasons to teach the NOS. For instance, they may indicate understanding a particular component of the NOS helps students deal with a certain science idea. More frequently, these teachers provide generic reasons for teaching the NOS with very few links to significant examples of practice. For instance, these teachers may indicate teaching the NOS “relates science to students’ everyday lives” or helps them grasp science content.

Affective Factor

To address research question 2e. participants’ interview responses were analyzed to determine if the affective factor of interest in the NOS was associated with their NOS implementation. Interviews were analyzed through the following coding scheme.

Interest in the NOS

Teachers’ interest in the NOS was rated high, medium or low. Teachers rated as having high interest in the NOS would indicate they had enthusiasm to engage in the NOS
beyond utilitarian reasons (i.e. its functionality as a part of effective science teaching). These teachers passionately describe NOS ideas and historical science accounts in a manner that indicates they would pursue this knowledge irrespective of their chosen profession. For instance, teachers rated as having a high interest in the NOS may describe with zeal a discussion they had with colleagues or students about the relationship between science and religion or how science and culture shape each other. These teachers may also provide a list of NOS literature they recreationally read in their own personal time. These individuals may even state directly that they have a high interest in the NOS.

Teachers rated as having a medium interest demonstrated an enthusiasm for the NOS equivalent to any other science idea they teach. For instance, they may only demonstrate an interest in the NOS only because it is a part of effective teaching and/or a part of science. These teachers would probably not invest personal time learning more about the NOS or finding materials to teach the NOS. For instance, they may admit the NOS course in the ISU-STEP was interesting and changed their views, but also admit they have not put additional personal investment into learning the NOS.

Teachers with low interest in the NOS demonstrate no enthusiasm for engaging in NOS ideas. For instance, these teachers may admit they neglect or had forgotten the NOS ideas they learned in the ISU-STEP as a component of science teaching. Furthermore, they may also indicate the NOS is uninteresting compared to science content ideas.

**Teaching Constraints**

To address research question 2f. participants’ VASSIST and interview responses were analyzed to determine if teaching constraints, and participants’ ability to cope with
teaching constraints, were associated with their NOS implementation. Interviews were analyzed and the teaching constraints participants face, and their abilities to cope with them, were determined through the following coding schemes.

**Institutional and Classroom Constraints**

Institutional constraints cited by teachers include but are not limited to: administration, colleagues, parents, performance indicators (e.g.: standards), professional developmental requirements, time constraints, and additional duties. Classroom constraints include but are not limited to classroom management issues, students’ cognitive abilities, and classroom administrative tasks. Teaching constraints participants faced were rated as high, medium, or low. A high rating was granted if the constraints teachers face occurred recently and over a majority of their past professional career, and had the potential to severely impair their practice. For instance, in respect to institutional constraints, teachers may indicate that for the majority of their careers colleagues placed great pressure on them to teach the same content in the same sequence. With regard to classroom constraints, teachers may state classroom management problems caused by the culture of their school have limited their practice the majority of the time they have been there.

Constraints that had the potential to severely impair practice but occurred in the past and/or over a minority of a teacher’s career were rated as medium. For instance, a teacher could indicate they faced harsh constraints from colleagues or students during their first year, but haven’t faced them for a number of years since moving to a different school. Also receiving a medium rating would be if the constraints teachers currently faced were more of a continuous minor hindrance rather than severely limiting their practice. For instance, teachers
may cite the high number of special needs students integrated into their science classes makes certain inquiry activities difficult. In addition, the teacher may be expected by his or her colleagues to give the same content on semester tests but is completely left alone to conduct practice as he or she sees fit. Completely apathetic colleagues and/or administration that provides little support may also be considered a medium institutional constraint.

A low rating was granted if a teacher indicated they did not have classroom or institutional factors that were noticeably constraining. For instance, teachers may say they never experienced irritating or significant problems with classroom management, colleagues, and/or administration over an extended period of time.

**Coping Strategies in Response to Teaching Constraints**

Four codes were attributed to the coping strategies teachers indicated they used in response to teaching constraints. These were *assert*, *navigate*, *avoid*, and *concede*. The first three strategies are taught to ISU-STEP students to help them cope with teaching constraints that may erode reform-based practices, including NOS teaching. The last strategy (concede) is taught to ISU-STEP students as unacceptable. This is because through this strategy teachers have given up reform-based practices because of the constraints they experience. This strategy is often referred to in the program as “punting on students.”

Teachers whose primary strategy was rated *assert* would take proactive and/or reactive direct measures to maintain practice in the face of teaching constraints. For instance, these teachers may respectfully and openly explain their research-based rationale to colleagues or parents. These teachers may also proactively engage classroom management
issues by teaching students how to behave, and then providing a rationale for why that behavior is important for learning.

Rather than confront constraints directly, teachers rated as *navigators* tend to find ways around them. For instance, if pressured to teach like their colleagues, they may “appear” to do so in order to maintain reform-based practices. Instead of distributing consequences, these teachers may restructure lessons that maintain effectiveness, but relieve classroom management problems. Another way they may navigate classroom constraints is by simply modifying and integrating an otherwise valueless professional development requirement into reform-based practice.

Teachers whose primary strategy was to ignore or take no action to mediate the impact of teaching constraints were rated as *avoiders*. This strategy is most applicable to institutional constraints with which the teacher acts as if the constraints were not there. For instance, if a colleague is imposing constraints upon them, these teachers may indicate they simply don’t talk to this individual but still maintain their preferred practices.

The last strategy, *concede*, was assigned if the teacher used a constraint as an excuse to not implement reform-based practices, including teaching the NOS. Teachers choosing this strategy may cite classroom constraints are too great to implement reform-based practices by making statements such as “Students are unable to comprehend the NOS” or “Students misbehave too much for inquiry based practices.” Teachers may also use institutional constraints such as standards and benchmarks or having to teach the same content as colleagues as excuses why they are unable to implement practices taught in the ISU-STEP that include teaching the NOS.
Other Factors Associated with NOS Instruction

Research question 2g. addresses other factors that may be associated with teachers’ NOS implementation in teaching. As this study progressed, two emergent variables became apparent through preliminary data analyses. The first variable presented is a participant’s personal sense of responsibility to implement reform-based and NOS teaching practices. The second is the level of participation in collaborative support groups composed of ISU-STEP faculty and students. VASSIST items and interview questions were developed and administered to determine if these emergent variables were associated with participants’ NOS implementation. Interview responses were analyzed and levels of responsibility to implement reform-based and NOS teaching practices and collaboration with others from the ISU-STEP were determined through the following coding schemes.

Responsibility

Teachers were categorized into one of two levels of responsibility (high or low) to implement reform-based practices including teaching the NOS. A rating of high responsibility was assigned if the teacher was fully committed to implementing reform-based and NOS teaching practices, regardless of the presence of teaching constraints. This responsibility may be in response to extrinsic or intrinsic sources. Extrinsic responsibility includes if the teacher demonstrated guilt, shame, or other emotive accountabilities to outside sources to implement reform-based and NOS teaching practices learned in the ISU-STEP. For instance, these teachers may express they would feel overwhelming guilt if others from the ISU-STEP witnessed them implementing traditional practices and neglecting to teach the
NOS. Intrinsic responsibility was demonstrated if teachers revealed an internal source of obligation to implement reform-based and NOS teaching practices learned in the ISU-STEP. These teachers may cite they implement reform-based and NOS teaching practices because “it is just the right thing to do.”

A rating of low responsibility was granted if teachers showed little or no commitment to implement reform-based and NOS teaching practices they learned in the ISU-STEP. This could be demonstrated if teachers directly state they see little reason to implement these practices. Low responsibility could also be demonstrated if teachers use reasons that do not deter others from the ISU-STEP to account for why they do not implement reform-based practices including NOS teaching. For instance, they may state that reform documents such as the NSES and/or NOS teaching as promoted in the ISU-STEP are too ideal, or teaching constraints are too prohibitive for them to implement reform-based practices including teaching the NOS.

**Support**

Teachers were categorized into one of two levels based on the level of support (high or low) they received from and/or provided to others from the ISU-STEP to implement reform-based and NOS teaching practices. Participants in the high support category consistently collaborated with others from the ISU-STEP in a manner that it significantly benefitted the reform-based and NOS teaching practices of those parties involved. Teachers in the low support category did not consistently engage in significant collaborations with others from the ISU-STEP. Therefore, these teachers did not benefit from collaborations with others from the ISU-STEP.
Additional Analyses and Considerations

In addition to the coding of interviews, memos were written to capture the decisions and thinking by the researcher. Although these memos are not presented in this work, they enabled the researcher to determine patterns pertaining to participants’ NOS teaching practices and factors associated with those practices. Additionally, these notes provide a trail of logic from data, through research decisions, to conclusions (Krathwohl, 1998; Merriam, 2002; Strauss & Corbin, 1998).

As indicated before, based on classroom observations and artifacts each participant’s composite NOS implementation in the classroom was categorized as high, medium, or low. Several simple tables were created to aid in determining the association of these teachers’ NOS implementation with factors that may impede or facilitate it (Miles & Huberman, 1994). The tables were organized according to the level in which teachers implemented the NOS, ranging from high to low NOS implementers, from top to bottom. These tables aided in the data reduction process and make evident the connections between participants’ NOS implementation levels and factors associated with those levels. Quotations accompany tables to provide context and make evident distinctions and patterns within and between high, medium, and low NOS implementers’ responses. All quotations from participants’ interviews are cited within parentheses using the teachers’ pseudonym, primary document number, and paragraph number as assigned in ATLAS.ti.

The research questions proposed in this study were developed to provide insight towards the development of a multivariate model of several interconnected factors that impact teachers’ NOS implementation. Considered as a whole, this dissertation is
determining which of these factors impact the final desired outcome of NOS instructional practices, and propose how they relate to one another.

Findings from each research question were utilized to arrange the variables they address in a proposed model that holistically accounts for the rich data present in this study. This model can hopefully serve as a guide for future research to test these variables in relation to one another, determine their predictability on NOS implementation, and generalizability of the model as a whole. The final goal is to better inform teacher education programs where their efforts can best be placed to ensure that the NOS is not only taught to preservice teachers, but also translates to practice.

Important to note is that factors not being accounted for in this study may impact teachers’ instructional practices. For instance, constraining factors present in this study are perceived as very real to the participants, but the program addressed the very constraints and issues they cite as prohibiting them from teaching in a manner reflective of the program. Thus, the researcher assumes that teachers who rely upon such rationales have a lower sense of personal responsibility to implement practices promoted in the program. The reader is cautioned not to interpret findings for this, or any other variable, as a personal accusation that a teacher does not care about students. Other issues in participants’ lives may account for why teachers feel that they cannot implement what they learned. For example, they may be dealing with health issues, family issues, etc. that place teaching as a lower priority than other pressing needs. The researcher fully recognizes that teaching in a manner promoted in the ISU-STEP is not at all easy, requires significant time, effort, and commitment, and may be met with fierce resistance in schools.
CHAPTER 4: RESULTS AND ANALYSIS

Summary of Problem

The nature of science has been considered an important component of science education for approximately one hundred years (Central Association for Science and Mathematics Teachers, 1907). More recently, reform documents have included compelling rationales and specific guidelines for NOS instruction (AAAS, 1990; 1993; NSES, 1996). Although this is the case, science teachers still fail to accurately and explicitly teach the NOS (Duschl, 1985; King, 1991; Abd-El-Khalick et al., 1998; Clough, 2006). Reasons provided in the literature why teachers fail to effectively teach the NOS include: inadequate NOS knowledge, low value for NOS instruction, classroom management concerns, content coverage requirements, perceptions of students, instructional intentions, and pedagogical abilities (Lantz & Kass, 1987; Duschl & Wright, 1989; King, 1991; Hodson, 1993; Lederman, 1995; Abd-El-Khalick et al., 1998; Lederman, 1999; Schwartz & Lederman, 2002; Clough, 2006). Although the reasons provided in the literature appear to account for this phenomenon, few practicing teachers have had a course in the NOS and little is known about how inservice teachers who had a NOS course as part of preservice preparation address the NOS, if at all, when they enter the complex reality of the classroom.

More empirical research is needed to accurately determine factors that influence practicing teachers’ NOS instruction (Abd-El-Khalick & Lederman, 2000; Lederman, 2007). Furthermore, teachers selected for study should come from very similar backgrounds that facilitate optimal abilities to implement effective NOS instruction. This would help ensure
factors associated with NOS implementation, that are beyond deficiencies and/or variances in teacher preparation, can be accurately determined. The goal of this study is to determine the extent to which teachers who had a NOS content/pedagogy course in their preservice program implement NOS instruction in science classes, and determine factors associated with varying levels of NOS implementation. To determine NOS implementation levels, teachers’ practices were investigated by collecting classroom observations and artifacts. Teaching practices, artifacts, interviews, and questionnaires were then analyzed to determine factors associated with NOS implementation practices. By understanding factors associated with teachers’ NOS implementation practices, recommendations can be made to inform teacher professional development (including preservice and inservice) to improve NOS instruction.

**Review of Research Questions**

This study addressed the following research questions:

1. NOS teaching practices exhibited by ISU-STEP graduates:
   a. To what extent do teachers explicitly and reflectively teach the NOS?
   b. To what extent do teachers accurately convey the NOS?
   c. To what extent do teachers contextually and decontextually teach the NOS?
   d. To what extent do teachers explicitly scaffold along the decontextualized to contextualized NOS instruction continuum?

2. Factors associated with varying levels of NOS instruction by ISU-STEP graduates.
   a. To what extent is an understanding of the NOS associated with teachers’ implementation of the NOS in instruction?
   b. To what extent are classroom teaching practices associated with teachers’ implementation of the NOS in instruction?
   c. To what extent are cognitive factors (understanding of NOS teaching, orders of consciousness, considerations of how people learn, self reflection) associated with teachers’ implementation of the NOS in instruction?
d. To what extent are motivational factors (self efficacy, utility value) associated with teachers’ implementation of the NOS in instruction?

e. To what extent is the affective factor of interest in the NOS associated with teachers’ implementation of the NOS in instruction?

f. To what extent are teaching constraints (classroom and institutional constraints) associated with teachers’ implementation of the NOS in instruction?

g. To what extent are other factors associated with teachers’ implementation of the NOS?

Data Collection and Coding

This qualitative study followed a naturalistic inquiry approach to investigate 13 former ISU-STEP students’ NOS teaching practices and factors associated with those practices. All participants except H5 completed all aspects of the ISU-STEP (i.e. NOS course, multiple science methods course – each with a required secondary school science experience). Participant H5 did complete the NOS course, one science methods course, and a course addressing the restructuring of science activities. All participants taught secondary science classes in high schools located in the Midwestern United States and were in their second to fourteenth year of professional practice. Data collection included classroom observations, artifacts (e.g. lesson plans, handouts), questionnaires and interviews.

NOS Implementation

Classroom Observations

Classroom observations were conducted to determine teachers’ NOS implementation and inquiry based practices. Observation days were often selected by the teacher. Some teachers scheduled observations to avoid days in which they felt the students may not optimally perform such as conference days, early dismissals and Homecoming activities.
Many teachers also encouraged visits on days in which the students would be doing something “interesting.”

Multiple observations were conducted for each teacher to ensure a representative picture of classroom practices. All teachers in this study, except one, were observed a minimum of three times. One teacher was observed only twice. All but two of the teachers in this study instruct more than one science discipline, and/or level of course difficulty within a science discipline (e.g. general chemistry and advanced chemistry). When possible, all observations of each teacher were conducted in the same course difficulty and science discipline. Additionally, when possible, observations occurred in disciplines with at least two participants teaching them. These measures facilitated comparisons across teachers by reducing possible differences in NOS implementation due to subject matter focus and difficulty.

Artifacts

Classroom artifacts were collected by the researcher approximately every two weeks from early-September to early-January. Other methods for artifact collection included electronic submission and downloading artifacts from teachers’ web sites. To ensure a high degree of triangulation and confidence in study results, artifacts that were collected and analyzed derived from the same courses that were observed.

The number of artifacts submitted by teachers varied widely with totals ranging from 22 to 104 (Table 6). These included assignments, readings, labs, activities, and Power Point presentations. Direct portrayals of the NOS appeared in 11% to 59% of the artifacts examined for each participant. The number of artifacts collected and/or the percentage of
artifacts that portrayed the NOS were not necessarily an indicator of NOS implementation levels. Some teachers had a few long-term assignments such as term papers that deeply addressed several NOS ideas while others had many artifacts such as “bell ringers” that portrayed the NOS in smaller increments and more superficially. Rather than focusing on the number of artifacts collected, or the percentage that directly portrayed the NOS, artifacts were analyzed to determine consistency and depth of NOS instruction over the course of the study and to provide triangulation with other data sources.

**NOS-COP**

The NOS-COP sub-items used to assess NOS instruction appear in Tables 2 and 3. Table 2 presents the coding scheme for NOS-COP sub-items one and two that determine the extent that the lesson structure/artifacts had *opportunities* for accurately and explicitly addressing the NOS. Table 3 presents the coding scheme for NOS-COP sub-items 3-8 that determine the extent that the instructor and/or lesson structure/artifacts actually *did* explicitly, accurately, and reflectively address the NOS. Notably, exemplars from observations are presented with the participant’s moniker and date observed in parentheses (e.g. H9, 10/29/09). Exemplars from artifacts are accompanied with the participant’s moniker and the number of the artifact in parentheses (e.g. H9, A:1).

The NOS-COP (*Appendix B*) was developed prior to the analysis of classroom observations and artifacts and served as a general framework for the coding schemes presented in Tables 2 and 3. Exemplars were added in Tables 2 and 3 as observations and artifacts were collected and analyzed. This ensured transparency of the data and a high level of consistency in the coding of subsequently collected observations and artifacts.
Table 2. Coding scheme for determining the extent that the lesson structure/artifacts had opportunities for accurately and explicitly addressing the NOS.

<table>
<thead>
<tr>
<th>Score</th>
<th>Observations</th>
<th>Artifacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Evident elements of inquiry are consistent in the lesson (e.g. learning cycle, interactive discussions that draw on previous activities and scaffold into new ones)</td>
<td>Inquiry consistent in artifacts. (e.g. inquiry activities coupled with open ended questions)</td>
</tr>
<tr>
<td>3</td>
<td>Approximately equal amounts inquiry and traditional instruction (e.g. lecture before inquiry activity, students being told results during inquiry activity, the entire class comprising of interactive discussion)</td>
<td>Approximately equal amounts inquiry and traditional instruction (e.g. fact recall) evident.</td>
</tr>
<tr>
<td>1</td>
<td>No inquiry evident in lesson (e.g. lecture with no interaction with students).</td>
<td>No inquiry evident (e.g. artifacts primarily consist of fact recall tests and assignments).</td>
</tr>
</tbody>
</table>

1. Science was taught through inquiry.

2. Historical/contemporary accurate examples of science and/or scientists were incorporated in the lesson.
Table 3. Coding scheme for determining the extent that the instructor and/or artifacts actually did accurately, explicitly, and reflectively address the NOS.

<table>
<thead>
<tr>
<th>Score</th>
<th>Observations</th>
<th>Artifacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. NOS ideas addressed were accurate?</td>
<td>NOS ideas are highly and consistently accurate.</td>
<td>NOS ideas are highly and consistently accurate.</td>
</tr>
<tr>
<td>5</td>
<td>NOS ideas are highly and consistently accurate. Exemplar: “How do scientists go about figuring out information, or an argument they are having? Why can’t we just vote in science?” (H1, 10/01/09)</td>
<td>Exemplar: “In what sense are scientific laws and theories different types of knowledge? In what sense are they related?” (H5, A3)</td>
</tr>
<tr>
<td>3</td>
<td>Minor inaccuracies present. Exemplar: “If you lie you will not do science again as science will not tolerate lying. Science relies on truthful evidence and we rely on these numbers as evidence in this class.” (H10, 9/23/09)</td>
<td>Minor inaccuracies present. Exemplar: “Researchers in the late 1800’s discovered that something smaller than bacteria could cause disease.” (H10, A1)</td>
</tr>
<tr>
<td>1</td>
<td>Consistent and/or major inaccuracies present. Exemplar: “Robert Hooke was doing this experiment of cork.” “Many people won’t buy it unless there is proof.” (H8, 9/23/09)</td>
<td>Consistent and/or major inaccuracies present. Exemplar: “Why is it extremely important that scientists do not allow past experiences, other people’s ideas or what they want to be the answer to influence their observations?” (H8, A5)</td>
</tr>
<tr>
<td>4. Students’ attention was explicitly and reflectively drawn to how classroom instructional practices reflect or distort the NOS.</td>
<td>Attention drawn explicitly, reflectively and deeply. Exemplar: “How is a law different than a theory? Think of how when we observed falling bodies and how they fit within those patterns. How did we attempt to explain those patterns?” (H5, 10/30/09)</td>
<td>Attention drawn consistently, explicitly, reflectively and deeply. Exemplar: “To what extent do you think that the way we progressed through these demonstrations modeled authentic scientific activity?” (H5, A2)</td>
</tr>
</tbody>
</table>
Table 3. (continued)

<table>
<thead>
<tr>
<th>Score</th>
<th>Observations</th>
<th>Artifacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Attention is limited in explicitness, reflectivity, and/or depth.</td>
<td>Attention is limited in explicitness, reflectivity, depth, and/or consistency.</td>
</tr>
<tr>
<td></td>
<td>Exemplar: In response to student mistakes in an inquiry based lab: “Having an issue with the validity of data is like an issue in science.” (H10, 9/23/09)</td>
<td>Exemplar: “What previous knowledge or experiences did you think of while writing your story? How might previous knowledge help and how might it hinder an investigation?” (H4, A4)</td>
</tr>
<tr>
<td>1</td>
<td>Non-existent</td>
<td>Non-existent</td>
</tr>
</tbody>
</table>

5. Students’ attention was explicitly and reflectively drawn to the NOS in the context of science content being taught.

<table>
<thead>
<tr>
<th>5</th>
<th>Attention drawn explicitly, reflectively and deeply.</th>
<th>Attention drawn consistently, explicitly, reflectively and deeply.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exemplar: In relation to glacially carved valleys: “Why should we not use supernatural ideas such as Paul Bunyan to explain the natural world?” (H13, 01/28/10)</td>
<td>Exemplar: “Lyell is studying nature. How is his work different from the idea that scientists do all of their work in a lab? In what way is his work similar?” (H13, A1)</td>
</tr>
<tr>
<td>3</td>
<td>Attention is limited in explicitness, reflectivity, and/or depth.</td>
<td>Attention is limited in explicitness, reflectivity, depth, and/or consistency.</td>
</tr>
<tr>
<td></td>
<td>Exemplar: Stating: “Schleiden and Schwann were sitting having dinner and then decided all things were made of cells and they made the cell theory” with no questions afterwards (H8, 9/23/09)</td>
<td>Exemplar: Asking: “What did John Bennet Lawes create, and what effects has it had on the world?” with no focus on a specific NOS theme (H6, A4)</td>
</tr>
<tr>
<td>1</td>
<td>Non-existent</td>
<td>Non-existent</td>
</tr>
</tbody>
</table>
6. Students’ attention was explicitly and reflectively drawn to NOS ideas implicit in inquiry activities.

<table>
<thead>
<tr>
<th>Score</th>
<th>Observations</th>
<th>Artifacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Attention drawn explicitly, reflectively and deeply. Exemplar: During an inquiry activity with dichotomous keys: “Think about the dichotomous keys in relation to plants and animals. To what extent do you think they were invented or discovered?” (H13, 01/28/10)</td>
<td>Attention drawn consistently, explicitly, reflectively and deeply. Exemplar: “How does this activity relate to the scientists we have learned about in this case study? What roadblocks did you hit while creating your thermometer? How do you know your thermometer really works? How might a scientist have figured out if their tool actually worked?” (H7, A11)</td>
</tr>
<tr>
<td>3</td>
<td>Attention is limited in explicitness, reflectivity, and/or depth. Exemplar: After lecturing on Mendeleev using patterns to sort elements asking in an inquiry based periodic table activity: “What characteristics did you use for sorting the cards? What patterns appear in your arrangements?” (H7, 9/23/09)</td>
<td>Attention may exclude explicitness, reflectivity, depth, or consistency. Exemplar: Only explicitly addressing NOS superficially in initial decontextualized activities and then not embedding NOS in later contextualized activities. E.G.: Asking: “Why are models like this used in science?” solely on an introductory tube lab (H2, A4).</td>
</tr>
<tr>
<td>1</td>
<td>Non-existent</td>
<td>Non-existent</td>
</tr>
</tbody>
</table>

7. NOS ideas were explicitly and reflectively scaffolded back and forth along the decontextualized to highly contextualized NOS instructional continuum

<table>
<thead>
<tr>
<th>Score</th>
<th>Observations</th>
<th>Artifacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Scaffolds constructed explicitly, reflectively and deeply along entire continuum. Example: “To what extent do our investigations with falling bodies relate to the tube activity? How did you have to use imagination and creativity in both of these investigations? In what ways was this like how Galileo used creativity and imagination?” (None recorded)</td>
<td>Scaffolds consistently constructed explicitly, reflectively and deeply along entire continuum. Exemplar: “In relation to quote from Einstein on studying closed systems: Using your own words paraphrase what Einstein is saying. In what ways is what Einstein saying relate to the tube activity? Give other examples from science that illustrate this idea.” (H3, A4)</td>
</tr>
</tbody>
</table>
Table 3 (continued)

<table>
<thead>
<tr>
<th>Score</th>
<th>Observations</th>
<th>Artifacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Scaffolds may be superficial</td>
<td>Scaffolds may be superficial, inconsistent</td>
</tr>
<tr>
<td></td>
<td>or incomplete (e.g. decontextualized to moderately contextualized).</td>
<td>or incomplete (e.g., decontextualized to moderately contextualized).</td>
</tr>
<tr>
<td></td>
<td>Exemplar: Asking: “Why did we</td>
<td>In inquiry based activity with density</td>
</tr>
<tr>
<td></td>
<td>need to make models of the</td>
<td>asking: “How does this lab compare to how real science works? How is this lab</td>
</tr>
<tr>
<td></td>
<td>tube in relation to making</td>
<td>like the tube activity?” and never linking the experience to real scientists. (H1, A6)</td>
</tr>
<tr>
<td></td>
<td>models of the moon, sun, and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>earth?” with no reference to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>real scientists. (H1, 10/01/09)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Non-existent</td>
<td>Non-existent</td>
</tr>
</tbody>
</table>

8. Students were required to reflect on explicitly identified NOS ideas in the lesson.

5 Reflection required was explicit and in depth.
Exemplar: In relation to models of the solar system: “Why do we still use this model even though it is flawed? Why do scientists use models even if they are not fully accurate? Why did we need to make models of the tube?” H1, 10/01/09

Reflection required was consistently explicit and in depth.
Exemplar: “It is often claimed scientific thinking is different than everyday thinking? To what extent do the force demonstrations and your experiences interpreting them support this claim? Be specific and give examples.” (H5, A2)

3 Reflection required may lack depth and or explicitness.
Exemplar: Asking surface level questions such as: “Are models in science always the exact reality of what is out there?” (H7, 9/23/09)

Reflections required may lack consistency, depth and or explicitness.
Asking: “Why do scientists use scientific notation?” on a test (H2, A2).

1 Non-existent Non-existent

As mentioned in Chapter 3, sub-items 3-8 were averaged to develop a NOS implementation score for each lesson observed. These scores were then averaged to develop a mean NOS implementation score for each participant’s lessons collectively. A mean NOS
artifact implementation score was also calculated by averaging sub-items 3-8 for each participant’s NOS-related artifacts as a whole. Finally, mean NOS implementation scores for each participant’s lessons and artifacts were averaged to create a composite NOS implementation score.

For the purposes of this study, each teacher’s levels of NOS implementation based on average classroom observation, artifact, and composite NOS implementation scores were rated as high, medium, and low. The cutoff values for NOS implementation levels were: 1 to below 2.3 = low; 2.3 to below 3.6 = medium; above 3.6 = high. The rationale for parsing the three levels along a 5 point scale, starting at 1 (no NOS implementation) and increasing in approximate increments of 1.3, was to retain congruency with the NOS-COP and LSC-COP scales.

**VASSIST**

Many of the responses participants provided on the VASSIST questionnaire yielded little clarity when analyzed. Fraser (2007) articulated the use of questionnaires in classroom learning research can be valuable for making constructs and patterns more evident. Conversely, their use can also obscure important patterns and phenomena that may be more evident through employing qualitative methods such as interviews. Similarly, Lederman and O’Malley (1990) explained questionnaires on the NOS provide overly generalized results which lack correlation to richer themes evident in interview responses. Only the items that lent clarity and richness to participants’ interview responses and/or were shown to be valid from prior research (Saderholm, 2007; Liang et al., 2008; Clough et al., 2010) were fully
analyzed and addressed in the findings and conclusions sections of this final product (See Table 4).

<table>
<thead>
<tr>
<th>Items</th>
<th>Variable</th>
<th>Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUSSI items 1A-10D, 12A, 12B, 13C, 13E, 14A, 14B, 14C, 14D</td>
<td>NOS understanding</td>
<td>Yes</td>
</tr>
<tr>
<td>19A, 19B, 19E</td>
<td>Orders of consciousness</td>
<td>No</td>
</tr>
<tr>
<td>20A-E</td>
<td>Constraint coping strategy</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Collaborations/support ISU-STEP</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Due to already being established as highly valid in prior science education research (Saderholm, 2007; Liang et al., 2008; Clough et al., 2010), SUSSI and SUSSI-like items from the VASSIST were retained and presented in the analysis and conclusions for this study. Also, items measuring the teachers’ self reflection of NOS implementation and levels of collaboration and support with others from the ISU-STEP were retained. These items were retained because their validity was determined through a rich degree of context provided by direct comparability with interview responses and observed teaching performance. For instance, item 12B states: “I explicitly address the nature of science throughout the school year”. Participants’ responses to this statement, as well as others measuring self-reflection abilities, were able to be directly compared to artifacts, classroom observations, and
interview responses. This provided context of how accurately the teacher self assessed practice through the VASSIST questionnaire.

VASSIST items associated with the variables teaching constraints, coping strategy used in response to teaching constraints, orders of consciousness, and responsibility were not used for the data analysis and conclusions in this study. Responses to these items revealed they were inconclusive, non-descript, and sometimes inaccurate in respect to interview findings. Several potential explanations for this can be proposed. First, the low sample size (N=13) may have reduced the chance for discernable patterns to emerge in relation to the variables measured by these VASSIST items.

Second, teachers may have concealed potentially embarrassing or sensitive information when completing these VASSIST items that they were unable to conceal during the interview. For instance, all of the low implementers answered “disagree” or “strongly disagree” in response to the statement: The outcome expectations of my school administration limit the way I teach science. Conversely, these participants indicated through rich descriptions in interviews that content policies enforced by administration limited their NOS and reform-based teaching.

Lastly, the VASSIST items associated with these variables lacked context and/or qualitative prompts for teachers to frame responses. This may have limited these items’ ability to illicit accurate, deep, and descriptive responses from participants. For instance, item 15C states: “When my ideas regarding effective science teaching deviate from my colleagues, I feel uncomfortable sharing my views.” This statement alone does not provide context for why the teacher feels the way they do, or how they respond to the situation. In
addition, this item does not prompt the teacher to provide detailed descriptions of how he or she frames this issue. Additionally, context for how the participant handles this situation cannot be gained through direct observation. Consequently, this item is of limited utility when trying to determine one’s order of consciousness. Conversely, if teachers were unsure of the context surrounding this question when asked in interviews, they can ask for clarity or provide the contextual landscape themselves. Therefore, the findings associated with these variables were primarily derived through analysis of rich interview data.

Findings

**NOS Implementation Practices of Former ISU-STEP Students**

**NOS Implementation through Classroom Observations**

Based solely on classroom observations, of the 13 teachers in the study, 3 implemented the NOS at a high level, 4 at a moderate level, and 6 at a low level. Table 5 shows NOS-COP ratings for classroom observations with participants in descending order from high NOS implementers to low NOS implementers.

**Opportunities for NOS Implementation**

The first two columns in Table 5 (“Inquiry and Historic” categories) address the opportunities that a lesson had for addressing the NOS. As can be observed in the table, the observed lessons varied greatly in their opportunities for addressing the NOS through inquiry based practices and/or historical and contemporary examples. 67% of the total lessons observed were rated 3 or above on the NOS-COP for being structured in a manner in which
opportunities existed to explicitly and reflectively address the NOS through inquiry based practices. These opportunities ranged from including some elements of inquiry based teaching practices (e.g. interactive discussions) to being entirely inquiry based (e.g. effective learning cycle activities). For instance, in teacher H5’s 10/22/09 lesson (coded as a 5) addressing forces, several inquiry based activities and demonstrations were used to scaffold into interactive discussions pertaining to force diagrams. This lesson had students investigating phenomena much like real scientists, and therefore possessed more opportunities to explicitly and reflectively address the NOS in the context of inquiry than the lesson conducted by H13 on 1/23/10. This lesson was rated as a 3 because it was composed mainly of students engaged in an interactive discussion about glaciers and erosion with no hands-on activities.

Unfortunately, over 20% of the lessons observed were structured in a manner in which no inquiry opportunities existed (rating = 1; “Inquiry” category) to integrate the NOS. These lessons primarily consisted of teaching practices such as lecture, almost no questioning to generate student interaction, and/or cookbook activities. For instance, the lesson conducted by H6 on 09/29/09 consisted of students sitting through a lecture on punnet squares with little interactive discussion and no activities.

Only 21% of the lessons observed had historical examples present that provided significant opportunities (rated ≥4; “Historic” category) to explicitly and reflectively instruct on the NOS. Notably, only two lessons were rated as a 5 on this measure. In both of these lessons the historical account was accurate, relevant, and effectively integrated in the lesson. Conversely, 67% of the lessons observed were rated as a “1” as they did not utilize historical
and/or contemporary science examples in a manner that would create clear opportunities to address the NOS.

Interestingly, both of the lessons that rated a 5 for integrating historical and contemporary examples (“Historic” category) also rated 3 or higher for exhibiting opportunities to effectively instruct on the NOS through inquiry (“Inquiry” category). For instance, on 09/24/09 teacher H7 utilized a historical account of Mendeleev to scaffold into an inquiry based activity in which students were to collaboratively construct a decontextualized periodic puzzle. The account outlined Mendeleev’s imagination, creativity, and human struggles; while the activity was structured to mimic his experience in constructing the periodic table.

**Teachers’ NOS Implementation Practices**

In Table 5, six categories (“Accurate” to “Reflect”) address the extent teachers actually implemented the NOS during classroom observations. The overall NOS score for each lesson was calculated by averaging the scores for these six implementation categories. Inspection of Table 5 shows that a teacher’s overall NOS implementation score for a lesson is associated with the way that lesson was structured by the teacher. All overall NOS scores of 2.3 or above (i.e. medium or high NOS implementation) also scored 3 or above on at least one of the categories (“Inquiry and Historic” categories) addressing opportunities present in the lesson for effectively addressing the NOS. Conversely, lessons that received low ratings for having few opportunities to address the NOS also scored low on almost every indicator of NOS implementation practices. Only two of the thirty-one lessons coded 3 or higher for opportunities to integrate the NOS (“Inquiry and Historic” categories) had low (≤ 2)
explicit/reflective NOS implementation ratings. These lessons characterized by “missed opportunities” to implement the NOS were conducted by teachers who consistently received low NOS implementation ratings for other teaching observations.

Teachers varied greatly in the extent they implemented the NOS accurately, explicitly, and reflectively during observations (Table 5). Teachers that received medium and high mean NOS implementation ratings (2.3 or above) for their lessons were consistently accurate in their portrayals of the NOS. Accuracy scores ranged from 4 to 5 (“Accurate” category) in all but one out of twenty one lessons conducted by these teachers. This is a stark contrast to teachers who received low mean NOS implementation ratings. These teachers received an accuracy rating of 2 or below (“Accurate” category) in thirteen of eighteen lessons they conducted. In addition, 44% of the lessons conducted by low implementers received a rating of N/A for accuracy because the NOS was not explicitly addressed. This resulted in those particular lessons receiving low scores for the remaining indicators of explicit/reflective NOS instruction.

Only two high NOS implementers (H13 and H5) required students to consider in great depth how the NOS was portrayed through instructional practices (“Reflect/distort” category). Other teachers in the high and medium implementation categories drew their students’ attention to how inquiry based activities reflected the NOS, but only superficially though questions such as (e.g. Why don’t we vote in here? Why do we come to consensus instead? How is this like science?). Teachers in the low implementation category were rarely observed explicitly relating classroom activities to the NOS. If attempts were made they consisted of the teacher making superficial statements or shallow questions primarily
directed at how the lesson or activity resembled science (e.g. How is this like what scientists do? Why is getting the wrong answer not necessarily a bad thing in science?). None of the teachers observed in this study made explicit attempts to have students reflect how classroom activities distort the nature of science.

High NOS implementers were observed to be very proficient in utilizing opportunities present in inquiry based activities and science content to address the NOS. All lessons conducted by these teachers received ratings of 4 or higher for drawing students’ attention explicitly and reflectively to NOS ideas in either the context of inquiry and/or science content (Table 5; “NOS in content and inquiry” categories). Interestingly, 67% of high NOS implementers’ lessons received a score of 3 or higher for both of these categories. This indicates these teachers integrated inquiry and science content in a manner that allowed them to draw their students’ attention to the NOS. This contrasts with medium and low NOS implementers who only achieved these simultaneous ratings in 17% of their lessons.

Intuitively, these findings illustrate why high NOS implementers also had higher scores for requiring students to reflect on explicitly addressed NOS themes (“Reflect” category) — they purposely created these opportunities and took full advantage of them! All but one of the lessons observed for high NOS implementers scored a 4 or 5 on this scale.

Medium NOS implementers had students to a lesser extent reflecting on explicit NOS themes present in the lesson (“Reflect” category). Only five out of twelve lessons rated as medium NOS implementation (collectively shared by H4 and H5) received ratings of 4 or higher on this scale. All other medium NOS implementers’ lessons received a two or three on
this scale because students were only required to reflect superficially on explicitly identified NOS ideas.

Only one low NOS implementer (H6) required students to significantly reflect (rated 4; “Reflect” category) on explicit NOS ideas present in two of the lessons s/he gave. Conversely, NOS ideas were not identified in 44% of the low NOS implementers’ lessons, therefore making it impossible for students to reflect on them. This resulted in these lessons receiving a rating of not applicable (N/A) in regards to students being required to reflect on explicitly addressed NOS themes.

Table 5 shows all teachers in this study performed the poorest in scaffolding NOS ideas back and forth from decontextualized to highly contextualized in their lessons (“Scaffold” category). Although high NOS implementers outperformed medium and low NOS implementers in this aspect, none of the lessons appeared to have evidence of NOS ideas being scaffold fully along the decontextualized to moderately contextualized to highly contextualized continuum. High NOS implementers did achieve moderate scaffolds in 67% of their lessons (rated ≥3; “Scaffold” category). In these instances teachers scaffolded from decontextualized to moderately contextualized, or from moderately to highly contextualized NOS ideas. Collectively, medium and low NOS implementers completely neglected (rated 1) to scaffold along the decontextualized to highly contextualized continuum in 77% of their lessons.
Table 5. Classroom observation ratings using the NOS-COP ranging from low (1) to high (5) NOS implementation.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Date</th>
<th>Opportunities To Address NOS</th>
<th>NOS Implementation Practices</th>
<th>NOS lesson score</th>
<th>Mean NOS score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Inquiry</td>
<td>Historic</td>
<td>Accurate</td>
<td>Reflect/distort</td>
</tr>
<tr>
<td>H13</td>
<td>01/27/10</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>H13</td>
<td>01/28/10</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>H13</td>
<td>01/29/10</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>H1</td>
<td>10/01/09</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>H1</td>
<td>10/02/09</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>H1</td>
<td>10/06/09</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>H7</td>
<td>09/24/09</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>H7</td>
<td>10/06/09</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>H7</td>
<td>10/06/09</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>H4</td>
<td>10/22/09</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>H4</td>
<td>10/23/09</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>H4</td>
<td>10/30/09</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>H5</td>
<td>10/20/09</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>H5</td>
<td>10/22/09</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>H5</td>
<td>10/23/09</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>H5</td>
<td>10/30/09</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Participant</td>
<td>Date</td>
<td>Opportunities To Address NOS</td>
<td>NOS Implementation Practices</td>
<td>NOS lesson score</td>
<td>Mean NOS score</td>
</tr>
<tr>
<td>------------</td>
<td>------------</td>
<td>-------------------------------</td>
<td>-------------------------------</td>
<td>------------------</td>
<td>---------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inquiry Historic</td>
<td>Accurate Reflect/ distort NOS in content NOS in inquiry Scaffold Reflect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H12</td>
<td>11/09/09</td>
<td>2 3</td>
<td>4 2 4 N/A 2 3</td>
<td>3.0</td>
<td>2.9</td>
</tr>
<tr>
<td>H12</td>
<td>11/11/09</td>
<td>5 1</td>
<td>4 3 N/A 4 1 2</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>H3</td>
<td>10/20/09</td>
<td>4 1</td>
<td>4 1 N/A 3 2 3</td>
<td>2.6 2.3</td>
<td></td>
</tr>
<tr>
<td>H3</td>
<td>10/23/09</td>
<td>4 1</td>
<td>2 2 N/A 3 1 2</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>H3</td>
<td>10/30/09</td>
<td>5 1</td>
<td>4 2 N/A 2 1 2</td>
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<td>4 4</td>
<td>4 2 3 3 3 3 4</td>
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<td></td>
</tr>
<tr>
<td>H6</td>
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<td>3 1 3 1 1 4</td>
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</tr>
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<tr>
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<td>4 3 3 4 2 3</td>
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<td>Date</td>
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<td>NOS Implementation Practices</td>
<td>Mean NOS Score</td>
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<td>-----------------------------</td>
<td>----------------</td>
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<tr>
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<td>Inquiry</td>
<td>Historic</td>
<td>Accurate</td>
<td>Reflect/ distort</td>
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</tr>
<tr>
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<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>H11</td>
<td>11/11/09</td>
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<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>H11</td>
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<td>1</td>
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<td>1</td>
</tr>
<tr>
<td>H9</td>
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<td>2</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>H9</td>
<td>09/25/09</td>
<td>2</td>
<td>4</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>H9</td>
<td>09/29/09</td>
<td>1</td>
<td>1</td>
<td>N/A</td>
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</tbody>
</table>
NOS Implementation through Classroom Artifacts

Based solely on an analysis of classroom artifacts, of the thirteen teachers in the study, four implemented NOS at a high level, five at a moderate level, and four at a low level. Table 6 shows NOS-COP ratings for classroom artifacts with participants ordered top to bottom, from high NOS implementation to low NOS implementation. With few exceptions teachers’ NOS-COP scores for artifacts followed the same trends as NOS-COP scores for classroom observations (Table 5). The NOS related and unrelated artifacts from high and medium NOS implementers were more inquiry based and contained more historical and/or contemporary examples of science than artifacts from low NOS implementers.

High NOS Implementers

Each high NOS implementers’ collective set of classroom artifacts scored 4’s and 5’s for possessing opportunities to address the NOS through inquiry (“Inquiry” category) and historical and contemporary examples (“Historic” category). This group also scored 4’s and 5’s in categories pertaining to whether their artifacts that expressed the NOS did so accurately (“Accurate” category), explicitly, and reflectively in the context of science content (“NOS in content” category) and inquiry (“NOS in inquiry” category). The high NOS implementers that received ratings of 4 in the “Accurate” category did so because of the presence of a few minor inaccuracies (e.g. conveying a naïve view of discovery and ignoring the inventive character of scientific knowledge) embedded within accurate NOS ideas.
Table 6. Ratings for classroom artifacts using the NOS-COP.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Number artifacts</th>
<th>NOS artifacts</th>
<th>Inquiry</th>
<th>Historic</th>
<th>Accurate</th>
<th>Reflect/distort</th>
<th>NOS in content</th>
<th>NOS in inquiry</th>
<th>Scaffold</th>
<th>Reflect</th>
<th>NOS score</th>
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<td>81</td>
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<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4.3</td>
</tr>
<tr>
<td>H1</td>
<td>23</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>4</td>
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<td>4</td>
<td>4</td>
<td>4.5</td>
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<tr>
<td>H5</td>
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<td>7</td>
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<td>4.2</td>
</tr>
<tr>
<td>H7</td>
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<td>12</td>
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<td>4</td>
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<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3.7</td>
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<td>H4</td>
<td>26</td>
<td>9</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>2</td>
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<td>2</td>
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<td>3.5</td>
</tr>
<tr>
<td>H3</td>
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<td>3</td>
<td>2</td>
<td>2</td>
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<td>4</td>
<td>3.3</td>
</tr>
<tr>
<td>H10</td>
<td>38</td>
<td>15</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>2</td>
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<td>2.7</td>
</tr>
<tr>
<td>H12</td>
<td>35</td>
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<td>4</td>
<td>5</td>
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<td>3</td>
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<td>2</td>
<td>3</td>
<td>2.7</td>
</tr>
<tr>
<td>H6</td>
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<td>10</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>2</td>
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<td>2.5</td>
</tr>
<tr>
<td>H8</td>
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<td>1</td>
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<td>1</td>
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<td>2.0</td>
</tr>
<tr>
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<td>49</td>
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<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td>H9</td>
<td>48</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1.3</td>
</tr>
<tr>
<td>H11</td>
<td>36</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1.0</td>
</tr>
</tbody>
</table>
With the exception of H5, all high NOS implementers’ artifacts included decontextualized NOS activities and lessons reflective of those demonstrated in the ISU-STEP NOS course (e.g. tube activity, gestalts switches, Rutherford trays). Present in these decontextualized activities and lessons were explicit and reflective links to the NOS. For instance, a question posed in a “bell ringer” from H13 read: “When you see science labs in textbooks, they often show step by step methods, how did the tube investigation show that science is not a step by step investigation?” (H13, A18).

Although not obvious in the NOS implementation data for this study (Table 6), H5 conveyed during an observation, without solicitation, s/he recently decided to reduce the implementation of decontextualized NOS activities. H5 conveyed the reason for this decision was because the ninth and tenth grade science classes extensively employ these types of activities. Therefore, H5’s 11th and 12th grade students already possessed foundational decontextualized NOS knowledge that could be effectively drawn upon, thus allowing H5 to focus on more contextualized NOS examples.

All high NOS implementers provided artifacts that significantly drew students’ attention to NOS themes in the context of science content and/or inquiry in an explicit and reflective manner (rated ≥4; “NOS in content and inquiry” categories). If these artifacts were employed, students would also have been required to reflect extensively upon explicitly identified NOS themes that were present (rated ≥4, “Reflect” category). For instance, H5 provided a question set (H5, A5) that prompts students to write a paper relating inquiry based classroom experiences to historical accounts of Galileo’s falling objects experiments. Questions in this set included: “In what sense did the investigations of accelerating objects
(ball on rail and dropping weights) accurately portray the historical account you read, and in what sense did they not?"

In the previous example from H5’s artifacts, it should be noted how students would be drawn to how classroom experiences reflect or distort the NOS (‘‘Reflect/Distort’’ category). All four high NOS implementers received a rating of 3 or greater in this category, but only one teacher (H1) received a 5. This was because H1’s artifacts embedded questions that consistently required students to compare their classroom experiences to science in a manner that demanded deep reflection (H1: A1, 2, 3, 6, 7).

Of the four high NOS implementers only two scored a 4, and one a 3, for the extent they scaffolded along the decontextualized to highly contextualized continuum. At best, these teachers’ artifacts either consistently scaffolded between decontextualized to moderately contextualized, or sporadically from moderately contextualized to highly contextualized NOS ideas in a manner that required students to reflect deeply (‘‘Scaffold’’ category). For instance, H7 asked in an inquiry based thermometer lab “How can we come to consensus on the fixed points that we have listed as a class? How did De Luc and the rest of the fellows decide on a set of fixed points?” (H7: A11).

**Medium NOS Implementers**

Medium NOS implementers presented fewer opportunities than high NOS implementers through their artifacts to address the NOS through inquiry (‘‘Inquiry’’ category) and/or historical and contemporary science examples (‘‘Historic’’ category; Table 6). Medium NOS implementers consistently scored 3’s and /or 4’s in these categories. Much like high NOS implementers, medium implementers’ NOS-related artifacts were very accurate. If
inaccuracies were present they were only minor (e.g. conveying a naïve view of discovery, data “tells” us what to think), thus scoring 4’s for the extent they accurately (“Accurate” category) portrayed the NOS.

Common to all medium NOS implementers’ artifacts was evidence of introductory decontextualized NOS activities and lessons reflective of those demonstrated in the ISU-STEP NOS course (e.g. tube activity, gestalts switches, discussions on NOS tenets). These artifacts, if used, would require students to explicitly reflect on the NOS. For instance, H4 posed the following statement and questions in one of her artifacts: “Multiple tube models were possible when we ended the tube activity. Write a minimum of 3 sentences addressing these important aspects of models: Why are models useful in science? What are limitations of models? Describe advantages of multiple models. Describe disadvantages of multiple models”. (H4:A6)

Medium NOS implementers would also refer back to introductory NOS activities and lessons in other artifacts. For instance, H6 asked on her first test: “What is a scientific theory? How are scientific theories different than a theory about a book or movie? How is a hypothesis different than a theory?” (H6:A2) Similarly, H10 asked on his first test: “What are two big ideas about how science works that we learned from the paper square puzzle?” (H10:A5). The presence of introductory NOS artifacts and their later reference were significant reasons these teachers scored 3 or higher in relation to the extent they required students to reflect on identified NOS ideas present (Reflect category).

Medium NOS implementers’ artifacts scored 3’s or 4’s pertaining to whether they addressed the NOS consistently, explicitly, and reflectively in the context of either science
content (“NOS in content” category) or inquiry (“NOS in inquiry” category). Two of the medium NOS implementers’ (H3 & H4) artifacts achieved a rating of 4 for embedding explicit and reflective NOS themes within the context of inquiry (NOS in Inquiry category). For instance, H3’s artifacts indicated he had students complete an inquiry based “Mystery Powders” lab and then subsequently asked students on a short quiz how the lab emulated the process real scientists undergo (H3:A2). In another example, H4’s artifacts included a sheet which illustrated student generated steps to investigate a relationship, and the decisions that accompany those steps (H4: A9). H4 was observed to have students mark on the sheet when those steps and decisions were happening during inquiry based activities (H4: 10/22/09). S/he was then observed questioning students how these activities demonstrated the lack of a set scientific method (H4:10/30/09).

Medium NOS implementers’ artifacts as a whole did not extensively address the NOS consistently, explicitly, and reflectively in the context of science content (“NOS in content” category). The highest score for this category was 3, achieved by H10, H6, and H12. These three teachers’ artifacts contained readings that integrated science content with explicit NOS themes and/or content tests with decontextualized NOS questions present. Although this level of attention to the NOS is encouraging, no questions appeared in the readings or on the tests that would require students to deeply reflect on contextualized NOS themes. This indicates medium NOS implementers may be adept at accurately, explicitly, and reflectively addressing the NOS decontextually and/or in the “context of inquiry, but struggle to do so contextually.
Important to note is only two medium NOS implementers’ (H3 & H4) artifacts substantially required students to be explicitly and reflectively drawn to how classroom instructional practices reflect or distort the NOS (rated ≥3; Reflect/Distort category). Furthermore, only H3’s artifacts provided evidence of substantial scaffolding along the decontextualized to highly contextualized NOS continuum (rated 3; “Scaffold” category)-something H3 did inconsistently. For example, one of H3’s artifacts stated:

In relation to quote from Einstein on studying closed systems: Using your own words paraphrase what Einstein is saying. In what ways is what Einstein saying relate to the tube activity? Give other examples from science that illustrate this idea. (H3, A4)

Low NOS Implementers

Each low NOS implementer’s collective artifacts scored 1’s to 4’s for the extent they provided opportunities to address the NOS through inquiry (“Inquiry” category) and/or historical and contemporary science examples (“Historic” example). This indicates many of the artifacts they utilized were limited in characteristics that would facilitate addressing the NOS. In fact, low NOS implementers’ artifacts tended to not represent reform-based practices in science education as they were fact based, highly directive with little need for students to mentally engage in activities, and lecture oriented.

None of the low implementers received a rating higher than 2 on their artifacts for accuracy (“Accurate category”). This was due to many inaccuracies and contradictions in portrayals of the NOS present in their artifacts. For instance, many low NOS implementers’ artifacts consistently conveyed inaccuracies and contradictions such as science proves ideas, scientist must be objective, research methods follow a rigid order, and scientists discover (akin to discovering a lost item) knowledge.
Interestingly, two low NOS implementers’ (H8 & H2) artifacts indicated they did specifically use introductory decontextualized activities (e.g. tube activity and/or gestalt switches which are addressed in the ISU-STEP NOS course) to introduce the way science works and what science can account for. Additionally, they even presented artifacts that indicated they assessed students on these ideas. For instance, one of H8’s artifacts asks:

Why was the tube of science monkey (or leprechaun) still up on the board at the end of the activity? Why was it set aside?

Are ancestral stories considered science? Why or why not? (H8, A:75)

The requiring of students to reflect on these NOS ideas in this manner contributed to these participants achieving a rating of 3 for requiring students to reflect (“Reflect” category) on explicitly identified NOS ideas in the lesson.

Evidence of students being required to explicitly reflect on NOS ideas within the context of science content (“NOS in content” category) and inquiry (“NOS in inquiry” category) was lacking for low NOS implementers. For instance, only one low implementer achieved a rating of 3 in regards to explicitly drawing students’ attention to NOS ideas in the context of science content. This rating was given to H8 because of the presence of textbook like readings, lectures, and related fact recall questions of early cell scientists. (H8:A11, 12, 13, 17). All of these examples were superficial and required little reflection by the students beyond fact recall of the NOS or science ideas.

Only one of the low NOS implementers’ artifacts indicated they explicitly and reflectively drew students’ attention to how classroom instructional practices reflect or distort the NOS (“Reflect/Distort” category). H2 received a rating of 2 for this category because of two superficial questions (e.g. how is this similar to what real scientists do?) present on
introductory decontextualized NOS activities (H2:A3, A4). None of the low NOS implementers’ artifacts provided evidence of scaffolding (“Scaffold” category) along the decontextualized to highly contextualize continuum.

**Composite NOS Implementation Ratings**

Combined observation and artifact scores resulted in four high, five medium, and four low NOS implementers (Table 7). Notably, although individual teacher’s mean observation and artifact NOS scores were relatively the same, artifact scores averaged 18% higher for 77% of the teachers. This may indicate teachers were more willing and able to implement the NOS “on paper”. Another possibility for this occurrence may be the time span classroom artifacts and observations address. Classroom observations can be considered a “snapshot” of teaching practices and could have occurred when NOS instruction was not prevalent. Conversely, artifacts gave context of what happened in the classrooms over the course of the study and provide a more accurate picture of teachers’ NOS teaching practices longitudinally. Despite artifact scores as a whole being slightly higher, the relative congruency is encouraging because a high degree of triangulation between NOS-COP scores for observations and artifacts was realized.

Only three teachers’ (H5, H6, and H10) mean NOS artifact scores were in a different implementation category than their mean NOS observation scores. All of these individuals achieved a higher NOS implementation rating based on NOS artifacts (Table 7). The higher artifact scores resulted in these teachers achieving a composite NOS implementation categorization one step higher than what was observed in practice.
Table 7. Composite NOS implementation levels of participants.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Mean NOS Observation Score</th>
<th>NOS Artifact Score</th>
<th>Composite NOS Implementation Score</th>
<th>Composite NOS Implementation Level</th>
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</thead>
<tbody>
<tr>
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<td>4.3(High)</td>
<td>4.3</td>
<td>High</td>
</tr>
<tr>
<td>H1</td>
<td>4.0(High)</td>
<td>4.5(High)</td>
<td>4.3</td>
<td>High</td>
</tr>
<tr>
<td>H5</td>
<td>3.4(Med)</td>
<td>4.2(High)</td>
<td>3.8</td>
<td>High</td>
</tr>
<tr>
<td>H7</td>
<td>3.6(High)</td>
<td>3.7(High)</td>
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<td>High</td>
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</tr>
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<td>H3</td>
<td>2.3(Med)</td>
<td>3.3(Med)</td>
<td>2.8</td>
<td>Medium</td>
</tr>
<tr>
<td>H12</td>
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<td>2.7(Med)</td>
<td>2.8</td>
<td>Medium</td>
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<td>1.7(Low)</td>
<td>2.0(Low)</td>
<td>1.9</td>
<td>Low</td>
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<td>1.7(Low)</td>
<td>1.0(Low)</td>
<td>1.4</td>
<td>Low</td>
</tr>
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<td>H9</td>
<td>1.1(Low)</td>
<td>1.3(Low)</td>
<td>1.2</td>
<td>Low</td>
</tr>
</tbody>
</table>

Summary of Findings: Research Question 1

Analysis of classroom observations and artifacts resulted in four high, five medium, and four low NOS implementers. Each teacher’s NOS implementation practices through artifacts were highly congruent with those present in observations of classroom teaching. Findings show the extent to which lessons and artifacts contain opportunities through inquiry and/or historical and contemporary science examples strongly indicate the extent the NOS will be taught effectively. High NOS implementers tended to create and capitalize on these opportunities in lessons and artifacts to address the NOS accurately, explicitly, and reflectively in the context of science content and inquiry.
Much like high NOS implementers, medium implementers were accurate in their portrayals of the NOS but were noticeably less proficient at requiring students to explicitly reflect on NOS themes in the context of science content and inquiry. The majority of low NOS implementers’ lessons and artifacts lacked opportunities through inquiry and/or historical and contemporary science examples to address the NOS. Therefore, these teachers rarely required students to explicitly reflect on NOS themes. When low implementers did address NOS themes through artifacts and lessons, the portrayals were often inaccurate and students were not required to explicitly reflect on them. All teachers in this study performed the poorest in scaffolding NOS ideas back and forth along the decontextualized to highly contextualized continuum (Clough, 2006). Additionally, no explicit attempts to have students reflect how particular classroom activities distort the nature of science were observed in any of the lessons in this study.

Factors Associated with NOS Implementation Levels

NOS Implementation and NOS Understanding

Table 8 shows high, medium, and low implementers’ NOS understanding scores measured by the SUSSI. These scores, when divided by the total score possible (200) and averaged within the high, medium and low implementation categories result in 93, 86, and 83 percent, respectively.
Table 8. NOS implementation and NOS understanding scores of participants.

<table>
<thead>
<tr>
<th>Composite NOS Implementation Level</th>
<th>Participant</th>
<th>Overall NOS Implementation Score (1-5)</th>
<th>NOS Understanding Score (X-200)</th>
<th>Percent</th>
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<td></td>
<td>H1</td>
<td>4.2</td>
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<td>96</td>
</tr>
<tr>
<td></td>
<td>H5</td>
<td>3.8</td>
<td>177</td>
<td>89</td>
</tr>
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<td></td>
<td>H7</td>
<td>3.7</td>
<td>177</td>
<td>89</td>
</tr>
<tr>
<td>Med</td>
<td>H4</td>
<td>3.5</td>
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<td></td>
<td>H3</td>
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<td>181</td>
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<td>96</td>
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<tr>
<td></td>
<td>H11</td>
<td>1.3</td>
<td>172</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>H9</td>
<td>1.2</td>
<td>150</td>
<td>75</td>
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</table>

All of the high NOS implementers achieved at least 88% of the possible points on the SUSSI. While high implementers possess a proficient NOS understanding as measured by the SUSSI, three medium implementers and one low implementer scored as high as or higher than two of the high implementers. Medium NOS implementer H4 only achieved 74 percent of the total possible SUSSI score, but the qualitative portion of the SUSSI revealed H4 actually possesses a deep and robust understanding of the NOS similar to other high and medium NOS implementers. H4’s lower score was influenced by the apparent recognition that NOS issues are rarely definitive. This is evidenced by the qualitative statement made by H4:
I did not respond to any statement in the SD or SA categories. …indicating a strong opinion on a statement communicates that I had made definitive decisions on things (especially NOS ideas) that are not and really should never be finalized, but rather continuously developing in understanding. (H4: VASSIST questionnaire)

Triangulation between SUSSI Likert responses and qualitative responses revealed congruency between these measures for the remainder of the participants in this study. So, in line with prior literature (Abd El-Khalick & Lederman, 1998; McComas et al., 1998), an understanding of the NOS is likely crucial for accurate and effective NOS instruction, but it does not determine such instruction will occur.

**NOS Implementation and Instructional Practice**

Findings in Table 9 show an association between NOS implementation and quality of reform-based practice. Generally, if the lesson scored higher on the NOS-COP, it also scored higher on the LSC-COP, indicating effective reform-based practices may facilitate NOS implementation. Conversely, lessons that scored high on the LSC-COP did not necessarily score high on the NOS-COP. For instance, H4’s and H12’s lessons consistently scored high on LSC-COP capsule scores but never scored higher than medium for NOS implementation.
Table 9. Ratings for classroom observations using the LSC-COP and NOS-COP with scores ranging from 1 (not at all) to 5 (to a great extent).

<table>
<thead>
<tr>
<th>Composite NOS Level</th>
<th>Participant</th>
<th>Date</th>
<th>Design</th>
<th>Imp</th>
<th>Content</th>
<th>Culture</th>
<th>Capsule</th>
<th>NOS Observation Score</th>
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<td>5</td>
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</tr>
<tr>
<td></td>
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<td></td>
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</tr>
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</tr>
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<td>10/06/09</td>
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</tr>
<tr>
<td></td>
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<td>3.8</td>
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<td>H5</td>
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<td>4</td>
<td>4</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
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<td>09/24/09</td>
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<td>10/22/09</td>
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<tr>
<td></td>
<td>H3</td>
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<td>3-low</td>
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<tr>
<td></td>
<td>H3</td>
<td>10/30/09</td>
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<td>3-high</td>
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<tr>
<td></td>
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<tr>
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<td>4</td>
<td>4</td>
<td>4</td>
<td>2.8</td>
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Table 9. (continued)

<table>
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<th>Composite NOS Level</th>
<th>Participant</th>
<th>Date</th>
<th>Design</th>
<th>Imp</th>
<th>Content</th>
<th>Culture</th>
<th>Capsule</th>
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<tr>
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<tr>
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<tr>
<td></td>
<td>H11</td>
<td>11/11/09</td>
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<tr>
<td></td>
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<td>11/17/09</td>
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<td></td>
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<tr>
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<td>2</td>
<td>2</td>
<td>1</td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

With the exception of one lesson, those rated as at least medium implementation on the NOS-COP (2.3 or higher) also rated no lower than 3-high on the LSC-COP. Important to note is the lesson of exception was rated on the border between low and medium NOS implementation. Reasons for this lesson rating of 3-low on the LSC-COP was because of poor implementation by H8. This individual demonstrated a consistent pattern of asking yes/no questions and cutting off students by providing them the answers. In addition, the pace of the lesson was inappropriate for students because the H8 pushed them through the entire development of the cell theory in 90 minutes. This lesson was rated in the medium category of NOS implementation because H8 did introduce the cell theory through a short inquiry-based activity centered on Hooke’s drawings of cork. She then had the students complete superficial textbook-like historical short stories and make fact recall lists of significant points about cell scientists. Although the stories and inquiry based activity were
superficial and somewhat inaccurate in respect to the NOS, she did explicitly highlight a few basic but accurate NOS ideas for students to consider, such as creativity and collaboration in science.

Table 9 shows high NOS implementers also consistently employed reform-based practices in their classrooms. With the exception of one lesson, all high implementers’ LSC-COP capsule scores were rated at least 4. Notably, two of the lessons conducted by H13 and H5 scored the highest capsule ratings possible. Characteristic of all lessons that were rated a 4 or higher on the LSC-COP was the high degree of reform-based practice. For instance, teachers that received these ratings designed their lessons in a manner in which students were forced to speculate, explore, and investigate science concepts. In addition, these lessons were typically structured and taught in a manner that moved from concrete experiences to abstract concepts that account for those experiences. Also, teachers implementing these lessons seamlessly integrated inquiry, content, and many times the NOS through student-centered strategies such as effective questioning and scaffolding from students’ prior experiences. For instance, a lesson conducted by H13 began with students learning dichotomous organization through classifying items of clothing. After this introductory activity, H13 had students categorize rocks into groups also through dichotomous organization. Throughout this inquiry-based activity H13 seamlessly drew students’ attention to the NOS by asking questions such as “Why might scientists use this system to organize aspects of the natural world? How might their organization system change based on new information?” and “To what extent were dichotomous keys and classifications of rocks and animals discovered? To what extent were they invented?” (H13, 01/28/10)
Medium NOS implementers’ LSC-COP scores were consistently lower than those of high implementers. With the exception of lessons conducted by H4 and H12, all medium implementers’ LSC-COP scores ranged from 3-low to 3-high. These teachers’ lessons typically exhibited problems with lesson design and/or implementation. For instance, in many of the lessons rated as 3-high, teachers may have reduced the effectiveness of the lesson by transitioning from an interactive discussion to lecture-style interactions. These teachers often did not deeply scaffold to content or NOS ideas primarily because they struggled to ask deep meaningful questions that would help students make such connections. For instance, medium NOS implementers many times made statements or asked questions that were unproductive in linking lessons to the NOS. For example:

- Science relies on truthful evidence and we rely on these numbers as evidence in this class. (H10, 09/30/09)
- If you have a lot of data how does that help your conclusion? (H4, 10/30/09)
- If you were a scientist in this room what things would you want to convey? (H3 10/23/09)

Another notable issue with medium NOS implementers’ lessons was the seemingly unorganized structure evidenced by the presence of rough transitions. Not surprisingly, this impeded effective instruction. In the two lessons rated as 3-low, design and implementation issues were significant enough to facilitate minor classroom management problems to ensue. For instance, in one of the observed lessons the instructor lacked a clearly planned strategy, questions, and quite possibly pedagogical content knowledge to successfully conduct an interactive discussion pertaining to the rationale behind using percentages to standardize data in science (H3, 10/23/09). In this case the students became confused and subsequently off
task. Eventually, the teacher resorted to lecturing and simply providing the desired answers to students.

With the exception of two lessons by H2, low NOS implementers’ LSC-COP ratings were much lower than those of medium and high NOS implementers. This group’s LSC-COP scores tended to range from 1 to 2 which indicate significant problems in their lessons. For instance, in lessons taught by low NOS implementers, teachers were often observed providing a great deal of factual information through lecturing in a “pedantic” (HRI, 2006) manner. In addition, the teachers receiving low LSC-COP ratings planned and implemented lessons consisting of cookbook activities, textbook work, and/or worksheets. Not surprisingly, most of these lessons did not explicitly address the NOS whatsoever.

Interestingly, one of the low NOS implementer’s lessons (H2, 10/01/09) did achieve a medium NOS-COP implementation rating in conjunction with a 3-high LSC-COP capsule rating. Many aspects of this lesson were congruent with reform-based practice. For instance, in this inquiry based lesson students were initially required to organize images of protists into groups according to morphological similarities and differences. At the conclusion of the lesson students had come to consensus which categories (animal-like and plant like) each protist belonged. Within this lesson questions asked to draw students to the NOS included: “What did we do to come to consensus? What do scientists do to come to consensus?” Unfortunately, the following day H2’s lesson reverted to more traditional practices with no explicit NOS instruction.

In summary, based on classroom observations the level of implementation of the NOS was associated with the extent the lesson was congruent with reform-based practice.
Lessons that had high levels of NOS implementation were achieved through deliberate design, implementation, and content selection. In addition, these lessons shared similar classroom cultures that encouraged characteristics congruent with NOS instruction such as speculation, inquiry collaboration, creativity, imagination, and coming to consensus.

**NOS Implementation and Consideration for How People Learn**

The manner in which participants considered how people learn in their teaching decision making was elicited in interviews. Participants’ considerations were coded as consistent or inconsistent with how the ISU-STEP promotes people learn. Table 10 shows participants’ level of NOS implementation is associated with how they consider people learn. The majority of high and medium NOS implementers’ considerations for how people learn were consistent with that promoted by the ISU-STEP. Conversely, low NOS implementers’ considerations for how people learn were either non-existent or far less congruent with contemporary views promoted by the ISU-STEP.

High and medium NOS implementers’ statements indicated they consider the learning theories (developmental, constructivist, social, and behavioral) in their teaching. For instance, H3 demonstrated s/he considers aspects of the social learning theory when making instructional decisions through stating, “I know that students learn socially and so I incorporate social type actions in all my activities whether there is discussion with me, or discussion with their peers. We do a lot of white boarding where I have students put their ideas down on the whiteboard” (H3, 19:22). H10 discussed how s/he knows critical thought and knowledge construction is going on in the classroom by stating, “I like them to take something they know or something they may have learned some time ago, and take these
things in combination and get that synergy of learning where they say oh I know A, B, and C. And I can put them together to get real true critical thought.” (H10, 6:8)

Table 10. Consistency between participants and the ISU-STEP in their considerations of how people learn.

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<th>Participant</th>
<th>Consistency Level</th>
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</tr>
<tr>
<td></td>
<td>H1</td>
<td>Consistent</td>
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<tr>
<td></td>
<td>H5</td>
<td>Consistent</td>
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<tr>
<td></td>
<td>H7</td>
<td>Consistent</td>
</tr>
<tr>
<td>Med</td>
<td>H4</td>
<td>Consistent</td>
</tr>
<tr>
<td></td>
<td>H3</td>
<td>Consistent</td>
</tr>
<tr>
<td></td>
<td>H12</td>
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<td>Consistent</td>
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<td></td>
<td>H6</td>
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<tr>
<td></td>
<td>H9</td>
<td>Inconsistent</td>
</tr>
</tbody>
</table>

Statements made by seven of the nine high and medium NOS implementers indicated they deeply consider how people learn and that learning is a multi-faceted and highly complex endeavor. This contributed to their considerations of how people learn being rated as consistent with the ISU-STEP. Many of the statements made by these participants reflected the importance of moving from concrete experiences to a more abstract conceptual understanding in a developmentally appropriate manner. In addition, most of these teachers
used examples from their own practice in their explanations. For instance, H1 provided a
detailed example representative of other teachers whose considerations of how people learn
are consistent with the ISU-STEP:

Learning is maximized first by knowing where they are at and what I have to
do with their prior knowledge. I also have to keep in mind these are ninth
graders, not adults. They have limitations on what they can learn. People learn
better with something concrete and then you can move to things that are less
tangible and more abstract. For example, the mole. They can answer a dozen
but then answering how many or counting by that big of a number is just not
useful at this time. It is a fundamental tool that we use in chemistry but is not
fundamental for ninth graders. My point is you must figure out what ninth
graders can handle and that is how you maximize student learning. If you look
at: Would they just have to memorize it? Then it's not worth teaching. (H1,
1:3)

Similarly, teachers in this group stressed the importance of considering prior knowledge
when facilitating students to develop a deep understanding. Some did this through explaining
learning is a continual process of adding and integrating “layers” of knowledge. For instance,
H13 explained his approach to teaching students about the role particles play in the natural
world through stating:

I feel like I add pieces to the overall picture. It's not about moving from one
topic to the next to the next topic. It's about adding a new layer to what we
have already been talking about. It is not that I ever move from what I talk
about in class as far science content. For instance, the particle. I never stop
talking about particles. So I never moved on from particles, but what I've done
is added: Now how can we use particles to explain this phenomenon? And
how can we use particles to explain that phenomenon? And then I say, “How's
that phenomenon related to this phenomenon?” So I am constantly building a
network of ideas rather than saying okay were done with this idea. I don't go
on to the next layer for the students until the students have an understanding
and till they're able to articulate how that newest layer fits with the layer
underneath that, and how the layer needs that. So until they have that new
framework cemented in, I will not move on to another layer. Because if I add
that next layer to early the whole thing may come crumbling down. (H13,
17:3)
Reflective of conceptual change research, many high and medium NOS implementers also expressed that deep learning requires confronting one's misconceptions in a manner that will convince students to adopt the correct concept. Also, these teachers often expressed the tentativeness, disequilibrium, and effort that accompany the process of attaining a desired conceptual state. For example, H7 and H4 expressed the following considerations of how people learn and their implications for practice:

I know that if I don't find out what they know I could be reinforcing those misconceptions even though I am teaching something that does not agree with their misconceptions. I need to be able to know what they think. Then I think: How can I get them to leave their misconception behind and pick up a conception that is the more accurate version of it in science? (H7, 22:4)

The one thing I'm struggling with right now is: For deep and rich long-term learning to occur students don't feel okay with being comfortable on the fence for a while. So I'm trying to make them think not necessarily to be comfortable, but recognizing dissidence within themselves and thinking: It's going to be okay if I'm on the fence right now. I will get off the fence at some point in time. So how do I communicate to the students or model for them that long-term learning doesn't come immediately? It comes through multiple experiences and trying to interpret situations using certain strategies. How do I help them understand that satisfying that immediate need and moving on is not ideal? (H4, 2:2)

Also reflective of conceptual change, teachers in the “consistent” category sometimes recognized that learning requires an epistemological shift. These teachers indicated their teaching was aimed at not only students’ understanding of science content, but also an understanding of what it means to know and learn in a manner that will transfer to other aspects of life. For instance, teachers H1 and H5 state:

My approach goes further with their critical thinking problem-solving and meeting of the goals I have for them. For becoming human beings, I want their education to be more than just science. While the science is useful, but in their everyday lives if they meet the goals I have for them, they should be
using and developing a sense of things that will transcend anything they do in life. (H1, 1:7)

The way I go about things not only does it promote students to think more critically, but it also promotes them to think about the nature of learning for themselves. So, I don't think I'm just trying to teach them about physics. I think I'm trying to teach them to a large extent to make subtle changes in their epistemological views. (H5, 20:6)

Although rated as “consistent” with the ISU-STEP in their considerations of how people learn, two medium NOS implementers’ reflections were not as substantial as the other participants rated as “consistent”. Specifically, the responses from H3 and H6 demonstrated they understood important considerations for how people learn, but their responses superficially reflected the themes promoted in the ISU-STEP (e.g. learning theories and conceptual change) and possessed few practical examples. In a sense, the reflections provided by H3 and H6 resembled what Abell et al. (1998) called “noises that sound pedagogical”. For instance, in the following statement about using a learning cycle sequence, teacher H6 indicated s/he considers students learn from concrete to abstract:

I tried to present the information in a variety of ways. First we have an activity and then we can talk about it and then they can read about it. So I try to present it many different ways. I also question them periodically and use whiteboards and things like that so, kind of just like getting information in a variety of ways. (H6 21:3)

In another example, H3 superficially explained when structuring lessons how s/he considers people learn by stating, “I think about things. The fact that students are able to grasp a concrete idea more readily than abstract. So my units or lessons tend to move from concrete to abstract” (H3, 19:22).

As demonstrated in Table 10, low NOS implementers’ considerations for how people learn were either non-existent or far less congruent with contemporary views promoted by
the ISU-STEP (e.g. learning theories, conceptual change). At best, a small minority of these teachers’ statements very superficially resembled what the ISU-STEP promotes is how people learn. For instance, a few of H2’s considerations for how people learn were similar to H6’s, but not as advanced, numerous, detailed, and consistent with how the ISU-STEP promotes people learn. This teacher would describe learning would occur through engaging students, asking more than yes/no questions, and considering prior experiences. Although these responses are in line with what is promoted in the ISU-STEP, determining the extent this teacher considered how people learn during teaching was difficult because their expressions were vague with little reference to learning theories. For instance, when talking about teaching the NOS, teacher H2 demonstrated a very shallow consideration of how people learn by stating, “People in general when it comes to change are very set in their ways because when you're trying to change way they think or do something it can be hard [for them]” (H2, 18:15). As indicated before, the majority of the considerations provided by H2 of how people learn were inconsistent with the ISU-STEP. At one point this teacher even stated the teaching and learning promoted by the ISU-STEP were “too ideal” for her students (H2, 18:61, 67).

The majority of the remaining low NOS implementers’ considerations of how people learn were also vague, nondescript, and often inconsistent with what is promoted in the ISU-STEP. This was most evident when they made statements associating learning with the acquisition of skills and science content. For instance, when asked how H8 maximizes student learning s/he stated:

I try to incorporate as many skills as I possibly can other than just content knowledge. I try to maximize not only what they are learning but the degree
or the variations to their learning because not everybody's going to be in science. So like their skills, like scientific skills, like lab skills, or analysis skills, or were working on technology skills right now in my class. (H8, 23:4)

At times low NOS implementers would provide contradictory statements of what students should learn. For instance, H11 stated “I like big picture things. They are important to me. Knowing like definitions of things.” (H11, 26:2). H11 further expressed considerations of how people learn that are inconsistent with the ISU-STEP through emphasizing learning is absolute and the acquisition of facts. This was evident when s/he stated, “I thought, well gosh, if you are not going to go over the exams then how do you ever know what you did was right or wrong. That is an important part of the learning process” (H11, 6:3). Notably, H9 also demonstrated the similar views when s/he described the methods s/he employs to know how students’ learned science concepts. When asked how H9 knew when learning was occurring in the classroom s/he stated, “besides questions, the typical tests and worksheets and stuff like that” (H9, 24:1).

As indicated before, unlike high and medium NOS implementers, the majority of the statements made by low NOS implementers lacked reference to the learning theories. Interestingly, many statements made by low implementers revealed they actively take actions or positions that are the antithesis of how people truly learn. For instance, H11 insinuated s/he believes a more fact-based approach to teaching is more appropriate when stating, “I think we get bogged down trying to make sure everybody has a deep, deep, deep understanding. It is important for students to just get a view of what there is in the sciences” (H11, 26:8). When asked how s/he knows when to move on to new topic H11 stated:
I do admit. Occasionally I leave the lower ones behind because I have to move on. I mean there's material we have to cover. I know that is in disagreement with some teachers, that think that let's get a deep robust understanding versus a spray shot. (H11, 26:7)

This approach to moving on to new subject in the classroom was also reflected by H8 when s/he stated that:

I try to keep them all in line with each other and that's one of my deciding factors and I know that's a bad one. But unfortunately it easier on me if the kids are on the same spot. So, that's one of the reasons-for my own sanity. (H8, 23:5)

These low NOS implementers recognizing they teach in manner which is incongruent with how people learn indicates they quite possibly realize they're not implementing reform-based practices congruent with those promoted in the ISU-STEP. However, the lack of depth the responses centered on how people learn exhibited by all low implementers indicates they do not fully realize why and how their practices are incongruent with what the ISU-STEP promotes about how people learn.

**NOS Implementation and Self Reflection**

Tables 11 and 12 show the accuracy and depth of participants’ teaching reflections compared to observations and artifacts collected in this study. Although reflections are reported as percentages of statements, these percentages are not intended to be exact values. Instead, they were used to assist in data reduction and the categorization of participants’ reflection abilities.

Tables 11 and 12 show NOS implementation is associated with participants’ exhibited ability to accurately and deeply reflect on their general and NOS teaching practices. Interestingly, across all NOS implementation levels participants’ reflections demonstrated
more accuracy than depth. Seemingly, these teachers had to accurately establish the “what’s” within their practices before they could deeply articulate the “how’s” and “why’s”. This indicates that self assessment accuracy may facilitate and precede the depth in which one is able to self assess their NOS and general teaching practices.

Table 11. Accuracy and depth of reflection about teaching conveyed by teacher during interview, reported as percentage.

<table>
<thead>
<tr>
<th>Composite NOS Implementation Level</th>
<th>Participant</th>
<th>Accuracy</th>
<th>Depth</th>
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<td></td>
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<td>High</td>
<td>Med</td>
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<tr>
<td>High</td>
<td>H13</td>
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<td>H6</td>
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<td>Low</td>
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<td></td>
<td>H11</td>
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<td>22</td>
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<td>H9</td>
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</table>

As compared to teaching observations and artifacts collected in this study (Tables 7 & 8), reflections of general and NOS teaching practices became less accurate and in depth from high NOS implementers, to medium NOS implementers, to low NOS implementers. High and medium NOS implementers readily integrated their NOS teaching reflections within their general teaching reflections. Conversely, low NOS implementers rarely integrated NOS
teaching within general teaching reflections, and if they did so it was with significant
difficulty.

Table 12. Accuracy and depth of reflection about NOS teaching conveyed by teacher during
interview, reported as percentage.

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<thead>
<tr>
<th>Composite NOS Implementation Level</th>
<th>Participant</th>
<th>Accuracy</th>
<th>Depth</th>
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<td></td>
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<tr>
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<td>H1</td>
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<td>H9</td>
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As indicated by Tables 11 and 12, high NOS implementers’ reflections about their
general and NOS teaching practices demonstrated great accuracy and depth. For the most
part, these results match responses teachers provided on the VASSIST questionnaire (Table
13). As measured by questions aimed at self reflection abilities, all high NOS implementers
responded they took measures to explicitly and effectively teach the NOS.
Table 13. Instructional practices reported by participants on VASSIST questionnaire.

<table>
<thead>
<tr>
<th>Composite NOS Implementation Level</th>
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<th>12B</th>
<th>12E</th>
<th>13A</th>
<th>13C</th>
<th>13D</th>
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<td>SD</td>
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<td>H6</td>
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<td>Low</td>
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Contributing to the depth in which high NOS implementers accurately self assessed were the many concrete examples from practice integrated within their reflections. These examples provided both the actions they took in the classroom and how those actions related to how people learn. For instance, when reflecting upon their general teaching practices H1 and H13 stated:

For example, students right now they're understanding static. I want them to understand what things affect static. Like what can you do to get more static? What can you do to get rid of static? How does it affect it? Then we are going to jump into what is it? I want to make sure that a good foundation of what causes it and what things they can see. That something concrete is there. Then I'm going to move to the abstract. My overall objective is for them to learn that electrons simply moving is electricity. That's a major idea I want every kid to know. That is because that implies a lot of different things in life. Simply regurgitating that and spitting it back at me is not enough. I want them to apply this to new situations. So if I'm dealing with electricity in my home this is actually what is happening. Something more real. This is where I struggle the most is linking the science to their everyday lives. (H1, 1:4)

Rather talking about rocks right away we talk about Jolly Ranchers and what happens to them in your mouth under different circumstances. Like if you let it sit in your mouth then if you actually use your tongue or use your teeth. That's what I do as I link that to the concepts that I'm trying to explain about weathering. I then show the pictures of what is happening to a rock and a chemical weathering and mechanical weathering and things like that. So, I'm constantly trying to figure out where the students are at. (H13, 17:1)

An example of an accurate and deep NOS teaching reflection was also provided by H13. In this reflection H13 discussed the difficulty students had in determining whether the classification of animals was invented or discovered. Part of this reflection is provided below:

I feel I teach the nature science pretty well. I'm not going to say that I am as good as I could be because like I mentioned earlier with the invention and discovered thing. The kids kind of threw me for a loop there. I didn't imagine they were going to say these ideas were discovered because we have talked
about them before and the difference between discovered and invented. It just shows how tenacious they hold onto their naïve ideas. (H13, 17:14)

High implementers also deeply reflected by providing implications or solutions for improving general and NOS teaching practices. Often, this was meaningfully done without being prompted. That is, these teachers would many times constructively diagnose their own setbacks and then provide action plans to improve practice in significant ways. For instance H5 showed concern for treating the NOS and science content as divorced through the following reflection:

I am trying to find the ways to integrate the nature of science into the curriculum so that it is not just that big swing every now and then. How do I get it smooth and throughout the year? I know I'm not going to get better on the NOS unless I start practicing those ideas now. So I'm just kind of running down that dark alley right now. (H5, 20:8)

H5 then articulated ways to help remedy this short fall in practice. Included in H5’s self made recommendations were the following statements:

I think if I take it as I kind of plan out the semester in more detail and I get a feel for where I'm going I think that anxiety will diminish. I've been having them write and that has been a positive, but I need to spend more time probably getting them in and working that more into a routine-if they write. Part of the issue with them writing a paper is it takes a long time to get through all of them and provide feedback. I'm not necessarily bringing it to the surface in class as much as I think I probably could. In other words some more deliberate whole class discussions I think are required. (H5, 20:8, 9)

High NOS implementers’ reflections also illustrated the synergetic nature of teaching and the role of the teacher so often articulated in the ISU-STEP. Many times this group’s reflections would seamlessly link several components of effective practice together, thus indicating they knew teaching and learning are complex and cognitively demanding. For instance, H13 reflected through the following statement how s/he improves practice by
considering students’ prior knowledge in conjunction with the depth and context of the questions s/he asked:

I'm looking at my interaction patterns. I am also looking at: Okay this conversation did not go well but I'm asking thought provoking short answer and extended answer questions. Why did it not go well? Was it because the questions were open-ended but it was not rooted in something the kids already had experiences in? (H13, 17:6)

Some high NOS implementers also spoke directly of the complex synergetic nature of teaching. Many times this was in response to questions dealing with whether they thought reform-based practices were to ideal. For instance, H7 stated, “I think that some people probably didn't see that there's a time and a place for different things. You need to pick and choose and it's very complex” (H7, 22:29).

Tables 11 and 12 show much like high NOS implementers, medium NOS implementers accurately reflected on their practice. However, unlike high NOS implementers, medium implementers sometimes struggled to reflect deeply. This indicates most of the medium NOS implementers do not possess the deep reflecting abilities the high NOS implementers demonstrate. For the most part, these findings match responses medium NOS implementers provided on the VASSIST questionnaire (Table 13). As measured by questions aimed at teachers’ self reflection abilities, medium NOS implementers agreed they took some measures to effectively teach the NOS.

The majority of medium NOS implementers’ reflections were rated at a moderate depth in part because of the lack of concrete examples from teaching practice. In addition, although the themes present in medium NOS implementers’ reflections were congruent with the ISU-STEP and NOS courses, the majority of these reflections seemed “canned” and
superficial. This caused the majority of these teachers’ reflections to appear informed, yet generic. For instance, H3 spoke about how s/he knows students understand through the following statement:

There are ways that we can try to get that (students’ understanding) but I don't know. Asking them questions and testing them with formative assessments. We use white boarding. Putting them in situations where they have to use the knowledge that they have supposedly acquired. I would see if they were using what they've learned to explain new situations and predicting outcomes that they have not seen before. (H3, 19:2)

Similarly, H12 also spoke in generalities without concrete examples when s/he reflected about how s/he maximizes students’ learning in the following statement:

I think based on the things I do my classroom we had a lot of discussions. I think I do a pretty good job of getting students to express their thinking, and their thinking on any kind of assignment or assessment I ever give them. It is writing about their thinking in-depth. In addition, the discussion that we have with their thinking and their approach to problems and the processes they go through to collect and analyze and their data. Through that I see their thinking and I can see how the thinking changes over time. (H12, 27:1)

With the exception of H10, medium NOS implementers’ reflections about NOS teaching also were of moderate depth and lacked concrete examples from practice. For instance, in response to being asked to what extent they explicitly drew their students’ attention to the nature of science H6 and H12 state:

If I bring up the nature of science activity or topic I would say almost always explicit about it. I write down nature science on the board and say this is one of those big ideas about how science works. I am very explicit with it when I do bring it up. (H6, 21:73)

I think I do quite a bit because a lot of it is always connected to: How is this like what scientists do? It's how and what we implemented it in what we do. How do we even really know the epistemology? You know that's the big piece for me is it always goes back to how do we know and how do scientists know? (H12, 27:27)
Similarly, H3 did not provide specific examples from practice when reflecting on struggles with teaching the NOS. This is demonstrated through the following statement:

A lot of the ideas are very abstract so it's hard to. I've found it's hard to. It's hard to talk about. How do you discuss it on a level that is appropriate for the kids? I've also found that my knowledge of the nature science I use is not fully developed in some cases. It is superficial in some ways I've just become to examine these ideas myself. (H3, 19:11).

Upon being asked to articulate further, H3 finally indicated s/he struggled to teach the NOS because of a lack of historical and contextualized examples to draw from. Later, when H3 was asked what NOS ideas s/he used in the classroom s/he said, “I wish I had my list of the NOS ideas we teach actually.” Statements such as these indicate that although medium NOS implementers are to some extent teaching the NOS, they may struggle to articulate in depth how and why they chose their NOS content and implementation strategies.

Compared to high NOS implementers, reflections from medium NOS implementers provided fewer deep implications or solutions for improving practice. In addition, although many components of effective teaching were present in their reflections, they sometimes spoke of the synergetic components of teaching as disjointed or isolated parts. An example of this was provided by H3 when asked about how s/he maximizes student learning:

By keeping students on task and not wasting class time is always a tough one. Engaging activities as opposed to activities that they could do without thinking or their eyes closed. Concrete experiences. Putting them in positions where they have to defend their reasoning. Putting them in positions where they may come to the realization that the way they understand new ideas may be inadequate to explain what they’ve just observed. (H3, 19:3)

H10 responded to the same question to a similar depth when stating, “By going at their pace I know where I need to spend my time and effort. I know where their
misconceptions are and their difficulties in their struggles are, and how I can work around those and how they look at things” (H10, 25:4). Four subsequent questioning attempts were needed to push H10 to fully and specifically articulate how s/he did this. Finally, in many more words H10 stated s/he considered the “zone of proximal development” in order to set up activities, and used questioning to scaffold students between concrete and abstract concepts. H10’s struggle to provide a response that deeply articulates the synergetic nature of effective teaching was nicely summed up at when s/he conclusively said, “I hope I'm answering your question because I don't think I'm articulating.”(H10, 25:4).

Interestingly, H10 reflected upon NOS teaching in greater depth than about teaching in general. For instance, H10 provided the following reflection about how s/he addressed the NOS through discussing in class a highly contextualized scientific paper that described the retraction of a journal article about vaccines and autism:

We dissected that. Here's a real science example in which now we know what happened and why this was a big deal. Well what happened was they came to consensus to do more work and people examined his data and asked for more evidence. It is very open. You have to share everything. He wasn't hidden away and he wasn't working in a lab alone. Something small like that is really easy because they understand that. (H10, 25:39)

After this reflection, H10 proceeded to provide concrete examples of how s/he uses questions to link highly contextualized examples such as these to decontextualized activities. Perhaps H10’s enhanced depth of self reflection about NOS teaching is related to the high degree of interest s/he has for the NOS (Table 16). This phenomenon will be discussed further in the section NOS Implementation and Interest and Self Efficacy.
Compared to high NOS implementers, medium NOS implementers often struggled to articulate concrete strategies to improve their NOS teaching. If they did present options for improvement they were many in the form of outside support or activities and resources. For instance, H3 first explained s/he was limited teaching the NOS by difficulties in understanding the NOS and NOS teaching. H3 then insinuated in s/he would improve in efforts to teach the NOS by having access to historical science examples and examples of contextualized and decontextualized activities that explicitly address nature of science ideas. H3 then proceeded to say, “Just having more tools in the tool belt so to speak would be very helpful” (H3, 19:14).

Besides indicating s/he had recently improved questioning strategies when teaching the NOS, H4 indicated an urge to progress further in NOS teaching. Although this is the case, H3 provided no real avenue for improvement and instead sought external help. This was evident when H4 stated:

I know I'm not where I want to be. I know that I am not where I can be in the future. But I don't feel that is a weakness. I guess weaknesses that I currently identify are: How do I make that a more efficient and enriching process for my students? How do I move them past it is not a list of content to memorize? How do I get my students to see that without blatantly telling them? How do I model? How do I get them to be asking the questions? So if you have the answers to those that would be fantastic. (H4, 2:6)

These statements illustrate how medium NOS implementers may be adept at reflecting in depth enough to accurately spot areas needing improvement, but struggle at reflecting in depth enough to generate strategies to improve.

Overall, low NOS implementers differed markedly from high and medium NOS implementers in their self reflection abilities. Additionally, the majority of low
NOS implementers’ self reflections were inconsistent with practices noted in observations and classroom artifacts collected in this study. Tables 11 and 12 show most of the reflections provided by low NOS implementers about their general and NOS teaching practices received low accuracy ratings. Additionally, in comparison to high and medium NOS implementers, reflections of low NOS implementers were shallow.

For the most part, these results match responses low NOS implementers provided on the VASSIST questionnaire (Table 13). As measured by questions aimed at teachers’ self reflection abilities, all low implementers tended to agree or strongly agree they took measures to explicitly and effectively teach the NOS. For instance, all low NOS implementers agreed they use many stories and explicitly consider what activities, materials, and strategies to use to help students understand the NOS—a response that is in stark contrast to practices observed in the classroom and artifacts. In addition, two out of the four low NOS implementers agreed they created highly interactive discussions to address the NOS. The other two were undecided if they took this action in the classroom. Also, all low NOS implementers but H9 agreed they included items on tests throughout the year that explicitly addressed students’ understanding of NOS themes. This was something not present in artifacts. Instead, only a few decontextualized questions appeared on two of the low NOS implementers’ first test of the year. These findings indicate two possibilities. First, in reference to the contradictions between VASSIST responses and teaching practice, low NOS implementers may not fully understand what effective NOS teaching
practices are. Second, low NOS implementers apparently do not accurately self assess their general and NOS teaching practices.

Low NOS implementers’ self reflection inaccuracies in interviews took many forms. Most obvious was how low implementers’ general and NOS teaching reflections were incongruent with classroom observations and artifacts collected in this study. In addition, reflections of low NOS implementers were shallow with almost no concrete examples drawn from practice, or deep implications and/or recommendations for improving practice. Because these aspects were missing, low implementers’ self reflections also lacked an emphasis on the synergetic nature of teaching.

Through reflections, low NOS implementers’ insinuated they promoted goals such as creativity, problem solving and critical thought by utilizing questioning and inquiry based strategies. For instance, H8 stated s/he understands students’ thinking, “By the questions you ask them. Making sure the responses you can see that I like are happening. I guess that's the only way you can know.” (H8, 23:2). Not only is this reflection superficial, but it is also contradictory with H8’s observed practice as indicated on LSC-COP implementation scores (Table 9). H8’s consistent pattern of interaction was to ask low level yes and no and/or fact-recall questions, and then provide the students the desired answers. This is an interaction pattern that does not allow for students’ thoughts to be determined. Other low NOS implementers’ similarly reflected their practice shallowly and inaccurately. For example, H9 indicated the importance of the approach to teaching s/he took through the following statement:

I think that is important because it is going to get them to think critically about issues and obviously the more they think about them, the more personal
attachment that they have to it, I think. The better they will understand it then. So during that I will try go around and ask questions, get them to think about different points of view and different things they may need to address. To keep them thinking about different things other than just the obvious. (H9: 24:6)

H9’s artifacts and observations indicate otherwise. In fact, H9’s classroom artifacts and observed practice were consistently comprised of worksheets, multiple choice exams, and Power Point lectures. In comparison to the aforementioned artifacts and observations, H9’s self reflections continued to be inaccurate when s/he stated:

Activities and different things that I can give them. And things to engage students so it's not just repetition and not exactly the same thing over and over again, chapter by chapter. And it's not worksheet, homework, quiz, worksheet, homework, test. Try and change it up as much as possible and I think I do a pretty good job of that. Coming up with new ideas and different ideas for each chapter. (H9, 24:7)

When asked about their strengths and weaknesses in teaching practice, low NOS implementers also tended to yield inaccurate and shallow reflections. Rather than reflect upon significant areas needing improvement such as NOS or reform-based teaching, these teachers answered almost identically and/or superficially. For instance, when asked about strengths and weaknesses in teaching, and how to improve practice, H8, H9, and H11 provided similar reflections as exemplified by the following statements:

My strength is relating to the students. I think making the students feel comfortable in my class is a big strength of mine. Weakness, I would say I tried to really hard to give quick feedback on worksheets, test, papers and things like that. Unfortunately, I do not give as quick of feedback as I like. I always try to improve on that and give quick turnaround and usually it takes me a little bit longer than I would hope. (H9, 24:7)

Strengths are interacting with the kids, engaging with the kids, making and trying my very best to make it meaningful. Things I don't excel at, self admittedly I am the worst person to keep on track with grading. Probably not the worst but it's something that annoys and bothers me and I wish that I could
get their formative assessments or some little progress checks. It's always a goal of mine. Every year I find out that I say I'm going to get better. (H8, 23:9)

My strength it would probably be I really relate with kids and students. My biggest one (weakness) is I don't get assignments back in a timely fashion. I am working on that. I get better every year but I still don't get them back as fast as they should. (H11, 26:11)

When asked the same question, H2 provided a more compelling answer. Although not fully accurate because s/he utilizes many multiple choice tests, and did not address some of the major deficiencies in her NOS and reform-based teaching, the following statement did present some depth and truth:

I know strengths I have been really working on is when I ask questions of students that they are actually having to think and it's not a yes/no or one-word. I've even had students sometimes gets frustrated because I asked some questions and I won't just tell them. That's a sign that you're asking. Sometimes them getting a little frustrated because they are actually having to think is a good sign that you're actually having to try to push them and giving them a chance to try and do it themselves. With weaknesses, trying to find more ways to really figure out if they understand. There are common ways where with the system you take a test, or you turn in an assignment. I am trying to find other ways to learn whether or not they really learned it without having them feel the pressure of a formal assessment like a test. (H2, 18:8)

As indicated before, low NOS implementers’ reflections of their NOS teaching were much less accurate and in depth than those of high and medium NOS implementers. Interestingly, all low NOS implementers indicated early in interviews they did not explicitly teach the NOS throughout the entire year. Although this was the case, when later asked several questions about their NOS practice they attempted to explain how they proficiently teach the NOS through “incorporating” it into their lessons and activities.
Low NOS implementers may have responded in this manner because they were asked several questions about the NOS and NOS teaching on the VASSIST and in interviews. This may have made them feel as if they had to provide evidence they taught the NOS. Many times this resulted in low NOS implementers revealing misconceptions through “piecemealed” justifications of their perceived NOS teaching practices. For instance, H8 described teaching the NOS through the following statement:

I think pros are that the way I teach it, and I'm not saying I don't teach it. The way I teach it incorporates it into the lessons and is not explicit. The pros are that teaches the kids the nature of science in the context of science. So they're actually doing the science and they're actually going through and doing a lab and they're getting the wrong results, but I don't call them the wrong results. And it benefits them because they're learning the nature of science while actually doing the science. (H8, 23:15).

In a similar instance, H9 conveyed because of a lack of NOS understanding s/he did not address the NOS as much as s/he should. After conveying this, when H9 was asked what NOS themes s/he taught, H9 responded hesitantly, “Alternative theories and inquiry labs where it is not cookbook, history of scientists, those things.” After being asked specifically for concrete examples from practice, H9 provide the following example:

We talk about Darwin and evolution. We talk all about the life that he had that led him up to taking a trip on the Beagle and how he became to be, and how he flunked out of medical school and married his cousin and things like that. The kids are like what? He was a school dropout and find it interesting he married his cousin but is still considered one of the greatest scientist of the century. (H9, 24:14)

H2 provided an exaggerated picture of how s/he teaches the NOS through the following statement:
Lots of times when we are dealing with certain content we may talk about a specific scientists’ experiment and that's a good time to talk about you know the way scientists do their experiments, go about getting the results the way they do. And then you can talk to the students about comparing it to: Well if we did an experiment like this how would it be similar to what they did and how is it different. (H2, 18:13)

Although this reflection demonstrates some depth and understanding of effective NOS teaching, H2 was never observed implementing the NOS in this manner through classroom practice or artifacts. Therefore, H2’s description of this occurrence happening “lots of times” is also an example how low NOS implementers inaccurately reflected about their teaching practices. Responding in a similar fashion, H11 stressed the importance of teaching the NOS through the following statement:

> Whenever you see a moment you must put in the nature of science. You need to make sure that they know that word the nature of science and that concept. I will always say, “And here's another nature of science.” So I am very explicit in what I'm doing and I hit them over the head: And here's another case. And remember when we talked about that? Always it's just sprinkled throughout. As a specific section I have not been able to get it to work. (H11, 26:14)

This reflection was inconsistent with observations and artifacts that illustrate H11’s practice. This is because the NOS was not observed to be significantly addressed in these data sources in an accurate, explicit, and reflective manner. In another exaggerated and inaccurate reflection, H8 talks about how s/he uses a short story to teach the NOS in the following quote:

> I incorporate nature of science into the cell division unit. I always found that interesting and I loved reading books about the science and telling the kids the stories behind that. That's another way I incorporate nature of science. We also always have key examples of history. Some story that I read the kids where they can get a feel for what the science behind that development is. (H8, 23:51)
H8 was observed implementing this short story, which was also collected as an artifact. This artifact resembles that of a traditional textbook selection that addressed the development of the cell theory superficially without explicit reference to NOS themes that would require students to reflect deeply. Additionally, this story presented several NOS misconceptions such as science ideas are discovered and absolute.

On a positive note, H2 and H8 reflected somewhat accurately on their use of decontextualized NOS activities at the beginning of the school year. H8 in particular provided an in depth reflection illustrating why s/he utilizes the “Tube Activity” to help diminish students’ resistance to evolution. Part of this reflection appears below:

We do that with the tube of science. We talk about how science is one of the ways of knowing the world. That is why I pull that one in there. Because it really helps me to get to evolution. Because when we get there I say remember the tube of science. I do say “Remember we never discredited the supernatural being inside it. We just left it on the board. We set it aside.” And it really helps them struggle with their concepts of evolution versus all the different religions and how other things are answered, and how other entities answered questions of the world. (H8, 23:18)

**NOS Implementation and Understanding of NOS Teaching Practices**

The degree to which teachers understood effective NOS teaching practices was associated with their level of NOS implementation. Table 14 reveals high NOS implementers generally demonstrated the most accurate understanding of NOS pedagogy, followed by medium NOS implementers who were mostly transitional in their understanding. Both of these groups were followed by low NOS implementers who demonstrated a naïve understanding of how to teach the NOS.

Three of the four high NOS implementers provided reflections indicating they deeply understood how to effectively teach the NOS. These reflections came mostly in the form of
descriptions of classroom practice that were highly congruent what the ISU-STEP promotes is effective NOS teaching. For instance, H1 demonstrated s/he understands effective NOS teaching occurs along the decontextualized to highly contextualized continuum. H1 also understands student held misconceptions about NOS ideas are deeply intertwined with one another. H1’s understanding of effective NOS teaching is represented in part though the following statement:

Well I teach a unit on it in the beginning of the year and then I integrate it throughout what we’re doing. My typical mode of operation for integrating (the NOS) has been to do moderately contextualized, like an inquiry lab or something like that, and then linking it back to the decontextualized. Like I said, sprinkled throughout there's about six different historical things I try and bring in that scientists actually do, and then some anecdotal things here and there. So, I do teach it. I do emphasize it. I've been driving home why proof is not something, I've been really trying to drive home is at proof is not something scientists can do because I feel it's a gateway to a number of other misconceptions. (H1, 1:16)

H13 also demonstrated an informed view of NOS teaching through stating, “I teach the nature of science with every single word that I say in the classroom.” H13 then made similar statements as H1 about the interconnectedness of NOS concepts through the following statement:

All the nature of science ideas are connected, and I think that's a really good way to show that because they are really connected. And if you're going to teach about one, then you're going to be able to teach about another one, and other interconnected ideas, and help students develop a more accurate picture of how science works. For instance, there is no scientific method and that connects to science being creative because they have to create new methodologies to investigate new questions. But also you have to be creative to interpret data. That gets into data doesn't tell scientists what to think. (H13, 17:5)
Table 14. Level of understanding of NOS teaching practices conveyed by teacher during interview.

<table>
<thead>
<tr>
<th>Composite NOS Implementation Level</th>
<th>Participant</th>
<th>Level</th>
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<tbody>
<tr>
<td>High</td>
<td>H13</td>
<td>Informed</td>
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<tr>
<td></td>
<td>H1</td>
<td>Informed</td>
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<td></td>
<td>H3</td>
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<tr>
<td>Med</td>
<td>H12</td>
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<td></td>
<td>H10</td>
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<td>Low</td>
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<td>H11</td>
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<td>H9</td>
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</table>

H7 also demonstrated an informed understanding of how to effectively teach the NOS when critiquing an aspect of NOS practice in which s/he felt is deficient. Much like other high NOS implementers, H7 indicated how the NOS is deliberately and inadvertently conveyed through all aspects of practice by saying, “It is there regardless. So what is it that you are conveying to the students about science?” (H7, 22:14). H7 then proceeded to state:

My assessments I feel like are just really poor at this time because I don't ask them questions about the nature of science. So if it is something I talk about in class and I want them to value it, I must have it on my quizzes and tests. I'm going to present some form of the nature of science with these kids and some explicit and accurate (ideas) about it. I feel like I'm doing them a disservice by
ignoring it which in turn reinforces misconceptions and solidifies them more. (H7, 22:14)

All three of these high NOS implementers also provided ways in which they explicitly drew students’ attention to the NOS in their classrooms. Many of their responses reflected both an informed view of how to teach the NOS and a deep understanding of how effective NOS teaching is a part of effective science teaching as a whole. These teachers demonstrated this understanding through explaining how they used effective questioning and concrete examples to ensure effective NOS teaching. For example, H1 explained how s/he explicitly draws students’ attention to the NOS through using a developmentally appropriate inquiry based activity that addresses density. In the initial stages of this activity, H1 facilitates students to determine the density of bb’s and small pieces of Styrofoam. H1 then explicitly draws students’ attention to implicit NOS ideas present in the activity. H1 explained how this was done by stating, “Eventually they came to the idea that it [the density of smaller pieces of substances] was the same [as larger pieces of the same substance] after much help and talk and retesting and thinking. What nature of science ideas can you pull from that? Many. The one that I picked was consensus.” After H1 was asked how students were drawn to this NOS idea, s/he stated:

By leading them through the process. I ask: “But why can't we vote? Why would that be an issue? I mean we don't have any evidence to back it up [in a vote]. We are just putting our opinion in for it. Well, how does that work in science if we did that? It really wouldn't. You know they wouldn't do that.” So I draw attention to what scientists actually do and then model for them: This is what we need to do. I also ask: “And why would it be useful that we have to use evidence to figure it out? Why is that a different type of communication with people than voting?” (H1, 1:64)
H13 also demonstrated a deep understanding of how effective NOS teaching is synergistically part of exemplary science teaching. This was demonstrated when H13 explained how s/he explicitly draws students’ attention to the NOS by stating, “A lot of ways it's questions about stuff. There is some times I will make explicit statements but it is usually after having them wrestle with the questions or a problem” (H13, 17:17). H13 then explained through a concrete example from a science class s/he teaches how students’ attention was explicitly and reflectively drawn to the NOS. Part of this explanation appears below:

When we're looking at plate tectonics I will ask them, “What are you trying to figure out with how the planet works? How is that similar to what you do with the puzzles? What kinds of thinking are similar? How are the frustrations that you are experiencing similar to the frustrations that scientists experience?” So, I'm trying to get them to understand that the same types of thinking and problems and rationales they used in their decontextualized activity fits with how the science was and the science ideas came about. (H13, 17:17)

H7 also demonstrated an informed understanding of how to teach the NOS through integrating it into effective science teaching. In this example H7 articulated how students made thermometers and performed case studies on scientists who were involved with the standardization of temperature during the 1600s and 1700s. During the reflection H7 posed several questions that students would be asked such as: “How are you like these early scientists in the 1600s and 1700s that made their own thermometers? How do you align with them?” H7 then explained how s/he explicitly and reflectively draws students to NOS themes such as creativity and imagination in the context of this highly contextualized inquiry based activity.

Although H5 is a high NOS implementer, s/he was rated as transitional in understanding NOS pedagogy. This rating was granted for two reasons. First, H5’s
reflections of NOS teaching seemed tenuous, unsure, and lacked concrete examples that demonstrated links between effective NOS teaching and effective science teaching as a whole. For instance, H5’s following statement illustrates how s/he currently perceives teaching the NOS and science content may be at odds:

I find really good things students take from the nature of science perspective, but I don't want to get caught in this thing where I pushed both agendas, and it becomes I sacrificed a major content piece like energy when I'm still skeptical about the treatment I am giving to some nature of science. But I know I'm not going to get better on the nature of science unless I start practicing those ideas now. (H5, 20:8)

The second reason H5’s understanding of NOS pedagogy was rated as transitional was because of the very accurate self reflections of how well s/he understood effective NOS teaching. For instance, H5 stated, “I still say that I'm developing [NOS] pedagogical content knowledge, but I just don't have that sense or that heightened awareness that I need to have with some the conceptual ideas I teach. I do feel that it's developing.” (H5, 20:10).

Perhaps H5 was able to implement the NOS at a high level because of a high proficiency as a reform-based teacher. As noted earlier, H5 was the only participant who did not complete their entire teacher education in the ISU-STEP. Instead, H5 had instructed in a reform-based manner for over a decade prior to completing ISU-STEP coursework, including the NOS and Restructuring Science Activities courses. Additionally, H5 only completed these NOS courses approximately one year ago. Undoubtedly, H5’s many years of implementing reform-based practice, heightened pedagogical content knowledge within the discipline he teaches, and understanding of how people learn may have made this teacher able to compensate for a lack of understanding of effective NOS pedagogy. Although this is
the case, the road seemingly has been challenging for H5 as indicated by the following statement:

If you are going to do it you are going to have to dedicate some time to it early on. It is not easy. Even with as much experience as I have it has not been an easy road to go down, but I think to a large extent I need to have a new challenge in my career. It's kind of lit a fire under my butt. It is made me think: Look, maybe you are not as competent of a teacher as you once thought you were. Getting out of that perspective of content and just addressing the nature of science explicitly. It has been good for me in that sense. The other con is resources are an issue. How do I address the nature of science with the energy concepts that fits my instructional approach? (H5, 20:11)

Table 14 shows all medium NOS implementers but H10 demonstrated a transitional understanding of NOS pedagogy. Unlike the high NOS implementers who conveyed their informed understanding of NOS pedagogy through explanations of classroom practices, medium NOS implementers more directly articulated their transitional understanding. Usually this took the form of conscious and accurate self criticisms about lacking a full understanding effective NOS pedagogy, much like those from H5. For instance, when asked what impacts the way s/he teaches the NOS, H3 responded, “My not having a deep understanding of some of the ideas is somewhat of a hindrance in some cases. It is hard to pose questions when you only have one specific way that you know how to express the nature of science idea” (H3, 19:14). H3 also stated, ”Unfortunately, some of it I've found myself doing more telling than I would like to because I don't really have any concrete hands-on things that they can do to experience some of that” (H3, 19:16).

H4 also demonstrated a transitional understanding of NOS teaching by stating, “I know I'm not where I want to be. I guess weaknesses that I currently identify are the NOS issues that I communicated. How do I make that a more efficient and enriching process for
my students” (H4, 2:6)? Through the following statement, H4 then explained how s/he recognized a shift in how s/he understands effective NOS pedagogy:

I feel as though when we first started teaching I was looking for canned responses. I was looking for content driven responses. That is not my goal any more. The questions I've asked have changed. But the responses (from students) that I'm getting are not making the same shift. So, I guess originally it was because the questions were simple, the questions were, there wasn't a lot for students respond to. For example, one question I might have asked would be why might the scientists need to be creative? That was as the type of question that I was asking. Question that I'm trying to transition into might be more specific in nature such as: In what ways are scientists creative when trying to interpret natural phenomena? What are the benefits in being creative when interpreting the natural world? What drawbacks might there be if a scientist is creative when interpreting the natural world? As my interpretation of the nature of science changes so do the questions I ask. But I'm only seeing a slight change in their responses, and now it's: What is my role in that situation? (H4, 2:13)

H6 also indicated struggles to understand how to effectively teach the NOS. H6 conveyed this through explaining how s/he struggled to seamlessly integrate the NOS within science lessons. This was evident when H6 stated, “Sometimes this might be my own fault. It seems a little disjointed like I'm just throwing in lesson plans on the nature of science. Then I come back to them later on and I'm not sure they realize how much I come back to them and how and why they were important” (H6, 21:12). H6 then accurately indicated s/he possessed a transitional understanding of NOS pedagogy through articulating the following:

I could use more experience than that one semester. I think that would help me teach it more. That is a constraint. I just don't feel like I'm super, super knowledgeable. I feel like I have some really good knowledge of the nature of science, but I feel like in other ways I haven't even hit the tip of the iceberg yet. Would I say I am completely awesome at it? Probably not. Am I teaching it? Yes definitely. (H6, 26:15,17,53)

H12 was unlike other medium NOS implementers and H5 that directly indicated their transitional understanding of NOS teaching. Instead, the majority of H12’s statements about
NOS practice were somewhat superficial and so entrenched in modeling that it seemed s/he was confusing modeling pedagogy with NOS pedagogy. For instance, when asked how s/he explicitly teaches the NOS H12 stated,

The activities I choose specifically makes them [the students reflect], we are building models of things we can't see and it inevitably comes up and if it doesn't I'd bring it up and ask questions. So, how confident are you in this? Some questions I get them asking is: “Is this tangible or is this something you can really see? If you can't see it do you really believe in it?” And some are like: “If I can't see it I don't believe in it.” (H12, 27:13)

Later, H12 was asked again how s/he draws students’ attention to the NOS and s/he said, “Either we have some historical example that we see or I tell this story of something, or relate to something that they've heard before, or something we've done previously in the year” (H12, 27:15). When asked how s/he bridges the gap between NOS activities that take place earlier and later in the year H12 revealed an ill conceived understanding of NOS pedagogy by stating, “Usually it's pretty obvious. It is usually not a far stretch. Usually they're doing those specific things, like in the beginning of the year just getting them to start out thinking about nature of science ideas and how this is going to be very different than other classes” (H12, 27:15).

H10 was the only medium NOS implementer whose statements reflected an informed understanding of NOS teaching. Much like high NOS implementers who accurately understood effective NOS teaching practices, the majority of H10’s statements entailed concrete examples from classroom practice. Additionally, these examples usually included H10’s role in explicitly questioning students to reflect upon NOS ideas. An example of one of these statements appears below:
It is pretty regular and pretty consistent. I’ve given you examples where kids are saying it to each other, but I make sure that I when the opportunity arises, when I’m smart enough to catch it I say: What do we know about how science works. They say oh there can be more than one answer. I ask: What have we done to help you understand that? And they say: The tooth pick puzzle or the square puzzle. So I always take every opportunity that I’m given to draw their attention to that explicitly. Absolutely I draw them back to decontextualized. (H10, 25:20)

Although the majority of H10’s statements were rated as informed, s/he also often demonstrated a transitional understanding of effective NOS teaching. This was evident through the following articulation:

I would say that because I haven’t had the practice I miss many opportunities to explicitly teach it [the NOS]. So, somebody that has been doing this for a long time would see that. That comes back to classroom management; I miss the opportunity to teach the nature of science. When I’m worried about taking attendance and I don’t have a lesson plan ready for today then I’m not thinking about those sorts of things. (H10, 25:49)

Table 14 shows all low NOS implementers demonstrated a naïve understanding of effective NOS teaching. Absent from low implementers’ reflections were concrete examples from practice that would indicate they deeply understood how to extensively and effectively teach the NOS. Notably, all low NOS implementers seemingly felt compelled to provide responses when asked to articulate their NOS teaching practices. As indicated before in the section titled: NOS Implementation and Self Reflection, when these teachers were asked to reflect on unfamiliar concepts or potentially uncomfortable subjects (e.g. level of NOS teaching) they “piecemealed” answers. In addition, many times responses revealed low NOS implementers’ naïve conceptions of effective NOS teaching.
Interestingly, statements from three out of the four low NOS implementers indicated they thought implicit NOS instruction was sufficient for students to learn the NOS. For instance, H2 stated

I know at the starting of the year I kind of use a unit you could call nature of science, and try to use activities. But I wouldn't say that I sit down and tell the students we are talking about the nature science. It is something I like to incorporate into the other stuff that I am doing. (H2, 18:11).

Although incorporation of the NOS as explained by H2 is a component of effective NOS pedagogy, by not being fully explicit and informing students the NOS is being addressed they may not pick up on it. H2 did articulate that s/he would attempt to get students to relate how their experiences are like scientists through the following statement:

We look at sometimes dealing with a certain topic that may be considered or controversial in talking about: Well how do scientists deal with that situation? How do we deal with that situation? How are we allowed to address it compared to that? We are talking about stem cells in biology and that of course, that kind of research is kind of controversial. So letting students talk about the real aspects of science. In real life scientists are trying to do research with that, but there are some pressures that they face and I can ask: Are those the same pressures that we face in the classroom? So it is a way to prepare us. (H2, 18:70)

Considering H2 teaches a ninth grade class, this example indicates when and if she explicitly taught the NOS, it may have been developmentally inappropriate. Most students even at a high school level lack the cognitive ability to project themselves into the shoes of stem cell scientists to assess what their pressures are like.

H9 also indicated implicit NOS instruction was sufficient. When asked, to what extent H9 teaches the NOS s/he said:

Explicitly very little probably. We try to do labs and or where we talk about history of scientists, and I'm not trying to talk and say that this is how science
is and this is the nature of science. It is much more implicit than explicit. (H9, 24:14)

Notably, when H9 was asked if s/he thought students should be able understand the NOS through implicit instruction (e.g. through labs) s/he said “yes”. Interestingly, H9 was the only low NOS implementer who provided substantial and accurate criticisms for not explicitly addressing the NOS. H9 also stated s/he just came to this realization after completing the VASSIST questionnaire for this study.

H8 similarly reflected that implicit NOS instruction is sufficient when stating, “I think pros are the way I teach it, and I’m not saying I don’t teach it. The way I teach it incorporates it into the lessons and it is not explicit. The pros are that this teaches the kids the nature of science in the context of science” (H8, 23:15). H8 also demonstrated a naïve understanding of effective NOS pedagogy through reflecting how s/he addresses the idea of laws and theories. As demonstrated through the following articulation, H8 may be addressing some worthy NOS ideas, however the selection of materials and strategies to do so are not congruent with effective NOS teaching and reform-based practice:

We do some vocabulary terms in the beginning and it's part of their vocabulary terms in the book, but I think that the book does a rotten job of explaining it. So when they're looking through their vocabulary words, I don't do any explicit lessons with it. We just have a discussion about: “I hate to tell you this but how many of you think that if you take a theory and I do a lot of evidence it becomes a law?” You know they raise their hands and I say, “I hate to tell you this, maybe your teachers taught you're wrong before and that can happen. I'm just going to say that's not really how it is.” (H8, 23:19)

H11 was the only low NOS implementer that placed any importance on explicitly addressing the NOS when he said, “So I am very explicit in what I'm doing and hit them over the head: And here's another case. And remember when we talked about that? Always it's just
sprinkled throughout” (H11, 26:14). Although H11 perceives s/he teaches the NOS explicitly, the descriptions provided by H11 demonstrate a naïve understanding of how to do so. When asked specifically how s/he sprinkles in the NOS, H11 provided the following example:

It varies but things like, but that scientists that supposedly cloned a human. And then they found him to be totally false. There are some bad guys in science and that's important for people to realize. Scientists are not gods and all do good. There are scientists that plagiarize. There are scientists that just fabricate stuff. Whenever there is a case of that I always bring it up in class because it is important for them to know. Also the fact that things are always changing and it frustrates people. And that scientists don't believe this anymore. And see there is that word: believe. And we talk about that. Scientists don't believe but they go based on evidence. Then I say all of it is just a case of there is new evidence, and that changes their opinions or whatever the things like that. That is maybe just two examples. I can't think of some others but it happens all the time. (H11, 26:15)

Notably in the previous statement, H11 seemed to have hit a conceptual “dead end” when attempting to explain how s/he explicitly draws students’ understanding to the NOS. After this example, H11 continued to provide more examples. One example was about a student who provided an article about newly classified sea slugs that can photosynthesize. H11 discussed how s/he addressed the NOS in relation to this article through the following statement:

And I think: Oh my gosh! Just when we thought we had it figured out and everybody is nice and classified. Now you have this animal that can incorporate parts of what algae have that is photosynthetic. And I said you know what let's not worry about that because that's the nature of science. There are always new things discovered and you go from there. There is going to be research out there based on somebody else's work and who knows? Maybe someday we'll be able to do that and we won't have to go down to the cafeteria anymore. (H11, 26:15)
Not only do these examples from H11 have distortions of the nature of science (e.g. science ideas being discovered and science’s role is to advance technology), but H11 only articulated what NOS ideas were addressed. Much like other low NOS implementers’ statements, discussion was lacking of how effective NOS instruction was achieved. Instead, these teachers tended to simply indicate the NOS is “talked about” or “brought up”.

**NOS Implementation and Orders of Consciousness**

Table 15 reveals three of the four high NOS implementers and two of five medium NOS implementers operated from a fourth order consciousness. The remaining high and medium NOS implementers were rated between third and fourth order. None of the low NOS implementers were rated as fourth order. Instead, three were rated as third order and one was rated as between third and fourth consciousness.

Based on these results, a rough trend could be inferred that leads to the conclusion that NOS implementation is directly associated with orders of consciousness. Caution should be taken with making such a straightforward interpretation. As mentioned before orders of consciousness is a measure of ability to make meaning and construct reality of what is subject and what is object. The benefit for determining participants’ orders of consciousness was to account for how self directedness of the teacher interacts with many other factors that may be associated with NOS implementation.
Most teachers revealed their order of consciousness when discussing teaching pressures such as institutional or classroom constraints. Individuals demonstrating third order thinking usually allowed constraints, expectations, and opinions of others to control how they framed their problems and solutions. For instance, H2 discussed how she sometimes responds if she perceives she is receiving pressure from an administrator:

I think you put an emotional strain on yourself whether you intend it to be or not. Sometimes you take it with a grain of salt and sometimes you can't. You don't have control over those things. Maybe for that point you just, you just have to rethink why am I doing this? Is this the right thing? Is it better for me right now to change what I'm doing for the sake of that I have this pressure going on? (H2, 18:47)
In this quote, the change which H2 was referring is moving from the practice s/he feels is best to that which s/he perceives her administrator desires.

H8 responded to institutional constraints much the same way when conveying how s/he planned to navigate a potential department wide implementation of the same multiple-choice tests and content. Initially H8 tentatively claimed s/he would fight the initiative colleagues, but then s/he seemingly hit an epistemological dead end. This was evident through the following statement:

I don’t know, just roll with the flow, you can’t fight it. It is not worth it to get upset about. That’s the job that you are in. I mean we are in an institutionalized teaching job where you are going to be told to do stuff all the time and it is going to change. And if you get into a big huff about it your job will be miserable. So, roll with the flow. (H8, 23:36)

Interestingly, because H8 is the senior life science teacher in the school s/he teaches in, s/he was asked to lead the rewriting of the district’s 9-12 life science standards and benchmarks. Although s/he holds a position of authority, H8’s way of framing and solving problems is still very much subject to the expectations of others. This example illustrates that a person's order of consciousness does not fully dictate the position they hold or tasks they are assigned to complete in their profession. However, a person's order of consciousness does dictate how and where they derive their way of knowing to manage their position and decision making. H2, H8, and H9 frame their decision making from the institution of schools as a whole. Because of this, it is not surprising they struggle to autonomously implement the NOS and reform-based practice.

Much like the other low NOS implementers who were third order, H11’s decision making matched that of the school he was in. Although this is the case, H11’s statements
indicated his meaning making was between third and fourth order. When asked how s/he felt about having a standardized curriculum, H11 responded in the following manner.

It's terrible. Well, this gets to national standards and all that. And I'm not for national standards. I am for a national plan. I love the NSF program that they have, and also the big book the Atlas [Project 2061]. I love having that, because that is great to use because that is based on research and I think that is good. And I like the freedom to be able to take that and use it the way I want. I do not want people telling me what to do. Teaching is become more and more of that. You just look at the Iowa Core Curriculum. I'm not a big fan of it and I can already see it is getting to be a bureaucratic nightmare. (H11, 26:42)

In this statement H11 appears to be self directed. This is a characteristic of somebody operating from the fourth order. Later, when asked how the curriculum standardization has influenced the way s/he teaches, H11 replied, “Yeah but if that influence is good, then it's good and that means it's influenced me. If it's a bad influence, it is too bad because it is killing me. It is killing creativity in me” (H11, 26:42). In this statement H11 reveals a reaction that is subject to the situation s/he is in. This was evident when H11 indicated the influence of a standardized curriculum controls how s/he works and is creative.

Many other teachers besides H11 fell between third and fourth order consciousness and alternated in drawing from their own meaning making and the meaning making of the institution to make decisions. Like H11, some of these teachers faced teaching constraints such as a standardized curriculum. Unlike H11, all of these individuals were either high or medium NOS implementers and strived to employ reform-based practices. H6 provided an example below of how teachers between third and fourth order coped with implementing reform-based practice in a school with fierce institutional constraints:

I really don't talk about things that I've tried that I thought was good but didn't go well with that group because they will say see it doesn't work. So it's not
“Maybe you should try this next time.” It's, “See, it didn't work.” So you stay as positive as you possibly can which also brings you down because it is hard to keep improving when you can't ask somebody “How did you do it in this case?” You're not getting that reflection such as “Oh why don't you try this one? Why don’t you try this one?” (H6, 21:36)

In this example H6 begins by framing the relationship s/he has with colleagues as object. This was evident when H6 discussed limiting the amount of information s/he divulges about teaching. Additionally, H6 shows s/he is able to take the feelings s/he develops as object. This was evident when H6 indicated s/he stays as positive as possible despite colleagues’ disapproval. Indicative of fourth order thinking, H6 is not only regulating this situation, but is also regulating how s/he reacts to it. H6 also demonstrated third order thinking in this statement. This was evident when H6 revealed this situation causes the emotions s/he holds to be brought down. Also indicative of third order thinking is the way H6 desires external sources to frame and solve problems. This is evident when H6 expresses that improving is difficult without outside input.

Teachers that are not fully self directed (e.g. third to fourth order conscious medium and high NOS implementers) are vulnerable to frame and solve problems based on the expectations of the institution in which they find themselves. This is especially the case for teachers in institutions where the pressures to conform to established teaching practices are great. Additionally, if the expectations of the school are at odds with what these teachers learned in their preservice program, the teachers may develop a great deal of internal strife. This is because they may feel accountable to teach based on what they have learned in their preservice program and the expectations of the school they work in. Unfortunately, these teachers may cave into the pressures and expectations set by colleagues, parents, and
administration to implement practices antithetic to those promoted in programs such as the ISU-STEP. This happened to H6 who felt pressured to have students complete trivial bookwork for grades. When asked why H6 made this decision, s/he said, “Parents don't like it when their students have only a few major grades” (H6, 21:25).

Fascinatingly, all of the third to fourth order conscious medium and high NOS implementers have augmented their reform-based teaching decision making by collaborating with others from the ISU-STEP. These collaborations have enhanced these teachers’ abilities to employ reform-based and NOS teaching practices despite the presence of teaching constrains. More of this phenomenon will be addressed in the findings section NOS Implementation and Responsibility and Support.

Teachers exhibiting fourth order consciousness framed problems and decisions in a markedly different fashion than those operating from third order and third to fourth order consciousnesses. Because of the way they frame problems and solutions, fourth order teachers seemed to thrive despite many of the constraints found in their schools. That is, rather than be “owned” by the constraints found in the teaching profession, these individuals objectively navigated the system in a self-directed manner. For instance, H1 discussed the dissatisfaction s/he has with his colleagues’ wanting to make traditional practices the norm. H1 then proceeded to objectively reflect how s/he views the problem through the following statement:

So what I have come to realize is this. They have misconceptions just as students, and I want to help them overcome their misconceptions just like students. I subconsciously assume because they are educated that they should know better but they don't. So that is a fault of mine. They just haven't had the education that I have and I am lucky in that way. I'm glad I'm not starting where they're starting. But I think I need to help them get to a place where
they are moving away from their misconceptions, but it's very emotional for them because they stick a lot of their pride on their professional life and how they teach. So for me to say “Here why don't you try it this way.” is a subtle message they perceive is “You aren't good enough.” I'm not saying anything about who they are as a human being. I'm just saying what they're doing isn't matching with what research is saying is most effective. (H1, 1:30)

Indicative of a fourth order consciousness, H1 not only recognized the position s/he took as something to be objectively manipulated, but also provided ways s/he could do so. Also, H1 objectively provided reasons why the colleagues s/he works with reacted the way they did, without being manipulated by those reactions. H5 also provided an illustrative example of a fourth order response when describing why s/he faces struggles when discussing practice with colleagues.

I think when I project my views other people just don't understand what I'm trying to do. They perceive me as being too brash, too forward, and they perceive me to be cocky because I'm well-informed. What they don't hear is when I say something I back it up. That is part of their epistemological view. They think that there is a certain way that you go about teaching. They don't see that they are misinformed. I think it’s called belief preservation. Belief preservation in their opinion is enough; it is what inhibits them from hearing any messages that I have. (H5, 20:20)

H5 then provided insight of how s/he can objectively control the way s/he reacts to this situation by saying, “I have to, when I try and discuss my position with somebody, I have to find where they're at in that sense and find analogies and those types of things to get them to relate to the articles that I've read”(H5, 20:20).

These statements illustrate commonalities to all of the fourth order individuals in this study. These individuals are able to use their own system of meaning making to navigate and solve the many conflicts they face within the teaching profession. Conclusively, this may be
the only group, without significant support, that could extensively implement NOS and reform-based teaching practices in a traditional setting with severe pressures to conform.

**NOS Implementation and Interest and Self Efficacy**

Table 16 shows a clear association was not made between participants’ interest in the NOS and their NOS implementation levels. Caution must be taken when interpreting these results because many teachers only made one to a few statements that could be superficially linked to their interest level of the NOS. Based on interviews, all teachers in this study except one appeared to have a medium to high interest in the NOS. Approximately half of these indicated they have a high level of interest in the NOS. Statements made by teachers placed in the high interest category were much like the following examples:

I knew that history within science was interesting to me personally, but I've never thought that it was the way to engage students in a process of learning content. (H4, 2:10)

Well, so I put a lot of emphasis on the nature of science so I’m very, very interested in teaching the nature science. (H13, 17:56)

So the only resolution I could come to was for my own thinking was by going to get resources that went well beyond the standard published materials. And I had a philosophy professor in college that suggested I read Kuhn just because he knew that I was interested in science. (H5, 20:10)

I valued it even before I entered the program. They should understand the history of science. You know it disgusts them [the students] to no end (laughing). For instance I ask, “Isn't it cool that Niels Bohr liked Kierkegaard?” And I'll show them pictures of Bohr with Einstein and ask things like, “Do you think they're talking about girls or science?” (H10, 25:12, 17)
Table 16. Interest in the NOS and self-efficacy of NOS teaching conveyed by teacher during interview.

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<tr>
<th>Composite NOS Implementation Level</th>
<th>Participant</th>
<th>Interest in Topic</th>
<th>Self Efficacy</th>
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<tbody>
<tr>
<td>High</td>
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<td>H9</td>
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Approximately half of the teachers were categorized as possessing a medium interest in the NOS. Many times these teachers’ interest levels were vague and indistinguishable from the value they placed on the ISU-STEP NOS course and/or teaching the NOS itself.

Statements from these individuals included:

Undoubtedly my eyes were open when I took the nature science course through the Iowa State education program. That was where my view of science was really changed. The activities we did in the class, along with the literature that was presented to us was what shifted my understanding of what I think science is. (H3, 19:43)

Going through the nature of science class really made me see the value of, when you really understand it makes teaching science a lot easier. (H6, 21:13)
Effective (the NOS course), it drove the point home and was very interesting and I got a lot out of it the content. I remember everything that was taught. (H8, 23:59)

H9 was the only teacher who seemingly possessed a low interest in the NOS. The reason why H9 was rated in the low category was because s/he admittedly hadn't thought about the NOS since s/he took the NOS course in the ISU-STEP. This was evident through the following statement about how the questionnaire reminded H9 of the NOS:

And then thinking back to my own class how little I, how little it is I talk about it explicitly. I think that is why it is coming out in my answers as to why I see it as important. I think there are a lot of other things that are important. That is just one thing and so I saw the questionnaire and was like: Oh, I remember it, but I don't do it really as much and I feel like I should. (H9, 24:17)

Table 16 shows no apparent association between teachers’ self efficacy to teach the NOS and their NOS implementation levels. All of the high and medium NOS implementers felt moderately proficient to teach the NOS. In some regards, these results are intuitive given high and medium NOS implementers’ ability to accurately self reflect. These individuals commonly referred to their proficiency in teaching the NOS in the following fashion:

On a scale of one to what? I feel I teach the nature science pretty well. I'm not going to say that I am as good as I could be because like I mentioned earlier: With the invention and discovered thing the kids kind of threw me for a loop. (H13, 17:14)

I’d like to just integrate it more. How do we know the stuff? The problem is my own limitations on the stuff. I mean I don't know as much of the stuff as I should. I understand how to apply it, but I don't know where the ideas came from. (H1, 1:10)

So I'm just kind of running down that dark alley right now. I think if I take it as I kind of plan out the semester in more detail and I get a feel for I'm going I think that anxiety will diminish. (H5, 20:8)
My strengths are that I continuously strive to improve. I know I'm not where I want to be. I know that I am not where I can be in the future. But I don't feel that is a weakness, I guess weaknesses that I currently identify are the NOS issues that I communicated. (H4, 2:6)

My not having a deep understanding of some of the ideas is somewhat of a hindrance in some cases. It is hard to pose questions when you only have one specific way that you know how to express a nature of science idea. (H3, 19:14)

I think I'm doing a pretty decent job. I'm very explicit when I do it. It's very often (H12, 27:13)

Based on interview statements, all but one of the low NOS implementers demonstrated a high or medium self efficacy to teach the NOS. Given low NOS implementers’ struggles to self reflect, they may think they are more proficient at teaching the NOS than they actually are. For instance, despite H2’s struggles to determine what proficient NOS teaching is, s/he still stated s/he is capable of integrating the NOS into everyday teaching. This is illustrated in the following statement from H2:

I guess I have a very hard time with which to gauge what is proficient. And I guess that is open to interpretation with what one person thinks is proficient the other won't. I definitely think I'm capable of including it (the NOS) in my everyday teaching. I have a grasp of a lot of the concepts myself. You have to understand it yourself to be able to teach it, which is definitely true of anything. That you have to understand it yourself to be able to teach it if you expect those you teach to understand it. I feel that I have a pretty good understanding of a lot of the ideas. There may be some that I am not on board with or that I'm not just quite sure what they're trying to get at. Maybe I need to look at it more myself. (H2, 18:20)

Not only does this statement illustrate H 2’s inflated self efficacy to teach the NOS, but it also shows s/he struggles to be self directed in setting standards from which to self assess.
H11’s self efficacy to teach the NOS stemmed from the science background s/he possesses. Initially H11 stated, “I think I do a pretty good job. You can always improve but that gets back to me having to spend time and find additional things out there rather than just, I just haven't had a chance. It is definitely a work in progress” (H11, 26:20). After being asked why s/he feels s/he is pretty good at teaching the NOS, H11 stated, “I really think because of my background. I don’t want to sound like a snob. But sometimes I hear people talking [about] the nature of science and sometimes I wonder: How the heck do they know?” (H11, 26:20).

Low NOS implementer H8 also thought s/he was proficient in teaching the NOS. This was evident when H8 stated, “But I think that I really look to focus on that really good [an introductory NOS unit], but after that I kind of would be maybe 80% effective. I would need to look at more strategies on how to teach it to feel more comfortable with it” (H8 27:13).

H9 was the only low NOS implementer with congruent self efficacy to teach the NOS and NOS teaching abilities. H9 became aware of how s/he would struggle in teaching the NOS because s/he completed the VASSIST questionnaire for this study. This was obvious when H9 stated:

One of these things was that I realized the questionnaire that we filled out earlier, I realize that I don't feel like I have a strong of a nature of science understanding as I should have. Or as I would like to have, and I tried to bring up ideas and bring up the nature of science and talk about the history of science and modern-day theories and stuff. But I do know that at the same time I don't have the deep understanding that I would like to. I was definitely just kind of given awareness because of the questionnaire. (H9, 24:8)
NOS Implementation and Utility Value of NOS Teaching

Table 17 shows the degree of utility value teachers placed on NOS teaching and their NOS implementation levels were not clearly associated. Seemingly, teachers can be low NOS implementers, yet maintain NOS instruction has significant value for students. Notably, all high and medium NOS implementers placed a high utility value on teaching the NOS. Perhaps a high degree of utility value for teaching the NOS is a necessary but insufficient condition for NOS implementation. That is, to implement the NOS teachers must feel it is important. However, even if teachers feel the NOS is important they may still not implement it in their classrooms.

Conversely, only high and medium NOS implementers’ utility value for NOS teaching was highly congruent with that promoted in the ISU-STEP. In other words, these findings reveal teachers’ NOS implementation was associated with how congruent their utility value to teach the NOS was with that promoted in the ISU-STEP and science education literature. This indicates high and medium NOS implementers clearly see the many compelling reasons the NOS is a vitally important educational objective.

All high and medium NOS implementers cited more commonly referenced and superficial reasons to teach the NOS such as it humanizes science and makes science content more interesting and accessible for students. Although very important, these reasons typically are readily given by teachers and valued for more immediate goals that relate to students’ and teachers’ successes in the science classroom. For instance, H1 explained, “My reasons for teaching it are students find science more, I struggle use this word, but enjoyable. They find it more real. Like humans actually do it, instead of we are going to go study something in
nature that just seems like a waste of time” (H1, 1:17). H6 provided another example of the value these teachers place on NOS teaching when s/he stated, “I find it students are a lot less argumentative about controversial topics like evolution” (H6, 21:11).

Table 17. Levels of utility value conveyed in interview for teaching the NOS and its congruency with the ISU-STEP and NOS literature.

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<th>Composite NOS Implementation Level</th>
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<th>Utility Value</th>
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All high and medium NOS implementers also provided deeper and more compelling reasons than those mentioned above to teach the NOS. Additionally, these reasons for NOS teaching were highly congruent with the utility value placed on NOS teaching by the ISU-STEP and science education literature. Common to all of these teachers’ utility value for NOS teaching was that NOS instruction would meet goals that transcend students’ classroom
experiences. One of the reasons given was that effectively teaching the NOS helps students develop more accurate and effective ways of knowing and learning outside of the sciences.

For instance, H1 explained how s/he used the NOS as a vehicle to teach students the characteristics of deep learning. Part of this explanation appears in the following statement:

Why I teach it is for two reasons. One: students often have the misconception that learning occurs quickly, amongst many others about learning. So it [teaching the NOS] helps them realize that if you want to learn something it's going to take time to get it. If you want to learn it really well it's going to take a lot of time and effort. So what is it then is for their benefit? It is to tell them that scientists are no different and that takes them time to learn stuff and it takes time for them to figure things out, and it does not happen quickly. (H1, 1:23)

Very similar statements were given by H13 and H5:

There is a lot of application about the nature of science and the philosophy of science really that from philosophical ideas can apply to so much more than just science. So you can apply it to learning and how scientists use prior knowledge to understand their phenomena, and why is learning about something like the seasons so difficult. (H13, 17:8)

I think they develop a greater appreciation for science and its role in our lives. They develop a sense that it is an interesting topic. That it is worth thinking about and debating about. Those are all pros. I think in a sense that as you develop more appropriate nature of science views. To some extent I find it hard to believe that you don't have to have frame shifts in your epistemological value belief type views. I think those are good things. I mean I certainly think those are things that younger kids need to develop in order to be more critical. Not just with science ideas but with a significant number of ideas that we want them to have. (H5, 20:36)

High and medium NOS implementers also indicated teaching the NOS must be valued because it facilitates students to become scientifically literate members of society that can readily participate in socioscientific decision making. This was the main reason given by this group of teachers why teaching the NOS must be valued. As indicated by the following
examples, the type of utility value to teach the NOS possessed by these teachers closely reflects that expressed by the ISU-STEP and science education literature:

Some people are astonished and rightfully so with the technology that we've come up with, but people think that technology will save us and will solve our problems. [They think:] We don't need to reduce what we're taking in or reduce our production, and technology will solve global warming with science and such. That's a foolish stance. I will give you another example. I could eat whatever I want to, take a fat pill, and then eat whatever I want and it would all be fine. I think that's a very naïve view of how nature works. I hope they realize that coming out (of my class) technology can provide something. It takes something as well. It's not good at solving problems but it can make your life easier. It makes things more difficult too. And I want them to understand that science is interested in studying the natural world. And what we do with that information would be the technology. (H1, 1:17)

How do I get my students to walk out of my classroom to be informed and knowledgeable enough about science to make judgments about things in their life or things in society and culture? So, I don't feel just the content is going to give them all of the tools that they need. The nature of science provides a way of looking at science to try and understand how it works. And in order to maybe make decisions. I don't feel that I would be giving them the full picture if I didn't attempt to incorporate the nature of science. (H4, 2:8)

I think it is important for students who are going to be at some point citizens of our country to have a deep understanding of the nature of science. Because the controversial issues in the public would not be so controversial if our members of society had a deep understanding of the nature of science. (H3, 19:10)

The same goes with global warming. That is a big reason why I teach the nature of science because it also helps them understand how science works so when they go out and they read articles or listen to the television or things like that and they hear different professors or whatever. It might be talking about science. I may have students come back and be like you know it sounded like maybe this wasn't really good science. (H6, 20:11)

These are the people that dictate policy and these are the people that decide which way they will world is going and I cannot send out our next group of world leaders [without an understanding of the NOS], people who make decisions and take care of me when I'm old. This has nothing to do with what would you spend money on [in relation to] global warming. That’s fine, it is what it is. I'm not making that policy, but these kids should be able to listen
and make their own choice based on what they know about science. (H10, 25:9)

It is that idea (the NOS) that is so critical in them learning about their world and realizing science, and that environmental sciences aren't telling us what decisions to make. They are helping us make decisions. It kind of tells you some of the consequences of your choices and that it helps to understand the consequences, but it doesn't tell you what to do or choose. (H12, 27:10)

As indicated before, low NOS implementers were not as uniform as high and medium NOS implementers with the level of utility value they placed on NOS teaching. However, all low NOS implementers received a low rating for the congruency of their utility value for NOS teaching with that of the ISU-STEP’s (Table 17). This was because although low NOS implementers provided some general and superficial reasons to teach the NOS, they omitted the deep and compelling reasons promoted by the ISU-STEP, that were provided by high and medium NOS implementers. For instance, none of the low NOS implementers deeply described how teaching the NOS significantly facilitates other ways of knowing and understanding outside of the sciences. In addition, none of the low implementers indicated in any manner they felt teaching the NOS was important in preparing students to be able to participate later in life in a democratic collective that solves societal problems related to science.

Much like high and medium NOS implementers, H2 and H11 indicated a high utility value for NOS instruction. However, the reasons provided by them were limited to those readily given by teachers that are valued for more immediate goals that relate to students’ and teachers’ perceived successes in the science classroom. This was evident with the
importance they placed on NOS teaching to help students see how science connects to “their everyday lives”. For instance:

That science is not just limited to the classroom but it is part of their everyday life and that it is some of the ideas that come out of the nature of science. Students tend to be a little more willing to try and grasp onto something if it is more relevant to them and so it is trying to make science more relevant to their everyday life then. (H2, 18:14)

I think the nature of science is what brings it down to the human level maybe. Otherwise it can get very boring if it is always just dichotomous keys of this, and this, and that. But when you bring in real life people like the guy who had 50,000 affairs and stuff like that, but he is a great scientist but his personal life was in the garbage can, kids will go: Oh my gosh. That makes them realize that nobody's perfect and you can be good in some areas and bad in others and still be a worthwhile person. It's not something like you are in the classroom and this is science. It makes it more kind of touchy-feely for them and not so ivory tower I guess. It helps them relate a little bit better into understanding it all, because a lot of these kids are not going to college either. (H12, 26:16)

When asked about the benefits of teaching the NOS, H2 even conveyed students understand the content better when s/he stated, “It gives students the chance to connect to science and get more excited about it, and gain more interest in it. Sometimes it a gives them a better understanding on ideas of how scientists did it. Then they understand the content and how they came to the conclusions of it” (H2, 18:15).

The level of utility value for NOS teaching was rated as medium for H8 and low for H9. For instance, H9 demonstrated s/he saw little use in teaching the NOS by stating, “They've been taught that (the scientific method) over, and over, and over again that I honestly don't think that, at least noticing in my class, I don't think it changes the way they look at science.” Conversely, H8 indicated s/he valued teaching the NOS primarily if standards, benchmarks, and current trends in science education deemed it important. This was evident when H8 stated:
If I explicitly said what is the nature of science they [my students] probably would look at me funny. That is a con because that is kind of a big thing or a big buzzword in science education. “Nature science: make sure your kids understand it” (sarcastically). I think that my kids get it but not the direct phrasing that we were taught how to teach in the methods class. (H8, 23:15) Because if you look at our standards and benchmarks it [the NOS] is not there, Um, and we focus a lot on it at the beginning, obviously with the nature of science unit and we talk about it a lot there, but not a lot in the rest of the units. (H8 23:22)

H8 and H9 were also rated as having a low congruency with the ISU-STEP for their utility value for NOS teaching. These teachers’ statements about the type of value they had for teaching the NOS were similar to H2 and H11. For instance, H9 stated, “It shows students a true picture of science. They get a better idea of how science works and what it is” (H9, 24:10).

Of all the low NOS implementers, H8 provided the most compelling reason to teach the NOS. This was when H8 reflected on how an introductory decontextualized activity helped students understand the content. Specifically, H8 stated, “It really helps them struggle with their concepts of evolution versus all the different religions and how other things are answered. I've never had problems with evolution because of my instruction on the tube of science and how it's just one of the ways to answer questions” (H8, 18:15). Notably, H8 reflected s/he taught this decontextualized NOS activity to help students understand evolution through better understanding what science can account for. Although positive, H8’s reasons for teaching the NOS in this case did not extend beyond making easier the teaching and learning of this particular science idea.
NOS Implementation and Constraints on Teaching

A clear association was not made between the constraints participants perceived they faced and their levels of NOS implementation. Table 18 shows all participants in this study but H5 faced at least moderate levels of classroom and/or institutional constraints during their teaching career. Not surprisingly, reported constraints varied in type, duration, and intensity over the sum of each participant’s teaching service.

Table 18. Levels of perceived teaching constraints experienced during teaching career and ways of coping conveyed in interview.

<table>
<thead>
<tr>
<th>Composite NOS Implementation Level</th>
<th>Participant</th>
<th>Institutional</th>
<th>Classroom</th>
<th>Coping Strategy</th>
<th>Coping Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>H13</td>
<td>Med</td>
<td>Low</td>
<td>Assert</td>
<td>Navigate</td>
</tr>
<tr>
<td></td>
<td>H1</td>
<td>Med</td>
<td>Med</td>
<td>Assert</td>
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<tr>
<td></td>
<td>H5</td>
<td>Low</td>
<td>Low</td>
<td>Assert</td>
<td>Navigate</td>
</tr>
<tr>
<td></td>
<td>H7</td>
<td>Med</td>
<td>Med</td>
<td>Assert</td>
<td>Navigate</td>
</tr>
<tr>
<td>Med</td>
<td>H4</td>
<td>Med</td>
<td>Med</td>
<td>Navigate</td>
<td>Avoid</td>
</tr>
<tr>
<td></td>
<td>H3</td>
<td>Low</td>
<td>Med</td>
<td>Assert</td>
<td>Navigate</td>
</tr>
<tr>
<td></td>
<td>H12</td>
<td>Med</td>
<td>Low</td>
<td>Navigate</td>
<td>Assert</td>
</tr>
<tr>
<td></td>
<td>H10</td>
<td>High</td>
<td>Med</td>
<td>Navigate</td>
<td>Assert</td>
</tr>
<tr>
<td></td>
<td>H6</td>
<td>High</td>
<td>High</td>
<td>Navigate</td>
<td>Avoid</td>
</tr>
<tr>
<td>Low</td>
<td>H8</td>
<td>High</td>
<td>Med</td>
<td>Concede</td>
<td>Navigate</td>
</tr>
<tr>
<td></td>
<td>H2</td>
<td>Med</td>
<td>Med</td>
<td>Concede</td>
<td>Navigate</td>
</tr>
<tr>
<td></td>
<td>H11</td>
<td>High</td>
<td>Med</td>
<td>Concede</td>
<td>Avoid</td>
</tr>
<tr>
<td></td>
<td>H9</td>
<td>Med</td>
<td>Med</td>
<td>Concede</td>
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</table>

Caution should be taken when interpreting these results as determining levels of institutional and classroom constraints participants faced over their inservice teaching.
experience was difficult at best. This was because determining what was constraining was entirely subject to the perceptions of the teacher being interviewed. Therefore, factors framed as a highly constraining by one participant may be framed as a moderately or lowly constraining by another regardless of the actual intensity. For instance, at least moderate levels of constraints were probably experienced at some point in H5’s career. However, H5 did not indicate s/he experienced significant constraints. This may be because s/he had been teaching for some time and had successfully dealt with them long ago.

Institutional Constraints

Teachers in this study perceived the greatest resistance from institutional constraints (Table 18). Teachers H10, H6, H8, and H11 indicated they faced high institutional constraints currently, and over a majority of their professional career, that have the potential to severely impair their practice. Although constraints such as time and standards and benchmarks were mentioned in these teachers’ interviews, the greatest institutional constraint they referred to was pressure to conform their teaching to be like that of their colleagues. For instance, H11 explained the expectation s/he experienced to teach the same science content and sequence as other teachers the following statement:

“I've been dragged into this but, we have sat down as biology teachers and we have basically very methodically set: We will cover this, this, and this first semester; and we are going to cover this, this, and this and the second semester. (H11, 26:9)

H11 then stated, “You are constantly under pressure to conform to some other person’s way of doing stuff” (H11, 26:25). H6 similarly described how the lack of administrative support coupled with pressure to assimilate to a traditional practice from
teachers and parents has made the school in which s/he works miserable through. This was in part articulated through the following statements:

Not having support from administration which then causes them to say things that might be inappropriate to other teachers like, “Maybe she should be doing a better job or change her practices.” And then parents come yell at me. So yes, administrators are one of the biggest problems. At least it's caused me the most emotional problems. (H6, 21:27)

H8 and H10 similarly described the institutional constraints pressuring them to conform. For instance, H8 described how administration and colleagues at the school s/he teaches at are increasing pressure for everyone to teach the same:

We have been having a lot more parent involvement. And we actually had twins in two different teachers’ rooms, and the parents sat down and actually recorded exactly what was happening with each student with each teacher and they brought that up to the board and the administrators and that was something our department had to look at too. (H8, 23:32). We have a lot more regulations on how we implement it than when I first came here. They told us it doesn’t really matter how you teach it and the sequence you teach it, that is kind of out the door now. We all have to teach it this unit, this unit, this unit, and go through it. And then we even try to test on it the same time. (H8 23:34)

When asked after an observation on 11/05/2009, why H10’s taught quantum numbers before periodic table organization, s/he responded, “Because I have to. Institutional constraints.” H10 also indicated s/he was being pressured by colleagues to employ the same science content and sequence as them in all science courses by stating, “Absolutely, I am questioned on a weekly basis about where are you? Where are you compared to everyone else?” Fortunately, H10 has recently experienced relief from these constraints. When asked how much freedom in teaching H10 had, s/he described the current situation as:

That's a loaded question. Here I am 75% happy. There are some perceived constraints about being on the same page at the same time as every other teacher but because of recent discussions we’ve started backing off of that. We
started going to this approach of: Here are the concepts we want our kids to understand. To get those concepts across here is your smorgasbord of activities, concepts, and labs you can do. (H10, 25:23)

H1, H2, H4, H7, H9, H12, and H13 were rated as facing medium institutional constraints in their career (Table 18). H13, H12, H4, H2, and H9 were placed in this category because they faced severe constraints that were potentially limiting over the minority of their career, but are not currently under these major constraints. Interestingly, all of these teachers faced these constraints during the first year of teaching at a new school.

The types of institutional constraints these teachers faced were vastly different. The strongest constraint H13, H12, and H4 faced was pressure to conform practice to be traditional and like that of their colleagues. Conversely, H9 and H2 received little to no support from administration. Examples of the constraints these teachers faced are evident through the following statements:

I ran into a lot of institutional constraints. In my first two weeks I was told to fall line and told to teach the way other people did it, and told to basically teach traditional. I was told by the principle that other teachers were questioning whether or not I was sticking to the curriculum and whether or not I was doing things with students to help them learn, or if I was teaching over their heads. (H13, 17:26)

My second year of teaching, the other class I taught it was with two other teachers who were not like-minded and I was expected [to teach like them]. It was a weird deal and I think it was on purpose. We actually had a class where we split the class. Every other day [the students were] with him, and then they came to me. I don't know if it was a ploy to keep me on some sort of schedule, but I had to stay a lot more in line with what they were doing. (H12, 27:34)

A couple parent-principal issues. Like an issue my first year of teaching where the principal did not back me with a parent. The parent had never discussed any of this with me. The principal was telling the parent to take this course of action. (H2, 18:32)
That was one of my issues with the old school was behavior problems. I felt never supported by the administration. The administration was very, very, slap on the wrist. “Don't do that, that's bad. How did that make you feel? Why did you do that? Alright, go back to class.” So students never learn anything. Students did not have any punishment basically for problems in class. (H9 24:28)

H1 and H7 were also rated as having faced medium levels of institutional constraints. This rating was given because throughout their career, and currently, they have faced constraints that could be a minor hindrance to their teaching. H1 faces a continuous moderate pressure from colleagues to move away from reform-based practices. This constraint was articulated in part when H1 said, “And the colleagues themselves. So there is pressure. Sometimes explicit most of time implicit” (H1:1:48). H7’s colleagues also assert moderate pressure on this teacher to instruct the same things they do. In addition, H7 perceives an additional constraint because s/he works with colleagues and administration that are significantly apathetic. This was apparent through the following quote:

I don't think I'm getting the support that I need as a still beginning teacher. I'm out of the cycle of someone coming in and watching me teach and giving me report on that. I'm frustrated with the fact that maybe that's just the school thing, there's no accountability with teachers and their actions. (H7, 22:8)

Only H3 and H5 indicated they experience low institutional constraints. Perhaps H5 experiences low levels of constraints because, as H5 indicated, s/he dealt with institutional constraints at the school s/he works in many years ago. During this time frame the constraints may have been much higher. However, because these potential constraints occurred prior to H5 taking coursework at the ISU-STEP, and attempting to teach the NOS, they were not considered for this study. A potential explanation for H3 experiencing low levels of institutional constraints may be because H5 is this teacher’s mentor. Seemingly, H5 does not
impose constraints on H3. Additionally, H5 may “shield” H3 from any potential pitfalls so often found in teaching institutions, thus resulting in H3 experiencing minimal institutional constraints. This was evident by the following statement:

I’ve been assigned as H3’s mentor so I think early on I just kind of approached him and told him, “Look, these are the different roles and I can fill for you. I can be somebody you can just complain to. I can be somebody that can negotiate with you. You just need to tell me what role you want me to slip into. If you just want me to listen so you get something off of your chest just do it.” But more often than not I find us in a dialogue rather than me fulfilling any role where I have to go to bat for him or he just has to get something off his chest. (H5, 20:23)

Classroom Constraints

Only H6 indicated experiencing a high degree of classroom constraints. The constraints H6 experienced stemmed primarily from school wide student discipline problems. Constraints H6 faced included students skipping class and misbehaving in class. This in part was explained through the following statement:

I am also struggling with management of the classroom. This is especially with tardies and absences. It is a school wide major issue. I have become lax on it because I am not getting administrative support and so, sometimes I am pulling back on my rules and regulations. That is a thing I am struggling with in the classroom. (H6, 21:6)

H1, H7, H4, H3, H10, H9, H8, H2, and H11 all faced medium classroom constraints. With the exception of H9 and H11, all of these teachers’ statements indicated they continuously faced typical classroom constraints (e.g. misbehaving, apathetic, and cognitively challenged students). H9 and H11 also faced these issues but had more intense classroom management issues during their first year of teaching at different schools. This contributed to their rating of facing medium classroom
constraints. Example statements illustrating the classroom constraints H1, H7, H4, H3, H10, H9, H8, H2, and H11 faced include:

They understand that we ask a lot of questions and that we don't often give direct answers when we know that students are capable of thinking and reasoning on their own. So students I think understand that. That doesn't mean we don't see a lot of apathy and some kids shutting down. It is more difficult for students come in and critically engage and critically think rather than sitting in a classroom and writing down notes and memorizing. So the students balk at this because it is very challenging. (H3, 19:48)

I feel like right now the students I'm dealing with are the biggest issues I've had in the past three years. Kids who have no responsibility in school or outside of school in essence have no responsibility for themselves. They don't see consequences of their actions. That apathy some of my students have towards learning right now and their laziness is probably the biggest thing I'm struggling with right now. (H7, 22:26)

How you teach science to kids who can't even, or I have kids that can barely type right now. I had a kid who handed in a paper with all the hyperlinks because he just copied them over for his answers. And I have to expect to teach them about cladograms in my course? How do you differentiate for kids like that? I have a class right now where they put in nine special ed kids, five at risk, and six highly functioning kids who are really passionate about it and I really mad about that. (H8 23:80)

Students would be the huge one, the level of students I have in my class. And an example of that would be my environmental science class. The students that I had this year is a much, much lower class. They are much less motivated as well than I had last semester. So I will not be able to do some of the extra activities that we did last semester. We cannot have some of the discussions we had because the students I have this semester cannot handle it. (H9, 24:18)

The intrinsic motivation even with the brighter kids is not necessarily there. If it is not graded than they do not want to do it. Then you run into the problem of cheating and cheating is rampant. (H11, 26:59)

Cons [with teaching the NOS] being from my perspective is classroom management. How do I incorporate it in a way that is natural? How do I incorporate it in a way that is engaging? (H4, 2:9)

The other major issue is probably classroom management. I think the reason why is that classroom management is a lot tougher when your teaching more
open ended things because the kids aren't always at the same spot. There aren't always doing the same things. They're not always thinking the same things. (H1, 1:12)

H5, H12, and H13 indicated facing low classroom constraints. None of these teachers indicated classroom issues were present in a significant amount or impacted their teaching. When these teachers addressed classroom constraints they mentioned their proficiency in handling them. For instance, H12 and H13 provided the following statements:

I think if you are creating high-quality things in the classroom you'll not have to focus on a lot of that (classroom management). I saw middle school, hard schools, and maybe I was a little over the top at first with my classroom management and crazy, but I learned a lot the first and second years. I learn every year how to manage kids and I think a lot of it was what I was creating my classroom. Because if it's meaningful a lot of the discipline problems go away. (H12, 27:45)

I don't have classroom management issues and I don't take kids to the principal’s office. I just don't do that. I think I respect those relations with the students and the idea we are in it together. (H13, 17:67)

**Constraint Coping Strategies**

Teachers’ levels of NOS implementation were associated with the type of strategy they used to cope with teaching constraints (Table 18). All teachers utilized at least two strategies to deal with these constraints and sometimes would use these strategies in combination with one another. For instance, a few times statements revealed teachers confronting some aspects of a particular constraint, but navigating around others. Table 18 shows high, medium, and low NOS implementers generally employed different primary strategies to cope with teaching constraints.

High NOS implementers’ primary strategy was to assert themselves, with a secondary strategy of navigating, in response to teaching constraints. These individuals tended to take
firm stances against teaching constraints to maintain practice. This was regardless if the constraint originated in the classroom (e.g. classroom management) or within the institution (e.g. disagreements with colleagues). For instance, H1 indicated s/he uses pre-emptive lessons directly aimed classroom management issues that often dissuade teachers from employing reform-based and NOS teaching:

I think the reason why is that classroom management is a lot tougher when your teaching more open ended things because the kids aren't always at the same spot. They aren't always doing the same things. They're not always thinking the same things. It happens regardless of whether you teach with structure or not, but the thing is if you stand and deliver and have the expectation that no one talks, it is easier to enforce rather than helping kids realize: It is an appropriate time to get up and sharpen your pencil, or it is not an appropriate time to get up and sharpen your pencil. It is an appropriate time to talk to your neighbor; it is not an appropriate time to talk to your neighbor. So, it is helping them think through. It is just becoming an adult. Those are skills of adults have to have and I'm trying to help them develop those things. (H1, 1:70)

Similarly, H13 provided a statement demonstrating how /she asserted himself in the face of a classroom constraint and potential institutional constraint. In this example a student had not been participating in class and the child’s parents expected H13 to change grading practices. H13 directly addressed the parents in a manner which conveyed fidelity to reform-based practices and care for the student:

I have had a lot of things like parents institutional constraints and colleagues attempt to affect my practices. For instance I had parents call me and say my daughter is getting a B in your class and it is because she doesn't participate in class. And I say “Okay, and?” They said, “I don't think she should be getting a B because she doesn't participate in class.” And I say, “I understand that, but my expectations are very clear that I expect people will participate in class and that you cannot earn an A in my class if you do not participate. Furthermore, the reason I want your daughter to participate in classes is because I want her to learn those social skills because she's a very bright person who ought to be getting A’s, but the problem is you have a very bright
person here who will not share their ideas so it doesn't matter how bright they are. It is much better to learn those lessons now than when they are in high school or college or in their job.” I say, “So this is a goal that I have for my students and I think you’d agree that it is an important characteristic for your daughter to have and I am trying to push her and give her those expectations she develops that.” Then the parents were okay with it and understood where I came from and saw that I had their daughter's best interests at heart. (H13, 17:60)

H5, and H7, also provided more direct indications of how they take firm stances against institutional constraints. In these statements both teachers discussed how using research-based rationales is a way to directly handle potential conflicts with colleagues:

As I stated in my questionnaire we have maintained pressure on this administration in this district for 10 or more years and they see the value in what we're trying to do with the kids when they come in and observe us. They see our questioning strategies and see our approach to trying to get the kids to learn things over time and they value it. I am not saying we didn't have to fight for it. I've been called into the principal’s office multiple times asking and being asked to back up or provide rationale to what I am doing in my class. Fortunately, I've been aware enough to do that. (H5, 20:26)

I think in that situation I would have to say, “Okay, I'm going to show you or try to help you understand why I'm doing what I'm doing.” and then tell them, “Read this and then get back to me and tell me how that fits in with what you would like me to do.” That is what I would like to do after teaching three years. I'm in a position where I can do that. In my first two years I probably would've tried to go with the flow is much as possible. (H7, 22:41)

Interestingly, H7’s statement also indicated how last year s/he would not have openly asserted the rationale s/he holds for teaching. Instead, H7 indicates s/he would avoid and navigate around the constraint. This was evident when H7 stated s/he would go with the flow as much as possible. H7 further explained how s/he navigated classroom and institutional constraints during the first year of teaching when stating, “Staying afloat and just keeping classroom management. Making it appear that I had control of things and not making any waves. I tried to do this as much as possible” (H7, 22:47).
Many of the medium NOS implementers took the approach H7’s did during the first years of teaching. The only exception was H3 whose statements conveyed s/he tended to be openly assertive against the few minor constraints s/he faced. Notably, as indicated previously H5 is H3’s mentor. Therefore, H3 does not have many constraints to deal with.

The remaining medium implementers’ statements indicated they tended to navigate the constraints of teaching. For instance, H10 provided an excellent example of how s/he navigates around a departmental requirement to teach content s/he feels is trivial and unnecessary:

> How do we know at the end of the day that all classrooms are addressing the same thing? I’m not fearing the pressure I did even a semester ago of why didn’t I cover certain things. There is still that and I worry about it. Like in our chemistry department people think it is important to draw orbital location and a lecture on filling diagrams and I hate those. And I hated them when I was in college. I understand the value, but that is because if you do chemistry for a living, to understand how things interact with each other. Otherwise, they're not important. When I had to teach it I spent a week talking about the old guys who figured it out rather than the math behind it, because there's little value behind [the orbital notation]. I feel there is behind knowing how they figured it out. So there's ways to get around it. (H10: 25:41)

Interestingly, H10 also indicated s/he spends a day or two quickly lecturing about orbital notation so s/he can “claim” s/he taught it. Coincidentally, H10 was observed on 11/05/2009 conducting this lecture oriented lesson which rated poorly on NOS-COP and LSC-COP scales (Table 9). By “appearing” to teach like everyone else, H10 has found ways to implement reform-based practices to include teaching the NOS.

H6 indicated s/he strives to create engaging lessons to navigate the classroom constraints of low attendance and behavioral issues described in previous sections. Interestingly, H6 has taken this route because the school administration does not enforce the
school’s attendance policy, thus leaving H6 with little support to enforce classroom attendance rules. Therefore, H6 is employing strategies to navigate around two forms of teaching constraints. The statement below partially illustrates H6’s strategies:

Some of the other issues go away like behavioral issues. Some of the issues like attendance issues. If the kids really know that something really neat or we are in the middle of a project and they will tell me that they don't want to miss this class. I came in only for this class or something like that. And I have had that happen, especially with the bigger projects when they were afraid to miss because of what they may miss for my class. This is because they are engaged. I think that takes away from all the other issues that kind of stop student achievement as student learning. (H6, 21:65)

Although H6’s primary strategy was to navigate she was only one of two teachers in the high or medium NOS implementation categories whose secondary strategy was to avoid. This very well may be because H6 faces fierce institutional constraints from colleagues and administration who wants teachers to assimilate to a standardized teaching practice. H6’s response to this pressure was evident when s/he stated, “I section myself off and I don't share what I'm doing. I haven't felt so much pressure that I'm changing what I do. I'm just trying to keep my head below ground so that I can continue doing what I want to do and not necessarily make waves” (H6, 21:36; 58). The other teacher whose secondary strategy was “avoid” was H4. Interestingly, last year H4 was in a similar situation as H6, but now is in a school with far fewer constraints.

Interestingly, H6 is responding to the constraints s/he faces in the same manner as two other medium NOS implementers, which is by actively pursuing an administrative role in their schools. By attaining these roles, H6, H10, and H12 feel they can shelter themselves from their colleagues’ pressure to assimilate practice and/or encourage the use of reform-
based practices within their schools. H6 described in part why s/he wants to attain a position through the following statement:

   I did apply for a director of the department job which is a curriculum job. It is an extra. They can't get rid of the department head. So they created these directors of the department jobs so we'll see how that goes. A big reason is to change up the curriculum and make sure that it matches Iowa Core Curriculum and you get people on board with that. (H6, 21:60)

Unlike the strategies used by high and medium NOS implementers, all low implementers’ primary strategy was to concede to the constraints of teaching. These teachers presented multiple statements indicating their NOS and general teaching practices were limited by institutional (e.g. colleagues, time, and curriculum standardization) and/or classroom (e.g. classroom management and students’ desires) constraints. Additionally, many times these teachers would relinquish themselves of accountability to implement reform-based and/or NOS teaching practices by insinuating these constraining factors were either too great to overcome and/or out of their control. For instance, H8 described several reasons below why s/he is limited in implementing the NOS and reform-based teaching:

   You can't talk at the kids for an hour and a half. You need to throw activities and discussions in, and peer sharing or something like that and that takes time up and it cuts away from the amount of content you can do. I'm not saying that those are not valuable experiences because they should be and they are, but you got to get the content out. So we decided that we need to take it off the [90 minute] blocks so we have time to get the content in. (H8, 23:43)

   But it [the NOS] is not the focus of our content. In either the model core [Iowa Core Curriculum] and in our standards and benchmarks that were made this summer by the science curriculum committee. (H8, 23:23)

   I kind of teach what everybody else in my department is teaching and I am really trying to do closely with what one of my other colleagues does. Her lessons don't reflect it [the NOS] either. I am not making excuses, but it's just that with some of the things I just do what they do. And none of us do it so. (H8 23:62)
H8’s comments clearly show s/he struggles to provide compelling reasons why s/he is not effectively implementing reform-based and NOS teaching. Interestingly, in the first comment H8 recognizes that you cannot “talk at” the students for 90 minutes like you can for 45 minute periods. H8 then justifies more time to cover content is realized with the 45 minute period. What H8 neglects to mention is that over the course of a semester of 90 minute periods, approximately 450 minutes of instructional time is gained because students are in class during an additional five minute passing period every day. In the second statement, H8 articulated the NOS is not covered in either the district standards and benchmarks or the Iowa Core Curriculum. What is interesting is that H8 also commented s/he was in charge of rewriting the district standards and benchmarks, thus having full control over whether the NOS was present in them. H9, H2, and H11 also provided statements citing uncontrollable institutional constraints that limit their practice. For instance:

That is difficult at times where you get so caught up in content and you need to cover this, and this, and this, and this. With the Iowa Core Curriculum coming down. There so many concepts there. I think the nature of science and inquiry take a little bit longer to teach sometimes. To get through some materials and with all that coming down I think that is going to be a difficult transition. (H9:23:48)

I think the nature of science, it's trying to show the idea that it's every day and you can incorporate some of those ideas into everyday life. So, it's not the hardest as far as finding an activity that shows it. It's may be trying to say this is what you're trying to cover that everybody should know. But you just can't get to all that. That is just too much. (H2, 18:76)

I have to talk with other teachers to make sure that I've covered the certain subjects so that if some of their students come over to my class I will not repeat and/or they will have had the [same] material. It can be very confining, but it does dictate to what I teach. I don't have the freedom that I think I should have. (H11, 18:76)
These teachers also cited several classroom constraints that limited their practice. Usually, indicated constraints were classroom management issues, students’ desires, and/or students’ inability to succeed in a reform-based teaching environment. For instance, H9 stated how classroom management issues controlled how s/he taught in the past through the following statement:

If they are having a good day in the class they would probably be productive in the work and they would to do it and not be a nuisance. If it was a bad day I would try not to, or probably not have them work because they may possibly destroy other students’ work or interfere with the other kids and the class would've been a waste. That was the biggest thing of trying to have two plans in place. If they're in a bad mood this is the one to have in place. If they were in a good mood this is the one in place. (H9, 24:29)

Other statements indicating how classroom constraints limited practice were provided by H11 and H2. In these statements H11 and H2 specifically indicated they conceded on implementing what they learned in the ISU-STEP because of their perceived limitations of students

I know there are some things that I did in my (NOS) class that I haven't actually implemented. My first year I used a ton of stuff straight from my (NOS) course and that was some those pictures when you're looking at those drawings you can see it in different ways and all that stuff. So I used a lot of that and to be honest with you I don't do that as much because that's the part that they don't take seriously. They think it's just I'm off on a tangent or something like that. (H11, 26:56)

This sense of time and how much time you can spend on things seems very idealistic [in the ISU-STEP]. We had attention spans that were much longer so when we talk about it and look at: This should take this long and expect to be able spend this much time on this. Idealistically, yeah I could get this much out of it and the responses and everything but we were going to try harder than a lot of these students are. (H2, 18:86)
NOS Implementation and Responsibility and Support

High and medium NOS implementers demonstrated high levels of responsibility to employ reform-based practice and NOS teaching (Table 19). In addition, all medium and high NOS implementers described to a great degree the role of seeking and drawing support from each other to help them maintain these practices. Conversely, low NOS implementers demonstrated a low responsibility to implement reform-based and NOS teaching practices. Additionally, these individuals did not actively seek out nor receive support from others from the ISU-STEP.

Table 19. Level of responsibility and support from other ISU-STEP graduates to enact reform-based and NOS teaching conveyed in interview.

<table>
<thead>
<tr>
<th>Composite NOS Implementation Level</th>
<th>Participant</th>
<th>Responsibility</th>
<th>Support</th>
</tr>
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<tbody>
<tr>
<td>High</td>
<td>H13</td>
<td>High</td>
<td>High</td>
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<tr>
<td></td>
<td>H1</td>
<td>High</td>
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<td>H5</td>
<td>High</td>
<td>High</td>
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<td></td>
<td>H7</td>
<td>High</td>
<td>High</td>
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<tr>
<td>Med</td>
<td>H4</td>
<td>High</td>
<td>High</td>
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<td>H3</td>
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<td>H12</td>
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<td>H10</td>
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<td>H11</td>
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<td>H9</td>
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High and medium NOS implementers explicitly demonstrated a high responsibility to implement reform-based and NOS teaching practices. Often, this responsibility seemed to be manifested intrinsically. For instance, when asked why s/he teaches the nature of science H1 included within the many reasons the following statement:

Helping them see that distinction that doing science just to know and that some things are worth doing just because they are. Goodness, being a good person is worth pursuing just because it is. In a similar way, understanding things about the natural world is worth doing just because. It is not because you're going to get something out of it. (H1, 1:54)

Similarly, H13 expressed an internal ethical responsibility to maintain reform-based and NOS teaching practices. This was evident when H13 gave the following statement:

That's me I'm just kind of that way. It is I guess at some point you get so fed up with seeing that teachers continuing to maintain status quo and I care about kids. I am sorry but what teachers are doing is not good for kids. So I get really upset by that and therefore I emotionally react when people question the things that I'm doing. (H13, 17:19)

Later in the conversation, H13 described online videos in which s/he taught. While doing this, H13 became highly critical of the teaching displayed on the videos. When asked why s/he holds himself to a higher standard, H13 responded, “I just have a general desire for excellence” (H13, 17:41).

High and medium NOS implementers’ intrinsic ethical responsibility for maintaining reform-based practice was often expressed when describing institutional and classroom constraints. An example of this was when H7 self-questioned why s/he should continue to implement reform-based practices when none of the colleagues s/he works with do. Eventually H7 stated s/he would continue to teach in a manner that was congruent with what
s/he had learned in the ISU-STEP. When asked why, H7 replied, “Because I know it's right. I didn't get into this profession just for a paycheck.”

A similar responsibility to employ reform-based and NOS teaching practices was expressed by H10 when s/he stated, “You don't even have to convince yourself. You just have to. This is not being taught out there and it is my responsibility to just kind of do it” (H10, 25:15). When pressed on the issue, H10 replied “My kids, I walked into the classroom and I'm not teaching for a paycheck, and I'm not teaching for my administration or other teachers and not to impress the people that know me” (H10, 24:25).

Statements by H1, H12, and H13 indicating their response to the constraints of teaching further demonstrated high and medium NOS implementers’ responsibility to implement reform-based and NOS teaching practices:

The pressure comes from students sometimes. You don't teach like so-and-so does. Yeah well sorry. And the colleagues themselves. So there is pressure. Sometimes explicit. Most of time implicit. But I think they're realizing they're not doing a very good job of wearing me down (H1, 1:48)

The second year I really expected: “Hey lets take a look at this and make it better.” And they (my colleagues) were always like: “Yes, let's look at that.” But when it came to it I'd talk about this is what we'd had done. I think tweaking to him meant something different than tweaking to me. So I just did whatever I wanted and disregarded what he did. (H12, 27:19)

Also my personality is kind of like: Oh you didn't just tell me what to do. I'm sorry that doesn't work for me. I'm going to do what I want to do. You can take a flying leap. So I would say that them telling me I need to fall in line probably pushed me harder to what I knew was good for students. (H13, 17:18)

In addition to displaying a high degree of intrinsic responsibility to implement reform-based and NOS teaching practices, all medium and high NOS implementers extensively described how support from each other helped them implement reform-based and
NOS teaching practices (Table 19). Also, many of these individuals often indicated their close relationships with others from the ISU-STEP caused a high degree of co-generated responsibility to implement reform-based and NOS teaching practices. Many times participants indicated their responsibility manifested itself in the form of guilt or embarrassment if they were caught not implementing these practices. For instance, H6 explained how s/he would feel if the ISU-STEP colleagues s/he collaborated with (H1 and H10) knew s/he had not employed what the ISU-STEP promotes is effective teaching. This dialogue is present in the statement below:

I don't know. Maybe it is a support system because I know that if I told. And maybe it's the embarrassment that if I told H10 or H1 what I was doing they would be like: Really? You are really doing that? And they would be like: Oh damn! All right (sarcastically). (H6 21:47)

H6 also made a point to convey to me that this was a positive relationship when s/he said, “It's not bad pressure it's good pressure” (H6, 21:31). Through the following statement, H6 also emphasized the program helped to instill some of this responsibility:

The professors say they don't want you to punt on the students. It gives you a sense of pressure to not fail the students. You are almost embarrassed if you talk to your classmates and you are like: “Oh yeah, I had them read a book today because I was exhausted.” Whatever it might be you feel like you're not only letting your own students down but how much you are letting this MAT program down. Because I think they taught us enough and gave us enough sense that we know what's right and wrong. I know when I'm doing traditional teaching versus when I'm doing good teaching. (H6, 21:31)

H10 also indicated the responsibility and reassurance felt because of collaborating with others from the ISU-STEP. Specifically, H10 is referring to collaborating with H1 and H6 when s/he stated:

It centers me and it reminds me of where I come from. It reminds me I am doing the right thing and gives me examples of other people that are also
doing, and trying to do the right thing. So it gives me someone to look up to or to emulate. How can I possibly feel good about trying to help someone else if I'm not doing those things? It keeps me honest I guess. (H10, 25:31)

H13 provided another example of feeling responsible to implement reform-based practices because of others in the ISU-STEP. In this example H13 discussed a video that was posted online in which s/he felt s/he demonstrated poor interaction patterns. H13 then explained how s/he would not want anybody from the ISU-STEP to see the video. When asked why H13 said, “It made me reflect and want to improve out of my own competitive spirit. If H1 was to see one of those videos I would be like, I would be embarrassed for him to see one of those videos” (H13, 17:39, 40)

H5 collaborates closely with H4 and H3. When asked how this affects the way s/he teaches, H5 stated, “I would say mostly our discussions maintain a positive pressure on continually justifying what we're doing in relation to how students learn. It's helped maintain pressure on some goals that I think sometimes get lost in the shuffle” (H5, 20:20). Similarly, H4 reflected the collaborations with H5 and H3 have created an accountability to implement reform-based and NOS teaching practices. This was evident when H4 said, “I guess I'm questioning myself a lot more now than I did initially because I am examining what I do much more closely. As a group of professionals we push each other and put pressure on each other, when if we didn't have each other that may or may not be happening” (H4, 2:36). H3 also confirmed the high co-generated level of responsibility within this group to implement the NOS and reform-based practices through the following statement:

Yes, they expect me to teach in a way that is best for students. Do I get pressured to teach in a way that I don't think is appropriate? No. Or very little. I guess in other words if my colleague H5 walked in here and every day I was
showing a film or students were reading out of books he would let me have it, and justifiably so. (H3, 19:23)

All high and medium NOS implementers alluded to why they interacted with others in the ISU-STEP for support. Seemingly, these individuals sought to improve their own practice by working with others that were “like-minded” about teaching and learning. Some sought out “like-minded” support from others from the ISU-STEP during their preservice experience, whereas others looked for like-minded collaborations after they left the ISU-STEP. This was evident through statements made by high and medium NOS implementers such as the following:

But it really goes back to the level of knowledge and understanding that we have of teaching and learning that we know what we ought to be doing, and that any deviation from that ought to be seen as not good enough. I think it is a character trait. (H13, 17:42)

I want to help them become the best teacher they can be, and I want to be the best teacher I can be and those two things go hand in hand. If I help them I will become better. So it wasn't so a selfish reason, it is just so we can all become better. (H1, 1:53)

I think it was a two-way street. They stayed in contact with me and I stayed in contact with them. So there were things that I, questions they had that they asked me, and I had questions that I asked them. (H7, 22:20)

I think everyone I talk about it has a certain mindset that we were taught about, H1, H6, H13, and all those people, and probably even H3. (H10, 25:15)

Since it was so discussion based [the ISU-STEP classes] you got a lot of ideas of what kind of teachers these people are going to be. Where are their ideas coming from? Who can I trust as far as good ideas and not good ideas? (H6, 21:48)

The nice thing is that I teach with a lot of colleagues that have similar views. I am not being pressured by them to conform to them. For the most part because we agree on a significant number of things and we are all at different places and how we go about doing things. I think we have the same goals and
we don't really worry about conforming to some standardized way of doing it. (H5, 20:18)

I didn't feel that there were any like-minded professionals in the building that I was working at, and so I knew that if I wanted to continue and maintain and build my own strategies I needed to get myself connected with two like-minded people who value certain strategies and teaching like I did. So I found them and they couldn't get rid of me. (H4, 2:37)

What I consider my true colleagues in my department have similar epistemological views as me. (H3, 19:27)

Results from VASSIST question 20B indicates high and medium NOS implementers feel their current teaching practices were significantly influenced through collaborations with others from the ISU-STEP (Table 20). In addition, results from question 20C indicate they saw much utility in collaborating with others from the ISU-STEP. Statements expressed in interviews match these findings. All high and medium NOS implementers explained their collaborations helped them progress in their understanding and implementation of reform-based and NOS teaching practices. In addition, high NOS implementers indicated they either collaborate with other high NOS implementers and/or serve(d) as mentors to high and/or medium NOS implementers. These findings provide an explanation why high and medium NOS implementers are similar in their understanding of how people learn, reasons for valuing NOS teaching, self reflection abilities, and the way they handle teaching constraints. Furthermore, these findings explain why all of these teachers’ strive to make their practice resemble what they learned in the ISU-STEP.
Table 20. Level of collaborations with others from ISU-STEP reported by teachers on VASSIST questionnaire.

<table>
<thead>
<tr>
<th>Composite NOS Implementation Level</th>
<th>Participant</th>
<th>Question 20A</th>
<th>Question 20B</th>
<th>Question 20C</th>
<th>Question 20D</th>
<th>Question 20E</th>
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</thead>
<tbody>
<tr>
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<td>A</td>
<td>SD</td>
<td>SD</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>H4</td>
<td>A</td>
<td>A</td>
<td>D</td>
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<td>A</td>
</tr>
<tr>
<td></td>
<td>H3</td>
<td>A</td>
<td>SA</td>
<td>SD</td>
<td>SD</td>
<td>SA</td>
</tr>
<tr>
<td>Med</td>
<td>H12</td>
<td>U</td>
<td>SA</td>
<td>SD</td>
<td>SD</td>
<td>SA</td>
</tr>
<tr>
<td></td>
<td>H10</td>
<td>A</td>
<td>A</td>
<td>SD</td>
<td>SD</td>
<td>SA</td>
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<tr>
<td>Low</td>
<td>H8</td>
<td>A</td>
<td>U</td>
<td>U</td>
<td>D</td>
<td>D</td>
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<tr>
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High and medium NOS implementers often explained the development and structure of their collaborative groups. Additionally, statements from these teachers exemplify the importance of early-career teachers having “like-minded” individuals to collaborate with to further the effectiveness of their reform-based and NOS teaching practices. For instance, H13 described collaborations with H1 as developing “organically” from the time they met when H13 was in the first year of teaching and H1 was finishing the ISU-STEP. H13 described how their relationship began when s/he mentored H1:

With H1 it was much more of a mentor relationship. Not so much now but that's how it started. Mostly because he was a year behind me. So when he
was in the MAT he came and saw H12 and I giving talks at conferences and things like that. (H13, 17:36).

This collaborative relationship has currently become one characterized as between peers. This was evident when H13 claimed, “As time goes on it is becoming more of equal partners in that relationship, which is the way I think it should be.” H13 also described how s/he benefits from the relationship through on-line co-planning with H1. For instance, H13 stated, “If I have an idea I will pass it to H1 in an e-mail, or s/he'll have an idea for tests and s/he will send it to me in an e-mail” (H13, 17:44).

As indicated in previous statements by H13, s/he also worked closely with H12 during their first year of teaching to present at conferences. H12 spoke of how interactions with H13, H1, and others from the ISU-STEP influenced the way s/he thinks about reform-based and NOS teaching practices. Because of these interactions, H12 feels s/he was influenced positively and significantly to implement reform-based and NOS teaching. This is evident through the following statements:

> Just reflecting on the big ideas and how things fell in line. And ideas of how students learn and how you take that into account and philosophically refining your research based framework in your head. I think the same goes for developing a deep understanding of what the nature of science is and how we implement it in the classroom and what things we've done. I think just talking about what that even means. And having philosophical conversations about the stuff that involved in the nature of science in your classroom in situations. (H12, 27:24, 25)

H1 also discussed how s/he collaborates with H13. These two high implementers are in contact with each other on a weekly basis to discuss teaching practices. When asked about the collaborations with H13, H1 stated:

> S/He has been essential to what I'm doing in my class and some of the ideas that s/he teaches I came up with. Some of the ideas I teach s/he came up with.
Yesterday, I just sent an e-mail asking: What do you think the most fundamental ideas of chemistry are? (H1, 1:60)

After articulating about the collaborations with H13, H1 mentioned how s/he presented and collaborated many times with H7 since their initial years in practice.

Evidence of these collaborations is apparent in the following statements:

We used to work a lot together our first couple years and we just had parted ways a little bit. Life has gone on. We still keep in touch. S/He (recently) borrowed some Rutherford trays that I teach with. [You know] Rutherford's gold foil experiment. (H1, 1:41)

Well with some of the planning H1 and I would talk about teaching inquiry and how do you take cookbook labs and make it into an inquiry lab. We were thinking about what our goals are for students, and what actions do we look for. (H7, 22:16)

H1, then discussed a closely nit collaboration group that has formed between this teacher, H6 and H10. This group formed two years ago while H10 and H6 were transitioning from the ISU-STEP into professional practice, and currently continues to meet a few times a month.

H1, having already taught for two years, indicated s/he had much to offer H6 and H10 when they left the ISU-STEP. This was evident when H1 described the course of their relationship as: “Initially it was a mentor now it is a peer. It has shifted over time now that they have more experience teaching. We can share ideas. I trust them both with what ideas they have” (H1, 1:40). H1 clearly demonstrated how s/he views the collaborations with these and others from the ISU-STEP as compared to colleagues s/he works with by stating:

First and foremost my collaborations with other people [those from the ISU-STEP] are so much more positive than they are with my department. I just don't have to fight. They don't care what I do or don't do. I mean they do, but the people I collaborate with don't care what I teach or don't teach in the extent that they want me to be a good teacher, but if I take their idea and use it or not they don’t take it personally. We are just spit balling ideas. That is not how the department works. It is a lot more political and a lot more emotional
than the collaborations I have with my friends. That sharing of ideas and trying to become all you can be. It is like I can do this idea, I can do this idea, or develop a more engaging cohesive worthwhile curriculum and activities. (H1, 1:37)

H6 discussed the collaborations s/he has with H10 and H1 by stating, “I talk to H10 at least once a week. And we talk about school and were you doing what am I doing? What worked? What worked well” (H6, 21:40)? H6 then discussed how they make a point to meet face to face when s/he said, “H10 and H1 and I get together at least once a month for dinner and throw out ideas of: What's going well? What's not going well? Here's what I'm facing. How might you guys deal with it?” (H6, 21:40) When asked how this affects the way s/he implements reform-based and NOS teaching practices, H6 articulated:

H10, H1 and I will sit down and have dinner and just throw nature of science ideas around such as: What are you doing for nature of science? And then we bring those ideas right back to our classroom. I think we planned from the last dinner that we had what we were going to do for the next week in regards to nature of science. So that definitely affects the way we bring in nature of science into the classroom. And it also affects how we are bringing inquiry into the classroom because we throw out: What are you doing here? And H10 and H1 both gave me great ideas to use. H10 made up a lesson plan for the Gestalt switches and what s/he does, and I literally used it two days later. (H6, 21:41)

H10 echoed the how the context of discussions between these three teachers center around the nature of science when s/he stated:

It's not a question of whether or not we're going to talk about the nature of science. It's about: How long we talk about it? And what are you going to do this year kind of stuff. And no one's afraid by that question or embarrassed by it. It's not even an expectation. We just do it. It is just part of it and so that really, it's easy to go along with the crowd I guess. (H10, 25:15)

H10 further verified that s/he collaborates with people from the ISU-STEP to better reform-based and NOS teaching practices by stating, “I have specifically taken things from other
teachers from the program such as H1 and H6, and H13 has helped me on a couple. I take those activities and try as hard as I can to make them fit or change things up” (H10, 25:18). Important to note about the collaboration group composed of H1, H6, and H10 is that they do not work in the same school district but have maintained support for one another for two years.

H5, H3, and H4 have also developed a closely knit support group that works together to promote reform-based and NOS teaching practices. Unlike H1, H6, and H10 these teachers work in the same school with adjoining rooms. The advantage for this situation is that H5, H4, and H3 are able to have many discussions throughout the day about how to effectively implement reform-based and NOS teaching practices.

Much like H13 and H1 have served in a mentorship role for medium NOS implementers, H5 has also served as a mentor for H3 and H4. Through the following statement H5 described how s/he perceives the relationship with H3 and H4:

I know that now that H4 is up here in the high school rather than down in the middle school I see our professional relationship has developed significantly. I've been assigned as H3’s mentor so I think early on I just kind of approached and told H3: Look, these are the different roles and I can fill for you. I can be somebody you can just complain to. I can be somebody that can negotiate with you. You just need to tell me what role you want me to slip into. If you just want me to listen so you get something off of your chest just do it, but more often than not I find us in a dialogue rather than me fulfilling any role where I have to go to bat for this person or s/he just has to get something off his chest. (H5, 20:23)

When H3 is asked about the relationship with H5 s/he states, “Even if H5 wasn't [my mentor] in that official capacity s/he would be a role model for me. I ask H5’s advice multiple times a day” (H3, 19:35). Although H4 did not explicitly state how s/he viewed H5, s/he did indicate their strategies were alike which was s/he and others. This was evident
through H4’s statement, “One administrator went so far as I'm really glad that you made the transition here because you are more like H5, and so I feel like it's valued-the strategies that I use” (H4, 2:21).

These three individuals indicated they have greatly impacted each other's reform-based and NOS teaching. For instance, H5 relates how the first year of teaching the NOS would have been different without H3 and H4 when s/he said, “I'm in contact with them every day. That is a positive. I definitely feel like my first year of addressing the nature of science would've been much less comfortable if I would've been going at it without those colleagues around” (H5, 20:22). H5 then discussed how s/he encourages H3 and H4 to implement the NOS when s/he stated, “I probably maintain as much pressure on them to keep pushing for things despite setbacks. Such as asking them questions about what they're doing and sharing nature of science ideas with them. I think I kind of see that as part of a role that I would have for them” (H5, 20:23).

H4 also explicitly addressed how collaborations with H5 and H3 have impacted the way s/he understands and teaches the NOS. When asked how working with H5 and H3 has impacted the transition toward effective NOS teaching s/he replied, “I think a great deal. I think the shift may have come later in my teaching career but it may not have come at all to be quite honest. I cannot make that judgment. I do not know. I know that I had not expected it. So as we started communicating with each other the impact was strong and fast.” (H4, 2:14). When asked why s/he thought the impact had been so strong s/he stated:

Not being secluded. Having different perspectives and having to verbally have an intelligent conversation. We have a common understanding that when we discuss what we do in the classroom and why we do it, we know what background the other person has. We know that the decisions that we make
need to be crouched in and supported in and cited in literature. So when we have a conversation. That is the type of conversation I have with certain colleagues that are very, very different compared to colleagues who don't have similar backgrounds. This helps in our communication process with each other because we don't have to explain to each other philosophically why we may have done something. Now it's at a different, very deep, conversation level where we know where each other is coming from. It is a conversation of strategy. (H4, 2:14)

H3 echoed H4’s statements of appreciation for “like-minded” colleagues that understand the importance of reform-based and NOS teaching practices. This was evident when H3 said, “I think that it helps to have colleagues that also appreciate it, that also believe it is important to explicitly and accurately teach the nature of science” (H3, 19:12). H3 further indicated meeting with other “like-minded” individuals from the ISU-STEP outside of school by stating:

I had dinner with faculty [from the ISU-STEP] and H1, H6, and H10 last week. I e-mail some of my cohort weekly. I teach alongside at least one, not from my cohort but the cohort above me (H4). I think I'm in pretty regular contact with other members of my cohort and other cohorts as well, and the faculty. (H3, 19:32)

H3 proceeded to indicate through the following statement how these support groups maintain positive pressure to implement reform-based and NOS teaching practices:

It's been very helpful. Not only just to commiserate like all teachers but also to bounce ideas off of and get suggestions. And ask questions if we need to if there is a new idea that we want to incorporate into our teaching and curriculum and we really don't how to address it. It's influenced me by keeping me honest. Every time we get together it's like a mini refresher course with all of the ideas that were instilled in us. Sometimes that just comes out by us making fun of or criticizing other people we work with about conducting things and conducting themselves that we know are not best for kids. Sometimes it's us really expressing our disappointment in our own behavior because we know we haven't done the best job that we are capable of doing. Sometimes it is just us asking each other questions of how to get better. (H3, 19:32)
An encouraging finding is through their collaborations H3, H4, and H5 have initiated a very aggressive approach to ensure each student gets progressive NOS instruction throughout their ninth through twelfth grade science experience. This effort was explained by H3 below:

As a department we generated a list of the ideas of what we would like to discuss or present to students at some point during their four years here in their ninth through twelfth grade experience in science. That list was generated not only from a paper that Dr. Clough put out, but there are themes that go with the nature of science course. So, they have a direct role in what we decided would be appropriate for high school students. (H3, 19:16)

All high and medium NOS implementers besides H5 indicated on the VASSIST questionnaire that collaborations with other ISU-STEP faculty and students were crucial during their first year (Table 20). H5 answered undecided on this question because s/he graduated from a different program many years prior to the other participants in this study. These VASSIST responses matched statements such as:

It certainly did. I would call people. The first year was a lot of venting. (H1, 1:36)

In the first year it was a nice support system. I ran into a lot of institutional constraints and so was nice to be able to call our methods professor and say, “Hey I think this sucks! Please talk me down off the ledge” (H13, 17:25).

I said you are not alone that's when I realized that I felt as horrible as everybody else did, and that's when H6 and I made the commitment with each other that we were going to at least make the attempt, and at least talk about getting together with people because it is so important to us. Because having that one night with her and H1 together really made me go back and that gave me gas in my tank for another two or three months. To see those like-minded people and to share with them. (H10, 25:32)

When asked how they felt their practice may be different without collaborations with others from the ISU-STEP, none of the high and medium NOS implementers stated their
practice would be the same. Instead, most answered they wouldn't be as effective in their reform-based practice, meaning they would have been more traditional. Others stated they would have become completely traditional or quit teaching altogether. For instance, the following statements made by high and medium NOS implementers when asked this question illustrate how they perceive their practice would suffer if they would had been isolated from others in the ISU-STEP. Furthermore, many of these statements also illustrate the co-generated responsibility these support groups produce to implement reform-based and NOS teaching practices:

I think it would've been a little slower process for me to become the teacher that I am today, and I may never have gotten there because I think I would of been a hybrid [between reform and traditional practice]. It is really attractive to see these multiple-choice test, and see teachers done with their grading in 20 minutes. And it is really attractive to see teachers watching students work on worksheets for the last 20 minutes of class. (H13, 17:30)

Well I'll be a little blunt. I don't think I would be here. (H1, 1:42)

I don't know if I would still be here. I would probably look more like the other teachers here. I probably would've fallen in line with doing some of the things they did [traditional practices] and not doing things differently. It would still be there [the NOS] obviously, but it would not be accurate or explicit to the students. (H7, 22:18, 19)

But if I didn't have any of that support I would say that probably would still teach some nature of science but it probably would've fallen away and I would say that probably would even become less. And then I would say I would probably become, purely out of time and effort, a more traditional teacher. You need that support system because without it, it all falls away. (H6, 21:29, 41) I knew it wasn't good and I felt a lot of guilt and that's why I'm trying to change so much this year. But that's me having that support system because without having that support system I would fall into the trap of okay I'll do just what you guys [my traditional colleagues] do. I would try to implement some of the stuff from the [ISU-STEP] MAT, but I don't think it would be nearly as successful without it and I don't think I would keep it up for very long. (H6, 21:43)
I could not have done it without them because it is too easy to be an island out here. It is too easy to cave into institutional constraints and have the person signing a paycheck dictating what you do, or having parents who have the ear of the person signing the paycheck determine what you do. If I would not have had them I don't think I would ever be a traditional teacher, but I would not be the teacher I am today. I would not feel guilty about my questioning fingerprint. I wouldn't feel guilty about not teaching the nature of science (H10, 25:33)

I think I would be more traditional. (H12, 27:26)

Without that support what would I have resorted to? It is hard to say. Would I have stayed up all night planning a great inquiry based lesson? Or would I've handed out a worksheet out the next day? It is hard to say. I would still like to think I would try my best to do what I know is best for kids, but I probably wouldn't be the same teacher I am today. I think I would be more traditional. (H3, 19:33)

I think it is safe to say that my practice would be drastically different. I think that if the conversation didn't lend itself to you questioning yourself how would you, or what other avenues are there for improving your practice? I don't know. If you become comfortable and you don't see opportunities or you don't feel dissidence then you become complacent, or you get out of the habit of recognizing where opportunities could be made. (H4, 2:36)

The only individual to not respond in this fashion was H5. This makes sense given that H5 has implemented reform-based teaching for over a decade prior to taking courses from the ISU-STEP. When asked this same question H5 stated:

For me I probably wouldn't be significantly different. Even though I would be doing it this year alone and not have anybody to discuss failures and successes with, I'm tenacious enough after taking the nature of science class I would've addressed the nature of science on a regular basis despite what other people in the department were doing. I have been through that before with inquiry practices. Everybody here was pretty traditional when I started. (H5, 20:25)

Table 19 shows low NOS implementers varied greatly from high and medium NOS implementers in their degree of responsibility to implement reform-based and NOS teaching practices. Statements made by low NOS implementers indicated a low responsibility to
implement these practices. Unlike high and medium NOS implementers, who many times explicitly indicated their commitment to implement reform-based and NOS teaching practices, low implementers’ indicated their levels of responsibility in a more subtle way. This was because statements that indicated a generally high level of responsibility often expressed by teachers were mixed with those that were contradictory, and indicated low responsibility. For instance, when asked why they teach in a certain way all low NOS implementers would generally cite their students as the compelling factor. Much like their high and medium NOS implementation counterparts, these teachers appear to be highly responsible to have their students’ best interests at heart. This was evident through the following statements:

I think that students need to understand that science is an everyday thing. That science is not just limited to the classroom, but it is part of their everyday life and that it is, some of the ideas that come out of the nature of science. (H2, 18:14)

I think that our job is to expose kids to many aspects of science, so I try to make sure that they see how those relate to everyday life. (H11, 26:8)

If the kids like it. That is my greatest influence. Am I doing something that I think they are going to get something out of it? Am I doing something that they see the value in? I will always think of that when I design my lesson. That is a challenge sometimes. I call myself a show pony sometimes with how I do my class, so I have to put on a face and do those things in class that really engages and excites them. (H8, 23:26)

I think it keeps the students at least interested. At least they are not just sitting doing nothing (H9, 24:4).

Although these statements indicate low NOS implementers do care about their students, they would also cite best practices were too ideal, the ISU-STEP program was too challenging, and/or classroom and institutional constraints were too prohibitive to allow them
to teach in a manner that was congruent with what the ISU-STEP promotes. Statements by these teachers indicated they did not feel deeply responsible, like high and medium NOS implementers, to promote reform-based and NOS teaching practices. Seemingly, these teachers have a high degree of responsibility to students in a typical sense, but find convenient reasons why they cannot implement reform-based and NOS teaching practices:

This sense of time and how much time you can spend on things seem very idealistic [in the ISU-STEP]. That takes time and that plays so much in how much can I really do. What is completely logical and some days it's just for my sanity, of me and the students, that if I go another day trying to go at the rate that I'm going at I'm going to crash. So sometimes you maybe have to find a filler or something for that day that can it gives you a chance to breathe. There are some days you just put in a movie and you need to just breathe. And you know you can't. Maybe a movie is not the best thing to help students understand but it is better than you trying to do something and then just losing the kids more because you are not comfortable with it, and you are not ready for it. And if you were not ready they're not going to be ready. (H2,18:30,62)

I try to keep them all in line with each other and that's one of my deciding factors and I know that's a bad one. But unfortunately it easier on me if the kids are on the same spot so that's one of the reasons. For my own sanity I move them on with the rest of the classes that I teach. (H8, 23:5)

Another one is sometimes it's a lot more content driven what I feel as though I am expected to teach. It is kind of content driven and obviously there's not a lot time for it [the NOS], which I know is a horrible excuse. Everybody says, “Oh you should have time for it and you can always [fit it in]. But it's how you feel, you are sitting there and we have a week left of school and I'm supposed to get through all of evolution. Another reason is I kind of teach what everybody else in my department is teaching and I am really trying to do closely with what one of my other colleagues does. [That person’s] lessons don't reflect it [the NOS] either. I am not making excuses, but it's just some of things that I just do is what they do. (H8, 23:14)

If I did everything I was taught [in the ISU-STEP] to do, I would be dead. I have so much other stuff going on right now. Sometimes you just need the kids to get out there vocabulary charts and make their note cards and their flashcards. Which is maybe not the most effective teaching strategy but you know how that is. You have to concede sometimes or you're going to kill yourself. (H8, 23:49)
I think unfortunately that they have been so ingrained with: This is the scientific method. This is how science works. These are the ideas that people have. There are no other ideas out there. They've been taught that over, and over, and over again. I honestly don't think that at least noticing in my class, I don't think it would change the way they look at science. That is difficult at times [to teach the NOS and inquiry] where you get so caught up in content and you need to cover this and this and this and this. With the Iowa Core coming down. (H9: 24:10)

I think the content that I teach, it is definitely a memorization oriented course. There is almost no way around it. (H9, 24:11)

I think one thing that I know is that I do not feel as comfortable teaching the nature science. It could be because I took it at the same time as the methods class. (H9, 24:12)

But I do admit occasionally I leave them [the students] behind because I have to move on. I mean there's material we have to cover. (H11, 26:7)

I've been dragged in this but, we have set down as biology teachers and we have basically very methodically set: “We will cover this, this, and this first semester and we are going to cover this, this, and this and the second semester.” I don't like that but the idea is now that we have courses that are multi-taught supposedly. (H11, 26:9)

Two low NOS implementers even more explicitly demonstrated a low responsibility. One implied there is a lower value in teaching well at the high school level than college. The other indicated a deep fundamental understanding of science ideas is not important. For instance, H2 discussed how “screwing up” in a secondary class is not as detrimental as a professor “screwing up” in a college class because of the lower expectations from high school students:

As college students, when a professor screws up sometimes you get on them little bit harder than a high school student would because you care a little more. You're paying for this, high school students aren't paying for it. This is free for them. When you're choosing it, it has to be good and you're choosing to pay to be there. You expect a lot more out of it than high schoolers may. That's a nice relief. (H2, 18:62)
H11 indicated a low responsibility to implement reform-based and NOS teaching practices through insinuating students don’t need a deep robust understanding of science ideas. Furthermore, H11 implied a commitment to cover material superficially through the following statement:

I think we get bogged down trying to get sure everybody has deep, deep understanding and I think they forget: Wait a minute, not only cognitively are we not only minimally ready for this, but that's also why some students choose to do further studies. It is important for students to just [get a] view of what there is in the sciences. (H11, 26:8)

As demonstrated by VASSIST questions 20A-E, low NOS implementers had little to no collaboration with others from ISU-STEP that would influence them to maintain or improve their reform-based and NOS teaching practices (Table 19). This claim can be made despite H8 and H9 indicating otherwise on questions 20 A and D. This is because H8 and H9 work in the same science department that closely collaborates to create the expectation everyone teaches similarly. Most notable of the responses on the VASSIST were those in response to question 20E. Unlike high and medium NOS implementers, low implementers did not see collaborations as crucial during their first year of teaching. These findings correspond to low implementers’ statements that overwhelmingly indicated they had little or no contact and support from others from the ISU-STEP, especially during their first year of teaching. For instance, when asked how much contact with others from the ISU-STEP they had during their first year of teaching low NOS implementers responded:

I stayed in contact with them [science students and faculty] and not so much with the science education people. (H8, 23:45)

I kind of lost touch with most of the graduates. I was pretty much on an island. I felt like I had to just use whatever knowledge and I had and try to remember
the ideas that I had from my methods and nature of science courses (H9, 24:30).

Not at all. I am very bad at that. (H11, 26:33)

My first year teaching I had minimal contact because of the smaller school. (H2, 18:54)

Unlike high and medium NOS implementers, low NOS implementers were unable to specifically articulate how support from others in the program would have helped them. Instead, they were either unsure how collaborations with others from ISU-STEP would help them, or saw potential collaborations as simply a way for them to have more activities or general support to meet the constraints of teaching. For instance, H8 responded:

I don't know. I am sure having a connection with them would have helped. And there's no way it could've been a negative influence to see them. I mean it can't hurt to go talk to other people who have the same experiences as you. I don't know if my teaching would've been impacted greatly because I didn't get the benefit of that, but obviously there are benefits to talk to people who are in the same boat as you (H8, 23:46)

When asked how the first year of teaching may have been different if s/he had access to others from the ISU-STEP, H11’s response was much like H8’s when s/he stated, “Yeah, the MAT since if they want to commiserate that would be great. I am not sure I would've needed them for the fact that they went through the MAT program. I just needed people to talk to” (H11, 26:40).

H9 responded differently than H8 and H11. Instead, s/he equated having more collaboration with others from the ISU-STEP as only gaining more access to activities. This was evident when H9 stated s/he would benefit through having:

More activities, more strategies, and more ideas. Being able to bounce ideas and making sure you are asking: Do you think this be a good way to do it?
would probably be more comfortable with the idea of teaching that. Because again I was all by myself and the 66-year-old chemistry teacher didn't understand the nature of science, didn't talk about the nature of science, and wasn't really the best to bounce ideas off of. That's where I could've been more comfortable—with more interaction. (H9, 24:32).

H2 seemingly misunderstood the question when asked how s/he teaches would have been impacted by collaborations with others from the ISU-STEP. This was evident when H2 stated, “I don't think I would've tried some of the activities or of some of the things I did, or wouldn’t look back on some things again”(H2, 18:55). In response to this question H2 was reflecting on how s/he just recently began to look back on her practice because a friend who just started teaching was struggling. H2 did indicate though the lack of support during the first year teaching presented a challenge through the following statement:

You are just trying to get into the groove of going through teaching all day and dealing with all the students and grading everything. Not necessarily having someone there to support you like you did when you student taught or had a practicum. You do all the planning, and you do all the tests, and all that assessment, and all the writing, and plan all the activities, and you set them up and clean them up. That takes time and that plays so much in how much can I really do. (H2, 18:30)

Interestingly, all low NOS implementers have had access to others from the ISU-STEP after they were isolated for the first year of their practice. For instance, H9 and H8; H11 and H12; and H2 and H1 work together. When asked how their practice has been influenced by working with someone from the ISU-STEP, the indication was that it has been minimal, or even worse an amplification of ineffective teaching practices. For instance, when H9 was asked about the impact of working with H8 s/he stated:

I got some good activities from H8. I would say activities and the labs would be the biggest thing. You know the materials were similar materials with what I was teaching with at the old school and I just adjusted them based on the
book and stuff. Different activities and different experiments and labs and things like that are probably the biggest thing that I've gained from H8. (H9, 24:37)

H8 confirmed they collaborated when s/he stated, “I've had conversations with my colleagues here and we have meaningful input on what we do here. Lots of us, H9 went through the program who recently started last year” (H8, 23:46). Given they both are low implementers of the NOS and reform-based practice, their collaborations may very well be reinforcing naïve views they hold of what effective teaching practices are.

H2 indicated s/he collaborates minimally with H1 by stating, ”So with H1 there are times that we'll talk and I'll get ideas, a lot of times I just don't see H1 that much” (H2, 18:52). H2 also alluded that s/he had some contact with others from the ISU-STEP over the years. However, this seemed to be non-significant in regards to H2’s practice. When asked how these minimal collaborations impacted how s/he taught H2 stated, “Not necessarily the practice. I would look at more like this individual activity, or this actual situation had an impact. As a whole not much of an impact” (H2, 18:53).

H11 indicated the way s/he taught was not influenced by H12. In fact, H11 seemingly works from a completely different teaching ideology than H12. This became apparent when H12 bluntly stated, “I don't have the views of H12. I just don't have the strong views of one of the people that came from the MAT program” (H11, 26:34).


**Organization of Support Groups**

Figure 2 shows where participants of this study are drawing their reform-based and NOS teaching decision making from. On the left are high and medium NOS implementers whose teaching ideology matches that of the ISU-STEP. Arrows between each of these participants indicates where significant collaborations have occurred. Dotted arrows represent collaborations that started during the end of the participant’s ISU-STEP experience and continued through their first year of practice and were significant and/or are currently of minor significance. Collaborations of minor significance are those that if stopped would probably not significantly impact the teachers’ practice. Solid arrows represent collaborations started at the end of or shortly after the participant’s ISU-STEP experiences and continue to this day. According to evidence from this study, if these collaborations were stopped the teachers involved would experience significant negative impacts on their reform-based and NOS teaching practices.

On the right are low NOS implementers whose teaching ideology is incongruent with what was learned in the ISU-STEP (Figure 2). In other words, their practice is much more “traditional”. No arrows exist between these and other former ISU-STEP students. This is because no significant collaborations existed between low NOS implementers and others from the ISU-STEP. Evidence from this study indicates the absence of participation in support groups by these teachers contributes to their lack of responsibility, understanding, and ability to implement reform-based and NOS teaching practices. Hence, the absence of support from others from the ISU-STEP to implement reform-based and NOS teaching
practices is associated with why these individuals are low NOS implementers and demonstrate a teaching practice that is incongruent with the ISU-STEP.

Figure 2. Collaborative support groups of high and medium NOS implementers (left) and isolated low NOS implementers (right) and their matching instructional ideologies (above).

Summary of Findings: Research Question 2

Congruent with previous studies (Abd-El-Khalick & Lederman, 2000), findings from this study demonstrate that a deep and robust understanding of the NOS is necessary for, but does not guarantee, its implementation in teaching practice. Also, clear links were not made between NOS implementation levels and teaching constraints, interest in the NOS, or level of utility value for NOS teaching. Additionally, teachers’ self efficacy to instruct on the NOS was shown to be a poor indicator of their level of NOS implementation.
The extent to which teachers implemented the NOS was positively associated with the degree they implemented reform-based practices. Also associated with NOS implementation was the accuracy and depth with which participants reflected upon their teaching practices. Other factors associated with NOS implementation included teachers’ (1) considerations of how people learn; (2) congruency of utility value for teaching the NOS with that of the ISU-STEP, (3) NOS teaching understanding, (4) coping strategies in response to teaching constraints, (5) responsibility to implement the NOS and reform-based practices, and (6) participation in support groups with others from the ISU-STEP.

High and medium NOS implementers exhibited high degrees of responsibility to implement reform-based and NOS teaching practices. Additionally, these teachers participated in support groups with one another to maintain and increase their responsibility and ability to implement the NOS and reform-based practices. Both, high and medium NOS implementers demonstrated similar reflections of how people learn, accurateness of self reflection about teaching practices, understanding of NOS teaching, and type of utility value for teaching the NOS. These teachers clearly saw learning as highly complex and multifaceted, and tended to use language reflective of the learning theories in their descriptions of general and NOS teaching. Additionally, they valued teaching the NOS for deep compelling reasons that transcend students’ classroom experiences. These reasons included facilitating students to have more accurate views of learning in general and preparing them to participate in society to solve large scale science related problems.

General differences existed between the depth of self reflections provided by medium and high NOS implementers and the way they dealt with the constraints of teaching.
Although both groups were accurate in their self reflections, high implementers tended to reflect in more depth on their general and NOS teaching through using concrete examples from their classroom practice. Conversely, medium NOS implementers generally reflected on their practice in the context of general concepts learned in the ISU-STEP with little reference to concrete examples from teaching. In respect to dealing with teaching constraints, one medium and all high NOS implementers’ preferred strategy was to assert their autonomy to implement reform-based and NOS teaching practices. The remaining medium NOS implementers tended to find ways to navigate around teaching constraints by engaging them inadvertently.

Although low NOS implementers clearly care about students, they demonstrated a low degree of responsibility to implement reform-based and NOS teaching practices. In addition, rather than using support groups of others from the ISU-STEP to augment responsibility and ability to implement effective teaching practices, these individuals were isolated within the educational institution. This may have contributed to low NOS implementers conceding to pressures inherent to the teaching profession and using them to justify why they did not extensively implement reform-based and NOS teaching practices. Low NOS implementers’ also varied from high and medium NOS implementers in respect to their reflections on how people learn, accuracy and depth of self reflection, understanding of effective NOS teaching practices, and the congruency of utility value of NOS teaching with the ISU-STEP.

Only one low NOS implementer spoke of teaching and learning with tangible similarity to what is reflected in the ISU-STEP, and this was vague and rudimentary.
Otherwise, these teachers often spoke of learning in terms of skills or content to be acquired, and also reflected on their own practice inaccurately and shallowly. None of the low implementers demonstrated an understanding of effective NOS teaching. Additionally, when asked to explain their NOS instruction they would provide explanations of poor practices or downplay the importance of teaching the NOS. Lastly, none of the low implementers could give deep compelling reasons to teach the NOS that would transcend students’ classroom experiences. Instead, more commonly cited reasons were given such as the NOS makes science more accessible for students and/or relevant to their everyday lives.
CHAPTER 5: DISCUSSION AND CONCLUSIONS

Summary of Purpose of Study

This study investigated the NOS teaching practices of graduates from the Iowa State University Science Teacher Education Program (ISU-STEP). More specifically, this study set out to determine the extent that former ISU-STEP graduates’ teach the NOS; explore factors associated with and that might account for the observed NOS teaching practices; and make recommendations to improve the ISU-STEP and science teacher education programs more generally. To achieve these overarching ends, this study addressed the following research questions:

1. NOS teaching practices exhibited by ISU-STEP graduates:
   a. To what extent do teachers explicitly and reflectively teach the NOS?
   b. To what extent do teachers accurately convey the NOS?
   c. To what extent do teachers contextually and decontextually teach the NOS?
   d. To what extent do teachers explicitly scaffold along the decontextualized to contextualized NOS instruction continuum?

2. Factors associated with varying levels of NOS instruction by ISU-STEP graduates.
   a. To what extent is an understanding of the NOS associated with teachers’ implementation of the NOS in instruction?
   b. To what extent are classroom teaching practices associated with teachers’ implementation of the NOS in instruction?
   c. To what extent are cognitive factors (understanding of NOS teaching, orders of consciousness, considerations of how people learn, self reflection) associated with teachers’ implementation of the NOS in instruction?
   d. To what extent are motivational factors (self efficacy, utility value) associated with teachers’ implementation of the NOS in instruction?
e. To what extent is the affective factor of interest in the NOS associated with teachers’ implementation of the NOS in instruction?

f. To what extent are teaching constraints (classroom and institutional constraints) associated with teachers’ implementation of the NOS in instruction?

g. To what extent are other factors associated with teachers’ implementation of the NOS?

**Study Conclusions**

*Conclusions Regarding Teachers’ NOS Implementation Practices*

Analysis of the 13 participants’ teaching practices in this study revealed four were high implementers, five were medium implementers, and four were low implementers of the NOS. Generally, each teacher’s artifacts and observed teaching practice were consistent in their portrayals of the NOS. Furthermore, the extent to which lessons and artifacts contained inquiry and/or historical and contemporary science examples strongly indicated the extent the NOS would be taught effectively. Additionally, when the NOS was effectively implemented, it reflected what these teachers had learned in their ISU-STEP NOS and Restructuring Science Activities courses.

High NOS implementers tended to create and capitalize on opportunities in lessons and artifacts to address the NOS accurately, explicitly, and reflectively in the context of science content and inquiry. Medium implementers were also accurate in their portrayals of the NOS, but were noticeably less proficient at requiring students to explicitly reflect on NOS themes in the context of science content and inquiry. Most low NOS implementers’ lessons and artifacts lacked opportunities through inquiry and/or historical and contemporary
examples to address the NOS. When low implementers addressed NOS themes through artifacts and lessons, often times the portrayals were inaccurate and students were not required to explicitly reflect on them.

However, even among the four low NOS implementers, artifacts indicated two employed decontextualized NOS activities at the beginning of the school year. Additionally, artifacts submitted by these two teachers indicated they required their students to reflect on these decontextualized activities at a later date. All thirteen teachers in this study performed the poorest in scaffolding NOS ideas back and forth along the decontextualized to highly contextualized continuum (Clough, 2006). Additionally, no explicit attempts to have students reflect how particular classroom activities distort the nature of science were observed in any of the lessons in this study.

Many studies have attempted to account for the challenges pre and inservice teachers face in implementing the NOS (Abd-El-Khalick et al., 1998; Lederman, 1999; Abd-El-Khalick & Lederman, 2000; Bell et al., 2000; Shwartz & Lederman, 2002; Lederman, 2007). When compared to the disappointing results of prior efforts to promote accurate and effective NOS instruction, the fact that nine out of thirteen teachers in this study implemented the NOS to at least a moderate level is most impressive. Further contributing to the significance of these findings are the several unique characteristics that set this population of teachers apart from those participating in previous studies. For instance, all of the teachers in this study are in at least their second year of professional teaching. This has provided a situation in which, unlike novice or preservice teachers, the teachers in this study:
1. Are not in any way under the authority of the ISU-STEP to teach the NOS as the program promoted.

2. Are embedded in, and familiar with, their teaching environments.

3. Have had time to understand and develop general, science content, and NOS pedagogical practices.

4. Have taught for at least two years in environments possessing varying levels of constraints.

Because of these characteristics, these teachers have been studied under conditions in which we could expect to find most teachers. The fact that so many in this study implemented the NOS under “normal teaching conditions” should give hope to science educators that promoting effective NOS instruct in professional practice is achievable.

Congruent with previous studies (Abd-El-Khalick & Lederman, 2000), findings from this study demonstrate that a deep and robust understanding of the NOS is necessary for, but does not guarantee, its implementation in teaching practice. All teachers faced some degree of constraints. No clear association was made between NOS implementation levels and teaching constraints, interest in the NOS, or level of utility value for NOS teaching. Additionally, teachers’ self efficacy to instruct on the NOS was shown to be a poor indicator of their level of NOS implementation.

Although no clear association was made between these factors and teachers’ NOS implementation, their impact on NOS implementation cannot be ruled as insignificant. A multitude of complex and interconnected factors participate in a teacher’s decision making. Perhaps these factors, much like orders of consciousness, are so tightly interconnected with
others their relationship to NOS implementation was obscured. For instance, all high and medium and two low NOS implementers demonstrated a high utility value for teaching the NOS. Perhaps viewing NOS teaching as important is a necessary but insufficient condition for NOS teaching. That is, this factor may only facilitate NOS implementation if it is in the presence of other factors that do also (e.g. the type of utility value, level of NOS teaching understanding, etc.).

The extent to which teachers implemented the NOS was positively associated with the degree they implemented and accurately and deeply reflected upon reform-based teaching practices. Also associated with NOS implementation was participants’ understanding of, and the accuracy and depth with which they reflected upon, NOS teaching practices. Other factors associated with NOS implementation included the way teachers considered how people learn, congruency of utility value for teaching the NOS with what is promoted in the ISU-STEP (e.g. teaching the NOS for socioscientific literacy), coping strategies in response to teaching constraints, responsibility to implement reform-based and NOS teaching, and participation in support groups with others from the ISU-STEP. Unlike low NOS implementers, high and medium NOS implementers generally:

1. Consider how people learn during instruction in a manner that is congruent with the ISU-STEP (e.g. consider learning theories and conceptual change).
2. Accurately and deeply reflect about their general and NOS teaching practices.
3. Deeply and/or proficiently understands how to teach the NOS, and often recognizes effective NOS teaching is embedded within effective science teaching as a whole.
4. Values NOS teaching for objectives that transcends the science classroom and into students’ future lives (e.g. understand and help solve socio-scientific issues, differentiate between science and pseudoscience).

5. Effectively circumvent teaching constraints to ensure they can implement reform-based and NOS teaching practices.

6. Remain connected to and collaborate with others from the ISU-STEP to manage institutional constraints and implement reform-based and NOS teaching practice.

7. Exhibit high degrees of responsibility generated from themselves and ISU-STEP support groups to implement reform-based and NOS teaching practices.

Many of the characteristics high and medium NOS implementers exhibited in the list above are seemingly interconnected and required for effective science teaching as a whole. This study provides compelling evidence that effectively teaching the NOS is linked to effective science teaching more generally. The more general and synergistic science teacher decisions that create powerful science learning experiences (Clough et al, 2009) provide a foundation for scaffolding to the NOS in a variety of contexts and among those contexts (Clough, 2006). Teachers in this study who most effectively taught the NOS did so from that foundation of highly effective reform-based science teaching practices. These practices and the mentally engaging environment that result appear to establish a platform conducive to teaching the NOS. For teachers who create this platform and value the NOS, explicit and reflective NOS instruction (Abd-El-Khalick et al. 1998; Abd-El-Khalick & Lederman 2000; Akerson et al., 2000; Khishfe & Abd-El-Khalick, 2002) and carefully scaffolding between different NOS contexts (Clough, 2006) is far more likely to be achieved.
Unfortunately, reform-based teaching practices are uncommon (Goodlad, 1983), and this may explain why even when teachers understand and value the NOS, they too often do not teach it well or consistently. Teachers’ own K-post-secondary experiences as science students create deeply held views of science teaching that interfere with their developing an understanding of effective science teaching practices and their synergetic nature. Because preservice teachers frame their beliefs of teaching on past experiences (Thomas & Pedersen, 2003) they often enter their programs equating effective science teaching with traditional practice.

Acknowledging this, the ISU-STEP employs conceptual change strategies to develop among its pre-service teachers an accurate understanding of effective science teaching. During early stages of the ISU-STEP, faculty work to create dissatisfaction with the current state of science education so that preservice teachers will, as students progress through the program, find reform-based practices more intelligible, plausible, and fruitful for effectively teaching children (Posner et al., 1982).

Reform-based documents and science education research advocate a deep and robust understanding of the NOS is a valuable end in its own right as well as a means toward achieving scientific literacy (AAAS, 1990; NRC, 1996; Clough et al., 2009). Implementing the NOS within reform-based practices is profoundly complex and difficult to understand. In response to these complexities the ISU-STEP takes extensive measures to prepare preservice teachers to teach the NOS. One measure is providing numerous opportunities for preservice teachers to understand the NOS and effective reform-based practices including NOS teaching. This is achieved through required NOS and science teaching methods courses
linked to practical teaching experiences. Through coursework and experiences preservice teachers should understand the NOS is one of many synergistically linked student centered goals (e.g. critical thinking, effective communication) reform-based teachers must promote. Furthermore, ISU-STEP students should learn classroom decisions must be made based on achieving these goals and how people learn (Clough et al., 2009).

Unfortunately, despite the best efforts of ISU-STEP faculty, some teachers struggle to implement effective practices (Bergman, 2007), including teaching the NOS, and revert to traditional practices once they have entered the teaching profession. Despite the presence of literature that proposes why teachers struggle with NOS implementation (Lantz & Kass, 1987; Duschl & Wright, 1989; King, 1991; Brickhouse & Bodner, 1992; Hodson, 1993; Abd-El-Khalick, et al., 1998; Abd-El-Khalick & Lederman, 2000; Schwartz & Lederman, 2002; Lederman, 2007) more studies need to be conducted to account for factors that impede or facilitate NOS teaching (Abd-El-Khalick et al., 1998; Lederman, 1999; Schwartz & Lederman, 2002; Lederman, 2007). Given the synergetic nature of teaching and the complex educational system teachers must navigate, a more holistic approach that accounts for why teachers either implement or ignore the NOS in their teaching is needed.

**Model Predicting and Accounting for NOS Implementation**

Accounting for why some teachers successfully implement NOS instruction while others struggle is the focus of the second research question in this study. Unlike prior research that analyzed variables in isolation and/or only studied preservice teachers, this study examined multiple factors that may contribute to NOS implementation within the
complex environment of the classroom. The factors analyzed in this study are seemingly interrelated, and some appear to be more influential than others on teachers’ classroom implementation of NOS instruction. Based on the data collected in this study, a model was developed that illustrates possible relationships between factors and their influence on NOS instruction. This proposed model is presented in Figure 3.

Figure 3. Factors associated with NOS implementation sequenced left to right.

**Influences between Variables**

**NOS Understanding and Reform-Based Practice**

This study provides evidence that an understanding of the NOS is a necessary but insufficient factor for effective implementation of NOS instruction in science classrooms. Additionally, LSC-COP and NOS-COP scores were associated, indicating that effective
teaching of the NOS in an explicit and reflective fashion is dependent upon the presence of effective science teaching practices.

**Pre-ISU-STEP Responsibility and Dissatisfaction**

Figure 3 proposes two factors not directly examined in this study that are potentially associated with teachers’ NOS implementation levels. The researcher suspects these factors (dissatisfaction with the current science education system and a high degree of responsibility) likely exist prior to, or shortly after, entrance into preservice programs. Therefore, preservice teachers may develop these factors before learning reform-based themes taught in the ISU-STEP. The factors of dissatisfaction and sense of responsibility may have overlap with the construct of “teacher beliefs” reported by Gess-Newsome (1999) and others. While this work primarily focuses on preservice teachers’ views of schools, schooling, teaching, and learning, research in this area indicates that prospective teachers enter programs with strongly-held views that influence how they perceive university coursework and field placements.

The reason for selecting and linking these two factors is to speculatively account for interview comments and observational evidence. As indicated in Chapter Four, the point at which the high degree of responsibility developed in high and medium NOS implementers is unclear. Quite possibly, this is a personality factor they bring with them to their preservice programs. For example, over half of the high and medium NOS implementers made statements in interviews indicating they became dissatisfied with some aspect of science education prior to or during their preservice experience. Research has shown dissatisfaction is the first step required for conceptual change, followed by the adoption of more fruitful, intelligible, and plausible concepts (Posner *et al*., 1982). Appleton (2006) noted that learning
to teach is a process of conceptual change due to the significant misconceptions preservice teachers possess about teaching and learning. Perhaps because these individuals were dissatisfied, they were better able to reconfigure prior ideas and learn the reform-based themes promoted in the ISU-STEP. Both of these factors warrant further study.

“Likemindedness” with the ISU-STEP

Literature supports the NOS is a cognitive rather than affective instructional objective (Abd-El-Khalick et al., 1998; Abd-El-Khalick & Lederman, 2000; Abd-El-Khalick & Ackerson, 2004). Additionally, pedagogical content knowledge and motivational factors such as utility value have been linked to NOS teaching and learning (Abd-El Khalick & Ackerson, 2004; Schwartz & Lederman, 2004; Lederman, 2007). Results from this study are congruent with and build upon this prior work.

The self reflection abilities, considerations of how people learn, understanding of NOS teaching, and type of utility value for teaching the NOS were generally not reflective of the ISU-STEP. This caused them to not share “like-mindedness” with high and medium NOS implementers and the ISU-STEP.
**Congruency of Utility Value for NOS Teaching with ISU-STEP**

ISU-STEP preservice teachers are taught many compelling reasons why NOS instruction is important. For instance, the ISU-STEP promotes more obvious reasons to teach the NOS, such as it makes science more accessible and enjoyable for students. The ISU-STEP also advocates more compelling reasons to teach the NOS, such as it helps develop a citizenry that can effectively engage socioscientific issues.

The type of utility value teachers placed on NOS teaching was associated with their NOS implementation levels (“Congruency of Utility Value for NOS” variable, Figure 3). Teachers who instructed the NOS at high and medium levels placed a deep and compelling utility value on NOS teaching that was highly congruent with that promoted in the ISU-STEP. High and medium NOS implementers indicated teaching the NOS would profusely augment students’ classroom successes (e.g. make them better understand the content). They also provided reasons the NOS should be taught that transcend students’ classroom experiences. For instance, these teachers indicated without a deep understanding of the NOS students would not be as effective citizens who can help solve socioscientific issues (e.g. climate change). Conversely, low NOS implementers did not provide compelling reasons to teach the NOS beyond how it may help them teach science, or help students succeed in their science coursework and/or see how science is “related to their everyday lives”.

**Congruency of Self Reflection with ISU-STEP**

The ISU-STEP extensively teaches preservice teachers how to accurately and deeply self-assess their practice. Teachers’ self reflection abilities were associated with the extent
they implemented the NOS (“Self Reflection” variable, Figure 3). Consistent with what is taught in the ISU-STEP, teachers who implemented the NOS at high and moderate levels accurately, and often deeply, reflected on their general and NOS teaching practices. High NOS implementers tended to reflect more in depth upon their general and NOS teaching practices. These teachers often used concrete examples from classroom practice and linked them to many aspects of effective teaching. Conversely, medium NOS implementers often reflected on their practice in the context of general concepts learned in the ISU-STEP with little reference to concrete examples from teaching.

Teachers who implemented the NOS at low levels reflected on their teaching practices incongruently with what is promoted in the ISU-STEP. Self reflection inaccuracies from teachers who instructed the NOS at low levels took many forms. Most obvious was how low NOS implementers’ teaching reflections were inconsistent with classroom observations and artifacts collected in this study. Additionally, the synergetic nature of teaching was not apparent in low NOS implementers’ reflections. Instead, their reflections were shallow with almost no concrete examples drawn from practice and/or deep implications for teaching. For instance, instead of focusing on areas needing significant improvement, such as their NOS teaching practices, low NOS implementers would claim they wanted to improve areas of practice such as completing grading faster.

**Congruency with the ISU-STEP of Considerations of How People Learn**

The ISU-STEP promotes effective teachers demonstrate in their reflections and decisions a deep fundamental understanding of how people learn. Teachers that implemented the NOS at moderate and high levels also provided considerations of how people learn that
were highly congruent with those promoted in the ISU-STEP (“How People Learn” variable, Figure 3). For instance, these teachers would often refer to learning theories (e.g. behavioral, constructivist, developmental, and social) when reflecting upon teacher decision making and classroom practice. Conversely, low NOS implementers’ considerations for how people learn were often absent during reflections or incongruent with what is promoted in the ISU-STEP. Often these teachers would indicate learning was immediate and/or the acquisition of skills or content. Additionally, these teachers indicated the type of teaching and learning promoted in the ISU-STEP may be “too ideal”.

**NOS Teaching Understanding**

The required ISU-STEP NOS and science teaching methods courses promote a deep understanding of the NOS and effective NOS pedagogy. Teachers in this study who implemented the NOS at moderate and high levels demonstrated either an informed or transitional understanding of effective NOS teaching (“NOS Teaching Understanding” variable, Figure 3). Teachers with an informed understanding indicated effective NOS teaching is embedded within effective science teaching as a whole. These teachers often conveyed they knew how to teach the NOS and spoke of effective NOS instruction directly or in the context of classroom lessons they used. Additionally, descriptions these teachers gave were highly congruent with themes present in the ISU-STEP and NOS literature (Clough, 2006). Teachers with a transitional understanding of NOS instruction recognized there are many components of effective NOS instruction, but they may have not “put all the pieces” of effective NOS instruction together (e.g. NOS understanding, questioning
strategies, NOS ideas being developmentally appropriate, integration of NOS and science content, etc.).

Teachers who instructed the NOS at low levels demonstrated a naïve understanding of NOS instruction. For instance, these teachers often believed students would effectively learn the NOS implicitly through inquiry-based activities and/or through traditional methods such as lecturing or vocabulary. Teachers with a naïve understanding also attempted to use nondescript conjectures as examples of their NOS teaching. For instance, they often described their NOS instruction as presenting facts about the scientists or their lives without articulating how they explicitly and reflectively taught any of the NOS concepts the ISU-STEP teaches.

**Responsibility to Implement Reform-Based and NOS Teaching Practices**

Lederman (1999) articulated the need to facilitate the internalization of the importance of the NOS as an important instructional objective. Teachers who implemented the NOS at medium or high levels indicated they had a strong commitment and responsibility to do so (“Responsibility” variable, Figure 3). Often, this was demonstrated through a high degree of intrinsic responsibility reflective of Fullan’s (1994; 2001) literature that describes the need for teachers to realize the moral and ethical purpose behind their work. For instance, these teachers demonstrated this responsibility in various ways from expressing frustration at colleagues for questioning their reform-based practice to providing sentiments that NOS and reform-based teaching was “just the right thing to do”. As indicated before, whether this high degree of intrinsic responsibility preceded the ISU-STEP or is a consequence of it is unclear. What is clear is these teachers are passionate individuals who are dissatisfied with the current
system and feel accountable to teach in a manner that is congruent with what is promoted by the ISU-STEP.

Low NOS implementers demonstrated low levels of responsibility to implement reform-based and NOS teaching practices. Often, these teachers would declare the methodologies learned in the ISU-STEP were too idealistic or difficult. Additionally, they would cite reasons such as institutional and classroom constraints why they were unable to implement reform-based and NOS teaching. Seemingly, these teachers’ justifications for actions resemble those proposed in the literature (Fenstermacher & Richardson, 1993; Blumenfeld et al., 1994) which are “rule bound” (based on institutional or curriculum requirements), empirical (based on what works in specific contexts), and/or preferential (based on beliefs or comfort level) (Fenstermacher & Richardson, 1993; Blumenfeld et al., 1994).

**Orders of Consciousness**

A clear and direct association between orders of consciousness and level of NOS teaching was not achieved (“Order of Consciousness” variable, Figure 3). This is most assuredly because of the inherent complexity of what an “order of consciousness” is, and what it affects. Although this is the case, evidence from this study supports the inclusion of this variable in the proposed model because it may very well work in tandem with other factors to impact NOS implementation levels (Figure3).

As mentioned before, a central feature of an “order of consciousness” is what an individual feels ownership over (“object”) and what they feel powerless to control (“subject”). Kegan (1994) stated those operating from fourth order consciousness tended to
be “self authoring” to frame problems and decisions. These individuals can make self-directed value judgments through drawing from their internal way of knowing without being controlled by the rules, opinions, and expectations of others. Conversely, those operating from third order tend to adopt the rules, opinions, and expectations of the others as their value and meaning making system. In other words, an outside source serves as their “fourth order” meaning making system. Lastly, third to fourth order individuals alternate between self-directedness and being subject to the rules, opinions, and expectations of the others.

Five of the nine high and medium NOS implementers were fourth order. This means they have the ability to take the expectations of the schools they worked in and what they learned in the ISU-STEP as object—that is something they could look upon as separate from themselves. Consequently, they may be able to objectively weigh what they learned in their preservice program versus what is being asked of them in their schools, and maintain practices based they feel are best for students. More bluntly put, these teachers implement reform-based and NOS teaching practices not because of the opinions and expectations of others, but because their internal sense of meaning making has determined these approaches are best for students. Therefore, these teachers stand the best chance without support to successfully implement reform-based and NOS teaching practices in schools fraught with constraints and conflicting ideologies.

Four of the nine medium and high NOS implementers, and one low NOS implementer, were between third and fourth order. These individuals often demonstrated their third order tendencies by subjecting the validity of their work and capabilities to colleagues’ and/or administrations’ standards. Conversely, they sometimes demonstrated
fourth order tendencies by explaining how they took actions such as regulating relationships with colleagues. Unfortunately, when those operating from third to fourth order find themselves subject to conflicting ways of meaning making they can often feel torn or confused. For instance, these individuals may attempt to frame and make teaching decisions based on what they have learned in the ISU-STEP, but are facing severe pressures from colleagues to do otherwise. This may make them feel accountable to both entities, thus causing them a great deal of stress.

Three of the low NOS implementers were rated as third order. The opinions, problems, and solutions of these individuals were almost entirely subject to an outside source. Consequently, the basis for these teachers’ reactions and decisions would often be at the mercy of the expectations of others in the teaching profession (e.g. administrators, colleagues, and teachers).

Coping Strategies in Response to Teaching Constraints

NOS implementation was associated with how teachers coped with teaching constraints (“Teaching Constraint Coping Strategy” variable, Figure 3). Teachers in this study primarily used one of three coping strategies in response to teaching constraints. These were assert, navigate, and concede. The first two strategies are taught to ISU-STEP students to help them be politically savvy in schools and circumvent teaching constraints that may erode reform-based practices and NOS teaching. The message portrayed by the ISU-STEP is for preservice teachers to navigate (e.g. appear to be teaching like their colleagues) teaching constraints early in their careers. Once established, they then may become more open by respectfully sharing their practices and rationales (assert). The last strategy (concede) is
taught to ISU-STEP students as unacceptable. This happens when teachers have given up reform-based practices because of the constraints they experience. This strategy is often referred to in the program as “punting on the students.”

High and medium NOS implementers generally differed in the way they coped with the constraints of teaching. High NOS implementers tended to assert their autonomy to implement reform-based practices in the face of institutional and classroom constraints. For instance, when their practice is in question they would rather openly explain their rationale for teaching.

With the exception of one teacher who handled constraints like the high NOS implementers, medium implementers tended to navigate the pitfalls of teaching. They accomplished this by finding indirect ways to protect their reform-based practices from constraints. For instance, they may “appear to look like everyone else” to ensure their reform-based and NOS teaching practices are not hindered.

All teachers in this study who implemented the NOS at low levels conceded to the constraints found in schools. For instance, these teachers would state they don’t implement the NOS explicitly because it is not in their districts standards and benchmarks and/or their colleagues do not teach the NOS. They also indicated time limitations, content coverage concerns, and students’ abilities were reasons for their lack of reform-based and NOS teaching practices.

A possible explanation for the characteristics of high and medium NOS implementers’ coping strategies may be the ISU-STEP’s teachings about how to deal with constraints may have transferred to these teachers’ practices. As indicated before, the ISU-
STEP teaches preservice teachers to either avoid or navigate constraints early in a teaching career, and become more open with practice as time goes on. Because most medium NOS implementers are earlier in their careers than high implementers, they may have not gained the experience, knowledge base, and confidence needed to assert themselves in the face of teaching constraints. Hence, they are still in the “navigation” stage of coping with teaching constraints.

Perhaps the reason why low NOS implementers do not use the constraint coping strategies taught in the ISU-STEP is because they do not fully understand them. This would make sense given they do not understand many of the other factors the ISU-STEP promotes that this study shows are associated with higher levels of NOS implementation (e.g. understanding of NOS teaching). Conclusively, if teachers do not understand how to be politically savvy in the complex landscapes of schools, then they probably will not thrive in them by doing anything other than the status quo.

**Support from Others in the ISU-STEP**

Central to the proposed model, the level of support teachers received from others from the ISU-STEP played a crucial role in degree they implemented the NOS (“Support” variable, Figure 3). High and medium NOS implementers provided a great deal of support to one another to: 1) further understand the themes promoted in the ISU-STEP (“Like-Mindedness” variables); 2) maintain and foster responsibility to implement reform-based and NOS teaching practices (“Responsibility” variable); 3) circumvent teaching constraints (“Teaching Constraint Coping Strategy” variable); 4) augment their orders of consciousness (“Order of Consciousness” variable); and subsequently 5) facilitate the implementation of
reform-based and NOS teaching practices ("Reform-Based Practice and NOS Implementations" variables). Conversely, teachers who implemented the NOS at low levels did not participate in support groups with others from the ISU-STEP. Therefore, they did not receive the help from others in the ISU-STEP to benefit in the many areas the variables in Figure 3 portray.

Participation in collaborative support groups with others from the ISU-STEP are perceived as vital by high and medium NOS implementers for understanding, maintaining, and improving reform-based and NOS teaching practices. Furthermore, these teachers indicated collaborating with others from the ISU-STEP was crucial during their first year of teaching.

The structure of ISU-STEP support groups appears to be a hierarchy of knowledge where more experienced high NOS implementers better understand the complex aspects of teaching illustrated in Figure 3 (e.g. NOS teaching understanding, how people learn) than their less experienced medium NOS implementation counterparts. For instance, high NOS implementers generally reflected on their NOS and general teaching practices in greater depth than medium implementers. Additionally, within the collaborative groups they reside (groups of H1, H10, and H6; and H5, H3, and H4, Figure 2, Chapter 4) high NOS implementers indicated a superior understanding of NOS teaching practices compared to their medium NOS implementation collaborators. This was even the case in the group of H5, H3, and H4 where they were all transitional in their NOS teaching understanding.

High NOS implementers initially served as mentors or peers to each other or as mentors to medium implementers (Figure 2). Seemingly, the more knowledgeable and
experienced teachers facilitated those they mentored into collegial peers. Important to note is
the mentoring present in these support groups is unlike typical teacher mentoring where the
relationship is often characterized as supervisor-subordinate. Instead, these support groups
share many qualities with Lemlech’s (1995) six stages of collegiality. For instance, several of
the individuals indicated they interacted with others from the ISU-STEP through the first
year of practice for emotional comfort and feedback on teaching practices. As time has
passed, these relationships are defined by comparisons of strengths and weaknesses,
reflective problem solving, and peer coaching (Lemlech, 1995) so the teachers involved
improve their understanding and implementation of reform-based and NOS teaching
practices. Seemingly, high and medium NOS implementers draw from their support groups
to improve their “like-minded” characteristics (“Like-Mindedness” variables, Figure 3). In a
sense, these teachers have created a situation so eloquently described by one medium NOS
implementer when s/he said: “It is just a continuation of the methods course.”

Low NOS implementers did not participate in collaborative support groups with
others from the ISU-STEP to implement reform-based and NOS teaching practices.
Furthermore, at the time of this study they did not fully recognize how collaborations would
have benefitted their teaching as a whole. At best, low NOS implementers indicated activities
and/or teaching strategies would be the benefit from collaborating with others from the ISU-
STEP. Otherwise, low NOS implementers were unsure how collaborating in ISU-STEP
support groups would be benefit their practice.

None of the low NOS implementers perceived collaborations with others from the
ISU-STEP as crucial during their first year of teaching. This in part may be because all low
NOS implementers initially taught in schools that did not have others from the ISU-STEP working in them. Furthermore, low NOS implementers did not make substantial attempts to collaborate outside of the workplace with others from the ISU-STEP during the first year. Seemingly, low NOS implementers may have never conceptualized the benefit of collaborating with others from their program. This illustrates the importance of novice teachers being explicitly drawn to the crucial benefits of keeping in contact and collaborating with others from their program. This is especially the case if these teachers are in schools without supportive colleagues that utilize and promote reform-based and NOS teaching practices.

Seemingly, to participate in ISU-STEP support groups means you share a similar understanding of effective teaching and learning, and a commitment to put that understanding into action. In fact, almost all high and medium NOS implementers indicated they selected for and/or against collaborating with others based on their level of “like-mindedness” (“Like-Mindedness” variables, Figure 3) with the themes promoted in the ISU-STEP, and whether or not a mutual benefit in teaching practice would be realized. These findings reflect the writings of Blumenfeld et al. (1994) who conveyed successful collaborations emerge when those involved perceive they mutually benefit through a shared investment toward focused goals.

The lack of “like-mindedness” with themes promoted in the ISU-STEP seems to be a contributing factor why teachers who implemented the NOS at low levels do not participate in ISU-STEP support groups. Generally, low NOS implementers’ considerations for how people learn, accuracy and depth of self reflection, understanding of effective NOS teaching,
and congruency of utility value for NOS teaching were incongruent with what the ISU-STEP and high and medium NOS implementers exhibit. In fact, these teachers often indicated the practices such as those learned in the ISU-STEP were too ideal or challenging, thus abdicating themselves of responsibility to implement them.

Low NOS implementers currently have immediate access to other ISU-STEP graduates in their work places but do not collaborate to ensure the implementation of reform-based and NOS teaching practices. Two low NOS implementers work with high and medium NOS implementers, and two low NOS implementers work together. Although this is the case, they still do not utilize collaborative support groups to implement the practices they learned in the ISU-STEP. This further supports the notion that “like-mindedness” with the ISU-STEP facilitates the development of support groups that promote reform-based NOS instruction.

Based on the previously mentioned condition set by Blumenfeld et al. (1994) for successful collaborations, an explanation can be put forth why low NOS implementers were not selected to, and did not select to, be in support groups with high and medium NOS implementers. Seemingly, those that implement the NOS at high and medium levels and those that implement the NOS at low levels may not share common teaching goals, and therefore see few mutual benefits in collaborating. Perhaps low NOS implementers’ chances of being in support groups with high and medium NOS implementers perished because they either lost faith in reform-based practice or never bought into them in the first place. This would explain why low NOS implementers do not share similar views of, and a commitment to, implement reform-based and NOS teaching practices.
Teachers’ participation in support groups (“Support”, variable Figure 3) with others from the ISU-STEP greatly impacted their responsibility to implement reform-based and NOS teaching practices (“Responsibility” variable, Figure 3). Teachers who implemented the NOS at high and medium levels co-generated responsibility to do so even if it meant circumventing the constraints inherent to the teaching profession (“Teaching Constraint Coping Strategy”, variable Figure 3). Often this responsibility would be manifested in the form of guilt and embarrassment if they fell short in their reform-based and NOS teaching practices. Responsibility was also manifested in the form of professional competition between high and medium NOS implementers to meet the standards they learned in the ISU-STEP. This competitive nature between these teachers was exhibited as an “if they can do it, I can too” attitude.

Unfortunately, because low NOS implementers were not in ISU-STEP support groups (“Support”, variable Figure 3) they did not experience the added accountability to implement reform-based and NOS teaching practices (“Responsibility” variable, Figure 3). Instead, these teachers were seemingly accountable to implement practices based solely on their schools’ demands and constraints. This was evident when low NOS implementers readily conceded (“Teaching Constraint Coping Strategy”, variable Figure 3) to the constraints present in their schools, thus resulting in them to implement reform-based and NOS teaching practices at low levels.

Without participating in collaborative support groups (“Support” variable, Figure 3), all high and medium NOS implementers admitted they would not utilize reform-based or NOS teaching practices to the degree they do now. Clearly, without support, teachers
operating from a fourth order consciousness (“Order of Consciousness” variable, Figure 3) stand the best chance of implementing reform-based and NOS teaching practices, in part by self-directedly circumventing teaching constraints (“Teaching Constraint Coping Strategy”, variable, Figure 3). Despite this fact, several fourth order individuals indicated that without support from others in the ISU-STEP they would not continue to teach in environments with fierce institutional constraints.

Collaborative support groups (“Support” variable, Figure 3) are more crucial for third order and third to fourth order individuals (“Order of Consciousness” variable, Figure 3). ISU-STEP support groups provide these teachers supplementary ways of handling the overwhelming constraints and complexities so often found in the teaching profession (“Teaching Constraint Coping Strategy”, variable, Figure 3). Without collaborations from support groups these teachers are especially in danger of drawing exclusively upon the school they are in for teacher decision making. This may cause them to turn away from reform-based and NOS teaching practices, or worse, become dissatisfied and quit the teaching profession.

Important to note is all low NOS implementers operated from third or third to fourth order (“Order of Consciousness” variable, Figure 3). Intuitively, because no support or pressure was provided from ISU-STEP support groups (“Support” variable, Figure 3), low NOS implementers are seemingly drawing their decision making from the only “fourth order” entity they have access to—the school they find themselves in. This would explain why all low NOS implementers so readily concede to the institutional and classroom constraints they face (“Teaching Constraint Coping Strategy” variable, Figure 3). In addition, this would
also explain why they have an understanding of, and approach to, teaching and learning that is found in most traditional classrooms. Conclusively, these teachers probably are not implementing the NOS effectively and extensively because the entity they are drawing their decision making from does not require them to.

Utility of Model Predicting and Accounting for NOS Implementation

Profiles of Participants Described in the Context of the NOS Implementation Model

Evidence from this study supports NOS implementation is associated with a multitude of factors present in Figure 3. Outlined below are three scenarios to demonstrate the utility of this model. The scenarios below are based on findings from this study and are written in a sequence flowing from left to right according to the model predicting and accounting for NOS implementation. Additionally, when variables associated with NOS implementation from the model are referenced in the text, they will be followed by that variable’s name in parentheses as it appears in the model.

Profile of Low NOS Implementer (H8)

H8 exhibits the following characteristics associated with the variables present in Figure 3:

- “Like Mindedness”
  - Sophisticated NOS understanding (95%; 4th highest in study).
  - Low congruency of utility value with ISU-STEP for NOS teaching.
  - Moderate accuracy and moderate to low depth for teaching reflections.
- Low consistency with the ISU-STEP’s considerations for how people learn.
- Naïve NOS teaching understanding.
  - Low responsibility to implement reform-based and NOS teaching practices.
  - Low support from others in ISU-STEP.
  - 3rd order of consciousness.
  - Concedes to teaching constraints.
  - Low reform-based practices.
  - Low NOS implementation.

H8’s profile illustrates a sophisticated NOS understanding does not guarantee the NOS will be taught. Furthermore, a low degree of “like-mindedness” (“Like-Mindedness” variables) with the ISU-STEP was exhibited by H8 in regards to utility value for teaching the NOS (“Congruency of Utility Value for NOS Teaching” variable), NOS teaching understanding (“NOS Teaching Understanding” variable), and considerations for how people learn (“How People Learn” variable). This was the case for all low implementers which indicates that of all the variables included in the “Like-Mindedness” category, these may have the biggest impact on whether or not the NOS is taught. Of all the low implementers, H8 demonstrated the best ability to accurately and deeply self reflect (“Reflection” variable). Although this was the case, H8’s teaching reflection abilities were still not as adept as any of the medium to high NOS implementers.

As indicated before, to seek out, or be sought out, to collaborate in ISU-STEP support groups (“Support” variable) teachers must have a high degree of “like-mindedness” with the themes promoted in the ISU-STEP (“Like-Mindedness” variables). Additionally, one must
exhibit responsibility to implement the themes they have learned (“Responsibility” variable). Because H8 and the other low NOS implementers do not deeply understand the themes promoted in the ISU-STEP (“Like-Mindedness” variables), they may not realize the need to feel responsible (“Responsibility” variable) and/or seek support (“Support” variable) to implement reform-based and NOS teaching practices.

H8 operates from a 3rd order of consciousness (“Orders of Consciousness” variable) and faces fierce institutional constraints at work. These factors in combination with H8’s lack of responsibility (“Responsibility” variable) to implement reform-based and NOS teaching practices, and no support from others in the ISU-STEP (“Support” variable), make H8 subject to the constraints present in the school in which s/he works. Therefore, H8 tends to concede to teaching constraints (“Teaching Constraint Coping Strategy”, variable) and as s/he stated “go with the flow”. For instance, because H8’s colleagues do not teach the NOS, s/he has also decided to not implement the NOS extensively.

Profile of Medium NOS Implementer (H6)

H6 exhibits the following characteristics associated with the variables present in Figure 3:

- “Like Mindedness”
  - Average NOS understanding (81%, 3rd lowest in study).
  - High congruency of utility value with ISU-STEP for NOS teaching.
  - Moderate to high accuracy and moderate depth of teaching reflections.
  - Considerations of how people learn that are consistent with the ISU-STEP.
  - Transitional NOS teaching understanding.

- High responsibility to implement reform-based and NOS teaching practices.
- High support from others in ISU-STEP.
- 3rd to 4th order of consciousness.
- Navigates teaching constraints.
- Moderate reform-based practices.
- Moderate NOS implementation.

H6 struggles to implement the NOS at a medium level. Based on H6’s profile evidence supports a high NOS understanding is not needed to teach the NOS at moderate levels. Compared to other medium NOS implementers, H6 somewhat struggled when reflecting upon practice (“Reflection” variable). Furthermore, H6’s considerations of how people learn (“How People Learn” variable) were consistent with the ISU-STEP, yet were superficial. Additionally, H6 is admittedly transitional in the way s/he understands effective NOS teaching practices (“NOS Teaching Understanding” variable). Although this is the case, H6’s utility value for NOS teaching (“Congruency of Utility Value for NOS Teaching” variable) demonstrated a high degree of “like-mindedness” with the ISU--STEP. Clearly H6 feels a deep understanding of the NOS is an important educational objective for students so they may become successful members of society. H6 feels deeply responsible to effectively teach the NOS (“Responsibility” variable) has sought out and participates in collaborative ISU-STEP support groups (“Support” variable). H8 admits heavily relying on these collaborations to improve how s/he understands and teaches the NOS (“NOS Teaching Understanding” and “NOS Implementation” variables). Additionally, because of participating in the support groups (“Support” variable), H6 feels more responsible (“Responsibility” variable) to teach in a manner congruent with what is promoted ISU-STEP.
Clearly these factors have enhanced H6’s ability to implement reform-based and NOS teaching practices.

H6 operates from a 3rd to 4th order of consciousness (“Orders of Consciousness” variable) and faces fierce institutional constraints. This makes H6’s decision making somewhat subject to the school s/he is in. Although H6 attempts to navigate around teaching constraints (“Teaching Constraint Coping Strategy”, variable) s/he admits on one occasion s/he made a decision that went against the teaching ideology s/he holds—that which is congruent with the ISU-STEP. This resulted in H6 feeling guilty during the interview for this study (“Responsibility” and “Orders of Consciousness” variables). Because H6 faces such fierce teaching constraints and operates from 3rd to 4th order, collaborations from ISU-STEP support groups (“Support” variable) is crucial to augment the way s/he makes decisions. H6 admits s/he would become a more traditional teacher and not implement the NOS if s/he did not participate in ISU-STEP collaborative support groups (“Support” variable). In summary, for teachers like H6, who struggle with fully understanding effective teaching practices and face fierce institutional constraints, support from “like-minded” individuals with similar teaching values and goals is imperative.

Profile of High NOS Implementer (H1)

H1 exhibits the following characteristics associated with the variables present in Figure 3:

“Like Mindedness”

- High NOS understanding (96%, 2nd in study).
- High congruency of utility value with ISU-STEP for NOS teaching.
- High accuracy and high depth of teaching reflections.
Considerations of how people learn that are consistent with the ISU-STEP.

- High NOS teaching understanding.
  - High responsibility to implement reform-based and NOS teaching practices.
  - High support from others in ISU-STEP
  - 4th order of consciousness.
  - Asserts against teaching constraints.
  - High reform-based practices.
  - High NOS implementation.

Of all the participants in this study, H1 implements the NOS at the second highest level. H1 is an ideal example of someone who possesses all of the traits of someone who teaches the NOS very effectively. H1 deeply understands the NOS and NOS teaching ("Understanding NOS Teaching" variable), and demonstrates accurate and deep self reflection abilities ("Reflect" variable). Furthermore, H1’s considerations for how people learn ("How People Learn" variable) and utility value to teach the NOS ("Congruency of Utility Value for NOS Teaching" variable) are highly congruent with the ISU-STEP.

H1 demonstrates a high degree of responsibility to teach reform-based and NOS teaching practices ("Responsibility" variable) and has actively sought out others from the ISU-STEP to form collaborative support groups ("Support" variable). Furthermore, H1 has filled a mentorship role for two medium NOS implementers and continues to collaborate with them after two years. Collaborations have been crucial to H1’s practice. H1 admits without collaborations with ISU-STEP support groups ("Support" variable) s/he probably would not be teaching because s/he would “grow tired of fighting the same battles all of the time.” This
statement is indicative of someone operating from a fourth order consciousness that has had others attempt to violate their self-directedness. This is an interesting finding given H1 operates at a 4th order consciousness (“Orders of Consciousness” variable) and tends to directly address teaching constraints (“Teaching Constraint Coping Strategy”, variable) through providing rationales to those that question why s/he implements reform-based and NOS teaching practices. Furthermore, this finding speaks to the importance of teachers operating from all orders of consciousness to participate in collaborative support groups.

**Summary of Participants’ Profiles**

Based on the three participant profiles and findings in this study are the following conclusions:

1. NOS understanding is a necessary but insufficient condition for NOS teaching.
2. Teachers’ reform-based practices serve as a platform for effective NOS instruction.
3. To implement the NOS effectively, teachers should possess a minimum degree of “like-mindedness” with the themes that are promoted in the ISU-STEP (understanding of NOS teaching, type of utility value for NOS teaching, teaching reflection abilities, and considerations for how people learn).
4. Among the factors that make up the “levels of like mindedness” ("Like-Mindedness" variables, Figure 3) a deep and compelling utility value for teaching the NOS appears to most significantly influence whether teachers implement the NOS. Additionally, teachers that do not possess this deep and compelling utility value also do not feel deeply responsible to teach the NOS.
5. Inclusion in ISU-STEP support groups is dependent on teachers’ “like-mindedness” with the ISU-STEP and their level of responsibility to implement reform-based and NOS teaching practices.

6. Teachers participating in ISU-STEP support groups co-generate responsibility that encourages the implementation of reform-based and NOS teaching practices despite the presence of teaching constraints.

7. Participation in ISU-STEP support groups facilitates teachers to substantially and effectively teach the NOS even if they struggle to self reflect, consider how people learn, and/or understand the NOS and effective NOS teaching.

8. Support groups augment teachers’ decision making in regards to instructional practices and teaching constraints. This is most crucial for teachers who operate below 4th order and lack self-directedness.

**Implications**

The goals of this study included providing implications and recommendations for the ISU-STEP and teacher education as a whole. Because of the effectiveness of the ISU-STEP in preparing teachers that implement reform-based and NOS teaching practices, many recommendations can be made from this study for science teacher preparation programs nationwide. The ISU-STEP is one of the few programs that prepares teachers to implement reform-based and NOS teaching practices by requiring three to four methods courses coupled with a NOS course. Consequently, this study provides an ideal scenario to determine factors associated with teachers’ NOS implementation practices beyond their preservice programs.
Findings from this study may be useful for pre or in-service professional development programs to facilitate science teachers to implement reform-based and NOS teaching.

"Would you tell me, please, which way I ought to go from here?"
"That depends a good deal on where you want to get to," said the Cat.
"I don’t much care where--" said Alice.
"Then it doesn’t matter which way you go," said the Cat.
"-so long as I get SOMEWHERE," Alice added as an explanation.
"Oh, you’re sure to do that," said the Cat, "if you only walk long enough."

The previous quote from Lewis Carrols’ Alice in Wonderland (1897, p. 31) resembles the journey teachers face beginning in their preservice career and extending well into professional practice. Often like Alice, teachers long for direction and will assuredly be lost if given only little guidance of the complex landscape they are in. Several works discuss how preservice teachers often think linearly and view teaching as a set of discrete strategies to try to help students learn (Clough, 2003; Clough & Olson, 2007; Clough et al., 2009).

Unfortunately by adopting this “patchwork” approach, teachers may implement one or two reform-based strategies well, but neglect others needed to make instruction effective. Because this invariably leads them to fail, teachers may become disillusioned and abandon reform-based practices all together. This leaves them nothing to choose but the more familiar well travelled road of traditional practices. Consequently, because traditional practices are incongruent with effective NOS instruction the NOS will most likely not be accurately, explicitly, and reflectively portrayed.

This study confirms effective implementation of the NOS is a synergetic component within effective science teaching as a whole. Because of this, the implications presented below include: (1) multi-faceted considerations for preservice teacher education (2) specific
considerations of how and why support should be provided for teachers to implement reform-based and NOS teaching practices, and (3) recommendations for further study.

Preservice Teacher Education

Promotion of Dissatisfaction with the Current State of Science Education

Unfortunately the general public, including incoming preservice teachers, does not recognize the complexities associated with teaching. Clough et al. (2009, p. 822) articulates the four erroneous beliefs held about teaching and learning. They are: “(1) command of subject matter is sufficient for effective teaching; (2) effective pedagogical practices develop naturally through teaching experience; (3) teaching is simply a matter of personal style; and (4) teaching is essentially the passing of information.”

Science teacher educators must facilitate their students to conceptually divorce from their traditional mental models of science instruction (Craven and Penick, 2001). One way to initiate this is through helping preservice teachers to become dissatisfied with their own educational experiences that were ineffective. This in part can be accomplished by presenting to preservice teachers the flaws in science education that are articulated in reform-based literature (Goodlad, 1983; Penick, 1986; Yeager, 1988; among others). More specifically, preservice teachers must also be shown their views of the NOS are rife with misconceptions (Abd-El-Khalick & Akerson, 2004). In line with conceptual change research, without this dissatisfaction preservice teachers are highly unlikely to adopt new and accurate understandings of the NOS and effective teaching (Posner et al., 1982)
Promotion of a Sense of Teacher Responsibility

Madsen (2005) speculated teacher attributes including a high degree of moral purpose and motivation to learn may be the most important factor in determining teacher effectiveness. In this study, the extent teachers felt responsible to implement reform-based and NOS teaching practices was one of the factors most strongly associated with levels of NOS implementation. The implication is clear. Preservice programs must facilitate students to develop and/or maintain a high degree of responsibility to implement reform-based practices including NOS teaching.

Teachers tend to instruct based on the way they were taught (Goodlad, 1983, 1984; Lortie, 1975). Because of this, teacher educators must model for their students the habits, attitudes, and sense of moral purpose Fullan (1994) and Craven and Penick (2001) state are at the core of effective teaching. Additionally, science teacher educators must explicitly draw preservice teachers’ attention to the moral reasons behind effective teaching. Without these efforts on the part of the teacher educator, preservice teachers may never fully understand the compelling reasons why they need to implement effective practices including teaching the NOS.

Promotion of an Understanding of the Synergetic Nature of Teaching

Many factors beyond an accurate understanding of the NOS are linked to effective NOS instruction (Abd-El-Khalick et al., 1998; Bell et al., 1999; Lederman, 1999; Schwartz & Lederman, 2004; among others). Clough (2006) articulated teachers’ conceptions about many factors including the purposes of schooling, what learning is, effective instruction, and
teaching constraints affect how science content and the NOS are conveyed. This study showed factors such as teachers’ considerations for how people learn, self-reflection abilities, understanding of effective NOS instruction, type of utility value for NOS instruction, and coping methodologies in response to teaching constraints are associated reform-based and NOS teaching practices.

Pre-service programs must recognize having students complete a NOS course does not guarantee effective NOS implementation in science classrooms. Instead, science teacher educators must help pre and inservice teachers understand effective NOS teaching is associated with a multitude of other factors that are required to synergistically and effectively teach science as a whole (Clough, 2003; Backhus and Thompson; Clough, 2006; Clough et al., 2009). To promote this understanding, science teacher educators must create an environment Craven and Penick (2001, p. 2) described as “values inquiry and thinking, one that presents a coherent and consistent experience for the learners, and one that seeks to be self-improving through processes of reflection, feedback, and critical inquiry.” More specifically, Clough et al. (2009) emphasizes the need for preservice programs to help future teachers cohesively understand the research base and apply it to promoting the goals of effective science education. These goals include students demonstrating a deep and robust understanding of the NOS.

Several recommendations are present in the literature base for preservice programs to help their students understand the synergetic nature of teaching that promotes effective NOS instruction (Craven and Penick, 2001; Clough et al., 2009). A few of them include requiring preservice teachers to: (1) develop a Research Based Framework (RBF) for teaching that
fully outlines goals for students, how people learn, and the synergetic nature of teaching; (2) work with peers, cooperating teachers, supervisors, and faculty to express and defend rationales for teaching decision making based on goals for students and how people learn; (3) develop, analyze, and self reflect upon crucial components of their own practice (e.g. lessons, interaction patterns, etc.) using the goals they have for students and how people learn as guidelines for effectiveness; (4) engage in inquiry and NOS experiences to develop their understanding and proficiency of teaching them (Craven and Penick, 2001; Clough et al., 2009).

**Providing Ample Opportunities to Understand NOS Teaching and its Value**

Views of the NOS affect whether teachers view classroom scientific investigations as constructive undertakings or trivial activities for verification of content (Duschl, 1990; Krajcik, 1994). Because of this, preservice programs should facilitate preservice teachers to internalize that the NOS is a crucial objective in science instruction (Lederman, 1999; Abd-El-Khalick & Akerson, 2004). To do this, teacher educators must help their students deeply understand the more compelling arguments why the NOS should be taught. In this study teachers that exerted greater efforts to implement the NOS provided deep compelling reasons why they did so. Furthermore, the reasons to teach the NOS provided from these teachers were related to goals that transcend beyond their students’ immediate classroom experiences. For instance, many of these teachers provided a rationale for teaching the NOS that was reflective of the following quote from Rudolph, (2007, p.1):

“Too many of our citizens simply don’t understand how it is that researchers figure out what’s going on in the world. It’s this misunderstanding about how
science is done that has been and continues to be exploited by various business and political interest groups.”

Rudolph poses a very grave problem in his article describing why a lack in a sufficient science education with accurate NOS instruction prevents our public from understanding large scale phenomena such as global climate change. The result of this often is confusion of what should be accepted as truth and a hesitation to react, or a negative reaction, towards serious environmental and social issues by individuals and the collective public. Science education literature clearly states that the teaching of the NOS, scientific inquiry, and the many methods science can utilize in an effective manner is imperative for students to become scientifically literate and understand large scale science ideas our society deals with (Clough & Olson, 2004; Clough et. al, 2008; Finley, 2006; Herman, 2009; Lederman & Abd-El-Khalick, 1998; McComas, 2004; Narguizian, 2004; Rudolph, 2007; Rudolph & Stewart, 1998).

If preservice teachers are not aware of the compelling reasons to teach the NOS, the chances they will implement it seemingly will be diminished. This claim is supported by findings in this study in which none of the low NOS implementers could give deep compelling reasons to teach the NOS such as the one above. Instead, low NOS implementers gave superficial reasons such as it makes science human, relates science to students’ everyday lives, and/or makes the science content more accessible.

Interestingly, results from this study agree and contradict work done by Abd-El-Khalick et al. (1998). Their findings indicated preservice teachers provided reasons to teach the NOS that were congruent with the reasons provided by low, medium, and high NOS
implementers in this study. Although this is the case, the participants in the study done by Abd-El-Khalick et al. (1998) did not have significant amounts of NOS instruction evident in their lesson plans or teaching. Therefore, they resembled low NOS implementers in this study with the exception they could give more compelling reasons to implement the NOS, such as it is important for people to engage in socioscientific issues.

Perhaps the discrepancy between the results of these two studies lies in the fact that this study analyzed inservice teachers rather than preservice teachers who just recently had instruction on the NOS and NOS pedagogy. This proposition is congruent with the explanation Abd-El-Khalick et al. (1998) gave when indicating they felt preservice teachers’ responses may have been influenced by recent NOS instruction. Also, Abd-El-Khalick et al. (1998) indicated the researcher’s interest of the NOS was known by the participants, thus potentially further influencing their responses on the utility value of NOS instruction.

Conversely, this study was designed to appear to participants as if the effectiveness of the ISU-STEP as a whole was being determined. This was deliberately done so teachers in this study would provide an accurate picture of their NOS instruction and reasons for that instruction. Additionally, teachers in this study haven’t had a NOS course for approximately one to five years. Perhaps the “lag time” experienced by teachers in this study created a situation where their utility value for NOS teaching was more indicative of their actual NOS teaching practices practice.

Beyond helping preservice teachers to understand the deep compelling reasons to teach the NOS, many opportunities must be provided for them to develop accurate notions of the NOS and how to effectively implement it in science classrooms. Clough (2006)
specifically addresses how teacher educators can model effective NOS instruction that is explicit and reflective and scaffolds along the decontextualized to highly contextualized continuum. The ISU-STEP requires a NOS course and offers an optional restructuring science activities course for all preservice teachers. In these courses students learn the philosophical underpinnings of the NOS. Additionally, they apply these concepts to develop lessons and modify cookbook activities so they accurately, explicitly, and reflectively portray the NOS in a manner that scaffolds along the decontextualized to highly contextualized continuum. Collectively, as described in Clough (2006, p. 487) these courses strive to have students “(1) understand the role of, and interplay among, explicit, implicit, decontextualized, moderately contextualized and highly contextualized NOS instruction; (2) attend to both continua in lesson planning and sequencing of lessons; and (3) map their own NOS implementation practices.”

Eleven of the fourteen teachers in this study completed the ISU-STEP Restructuring Science Activities course. The purposes of this study did not include determining the association of this course with teachers’ NOS implementation. Although this is the case, important to note is the three individuals who did not take this course were also low NOS implementers. Additionally, almost all of the participants who took this course conveyed it was one of the most beneficial courses they have ever taken and should be required. Specific reasons given why it was valuable included it provided concrete examples how to implement abstract NOS themes into classroom practice.

All students who take this course are required to restructure a “traditional” cookbook activity to more accurately, explicitly, and reflectively portray the NOS. At the conclusion of
the Restructuring Science Activities course all students are required to publish their restructured activity in the Iowa Science Teachers’ Journal (http://ists.pls.uni.edu/istj/issues/). Participants conveyed it was comforting to know they possessed these activities that were classroom ready and effectively portrayed the NOS. These statements imply more courses that facilitate preservice teachers to implement the NOS through restructuring already familiar traditional activities are needed to make abstract NOS ideas more accessible.

**Promotion of an Understanding of how to Cope with Teaching Constraints**

The constraints low NOS implementers in this study cited that prohibited them from implementing the NOS resembled those given by preservice teachers in previous studies (Abd-El-Khalick *et al.*, 1998; Bell *et al.*, 2000). Constraining factors cited in prior studies as well as this one included lack of time, other teachers were not teaching the NOS, lack of preparation to teach the NOS, and students were not able to understand the NOS deeply. The obvious differences between low NOS implementers in this study and the preservice teachers in previous studies are the degrees of autonomy and teaching experience they possess. Low NOS implementers in this study probably have greater freedom to implement the NOS and reform-based practices than most preservice teachers would. Furthermore, they also have three to five more years of experience, giving them a more complete base to implement the NOS from. Despite these factors, low NOS implementers used teaching constraints as reasons why they could not implement reform-based and NOS teaching.

High and medium NOS implementers enacted very different strategies in response to teaching constraints. These individuals either asserted themselves against constraints or navigated around them altogether to ensure they were able to implement reform-based and
NOS teaching practices. These findings affirm Lederman’s statements (1999) that indicated a wide array of strategies that facilitate teachers to be comfortable in handling the management and organization of instruction seemingly is a prerequisite for teachers to promote the NOS.

The ISU-STEP explicitly instructs preservice teachers how to handle the constraints of teaching. Preservice teachers are facilitated to understand to first quietly assess the landscape they are in while navigating the constraints of teaching found within it. These future teachers are then led to the understanding that once you have a degree of seniority and experience you are better able to assert your rationale for teaching to others you work with.

What is promising is that over 70% of the teachers in this study implemented the coping strategies taught in the ISU-STEP. This result alone should prompt other preservice programs to teach their students how to cope with the pitfalls so prolific in the teaching profession. Why all teachers in this study do not implement the coping strategies learned in the ISU-STEP is not fully known. Perhaps with the low NOS implementers it is due to a lack of responsibility to implement reform-based and NOS teaching practices, self directedness, and support from others in the ISU-STEP. Perhaps it goes beyond these factors and is a result of a personality trait present prior to them entering the ISU-STEP. Based on results from this and prior studies (Abd-El-Khalick et al., 1998; Bell et al., 2000), the use of constraints as limiting factors are seemingly initiated in preservice teaching and can persist well past the induction years. Further research is needed on exactly why some teachers and not others use constraints as a justification to not implement the NOS and reform-based teaching.
Facilitation of Continued Support through Cohorts

Beck and Kosnik (2001, p. 925) stated cohorts “intensify and crystallize programmatic experiences” and at best they “provide mutual support for prospective teachers and foster socialization into desirable professional norms and practices.” These authors describe the objectives of cohorts as: (1) develop a more synergistic and powerful link between theory and practice; (2) facilitate a stronger relationship between faculty and preservice teachers; (3) facilitate an environment that encourages mutual support; and (4) model a collaborative avenue to teaching and learning that can be utilized in professional practice. These objectives for cohorts closely reflect other authors’ statements on the benefits for teaching realized from collaboration which are: (1) teachers are facilitated to reflect upon, discuss, and modify their own practice; (2) increased levels of responsibility to enact best practices are realized; and (3) teachers’ understandings of the theoretical underpinnings of effective teaching and learning are facilitated (Calderhead & Gates, 1993; Krajcik et al., 1994).

Unfortunately, teacher education and subsequently professional practice as a whole remains an individualistic endeavor with little common focus on the goal of effective teaching (Lortie, 1975; Goodlad, 1990a; 1990b; Beck & Kosnik, 2001). Part of the blame lies with post-secondary institutions. Often times the pressures to publish and conduct research leaves faculty with little time to facilitate cohort groups (Whitford & Metcalf-Turner, 1999). Blame also lies specifically with teacher preparation programs because the facilitation of cohort groups is often ignored (Howey, 1996; Tom, 1997; Beck & Kosnik, 2001). Regardless of who is to blame preservice teachers will take the isolationist approach
modeled with them into practice. The consequence of not working with other teachers can be self doubt and a lowered self-efficacy of one’s abilities and practice (Kagan, 1992; Blumendfeld et al., 1994).

The ISU-STEP faculty recognizes the isolationism that happens in the teaching profession. In response, ISU-STEP faculty implements a cohort model that attempts to achieve objectives congruent to those previously mentioned (Calderhead & Gates, 1993; Krajcik et al., 1994; Beck and Kosnik, 2001). All but two of the high and medium NOS implementers in this study initiated their current support relationships in their preservice program. The other two include the teacher who had not gone through the full ISU-STEP, and a teacher who became involved in the support groups shortly after finishing the ISU-STEP. Important to note, these collaborative support groups have persisted for over three years with new teachers continuously being integrated. Furthermore, the groups consist of individuals from many different generations of cohorts.

High and medium NOS implementers’ cohorts have been very beneficial in a number of ways. These teachers’ support systems resemble their methods program by creating: (1) a network of trust and accountability that boosts morale; (2) teaching decisions more congruent with research; (3) more effective and innovative understanding and implementation of reform-based and NOS teaching practices; and (4) fuel to initiate change in the education system as a whole. All of these initiatives reflect what several authors describe should be present in professional collegiality and collaboration (Barth, 1990; Weinstein et. al., 1991; Ball & Runquist, 1993; Blumendfeld et al., 1994; Christiansen et al. 1997; Beck & Kosnik, 2001).
Much like the students they teach, pre and inservice teachers must have opportunities through social interaction to construct an understanding of their practice they would normally not achieve on their own (Simon & Schifter, 1991; Krajcik et al., 1994). Vygotsky’s (1978, 1986) work can be clearly linked to why collaborative cohort groups work. Vygotsky (1978, 1986) explained through collaborations more capable peers can model, explain, discuss ideas, and ask leading questions that push less adept peers to develop more complex understandings. High and medium NOS implementers in this study used interactions with each other to push their conceptual understandings of effective reform-based and NOS teaching. Additionally, they drew from one another strategies to cope with the potential pitfalls of teaching.

Several recommendations to facilitate support through cohorts like those set up by the ISU-STEP and its former students have been presented in literature. First and foremost, teachers must be able to communicate effectively about their practice to include teaching the NOS. Clough et al. (2009) explained how teachers need to be able to communicate the complexities of teaching based on a deep understanding of what research says is effective. By being able to articulate their teaching decision making in the context of the research base, teachers can establish common ground to work together to improve practice.

Teacher educators must also model for their cohorts effective collaborations so students may adopt them as their own. The most obvious way of modeling support for students is to be a supportive faculty member. In addition to support, Craven and Penick (2001) explain teacher educators’ classroom environments can model high expectations and facilitate social interactions between students. Teacher educators can also facilitate
communication of the value in collaborating in the context of the NOS. By explicitly discussing collaborations in the context of the discipline, preservice teachers will be more likely to buy into the benefits of generating knowledge through working together (Beck & Kosnick, 2001). Additionally, through using this strategy preservice teachers can develop more accurate notions of the NOS.

Collaborative conversations by themselves are not sufficient to motivate significant action to implement reform-based and NOS teaching practices (Krajcik et al., 1994). Teachers must have concrete experiences that accompany collaborative reflections to improve reform-based and NOS teaching practices. To accomplish this goal, pre and inservice teachers should be facilitated to work collaboratively on meaningful projects. For instance, in this study several of the high and medium NOS implementers collaboratively worked together prior to the school year to develop lessons that integrate explicit and reflective decontextualized NOS activities. Undoubtedly, these teachers’ NOS instruction wouldn’t be as effective if these collaborative sessions were eliminated.

Teacher educators must make a point of requiring preservice teachers to work collaboratively on meaningful projects that integrate effective reform-based and NOS teaching practices. Clough et al. (2009) explained teachers often struggle to provide rationales why and how their lesson plans are effective in relation to how people learn and the structure of the discipline of science. By requiring preservice teachers to collaboratively develop effective lesson plans that integrate the NOS and provide their rationales, several objectives congruent with effective teaching are met. Included in these are preservice teachers learning how to collaborate to implement reform-based and NOS teaching practices.
Also, they develop the ability to explain research-based rationales why they included and structured NOS instruction the way they did.

**Formal Induction**

Time is one of the more critical factors associated with people developing accurate and deep conceptions (Appleton, 1993; 1997; Grouws & Cebulla, 2000; Pintrich *et al.*, 1993). Although most were participating in support groups, evidence showed none of the teachers from this study understood everything promoted in the ISU-STEP about the NOS and effective reform-based and NOS instruction. Not surprisingly, this demonstrates there is not enough time or resources in preservice programs to teach future teachers all they need to know to be effective.

All high and medium NOS implementers admit to some degree their shortcomings in understanding the NOS, NOS teaching, and reform-based pedagogy. Not surprisingly, high and medium implementers in this study indicated they struggled most with these components during the first year of teaching. This combined with the fact that low NOS implementers were isolated during the first year from other ISU-STEP personnel, and performed poorer than high and medium NOS implementers in reform-based and NOS instruction, indicates facilitating support through cohorts during preservice programs is insufficient.

Roehrig and Luft (2006, p. 965) state, “If teachers are to enact inquiry-based lessons as called for in the current science education reform documents, their knowledge of science-specific pedagogies is critical”. Furthermore, Clough (2006, p. 488) remarked to explicitly and reflectively teach the NOS along the decontextualized to highly contextualized continuum requires “a deep understanding of NOS content, NOS pedagogical content
knowledge, and general pedagogy skills.” In addition to preservice programs’ implementation of cohorts, formal induction may be required to help novice teachers develop pedagogical content knowledge of reform-based and NOS teaching practices. This would be especially crucial for those teachers who managed to slip through preservice programs with a shallow understanding of reform-based and NOS teaching practices and/or were not afforded the chance to participate in collaborative support groups.

Induction research has shown support from teacher educators, mentors, and school districts is needed to help new science teachers to maintain and improve reform-based practices (NSTA, 2010). One way induction can be conducted is through the use of workshops (Roehrig & Luft, 2006). By conducting workshops on how to implement reform-based and NOS teaching practices, new teachers can develop a greater understanding of the pedagogical content knowledge that is so crucial to teach science content and the NOS effectively. Another way to improve practice is to facilitate teachers to experiment with inquiry based activities in a supportive environment with a mentor observing. After implementing the lesson evaluative feedback can be co-generated for further improvement. This would resemble the feedback high and medium NOS implementers in this study provide in their collaborative groups. Important to note is the crucial role “like-mindedness” played in ISU-STEP support groups to encourage its members to understand and implement reform-based and NOS teaching practices. If mentors are utilized in induction, they must share similar reform-based teaching ideologies with their mentees. Otherwise, novice teachers’ reform-based and NOS teaching practices will most likely not benefit from induction experiences.
Orders of Consciousness and Self Directedness in Teaching

The participants in this study who were best able to autonomously handle the mental demands of the teaching profession were those who operated from a fourth order consciousness. As mentioned before, those operating from a fourth order consciousness are not subject to the opinions and expectations of others and larger institutions. Because of this they can take the expectations of others as object while simultaneously framing and solving problems from their own meaning making (Kegan, 1994). Conversely, individuals operating from a third order consciousness are subject to the opinions and expectations of others and larger institutions. Therefore, they tend to frame and solve problems based on the higher institution they find themselves in.

Most preservice teachers will graduate and begin work in traditional education institutions while still operating at third to fourth order. Because of this, the efforts of a strong reform-based preservice program that promotes NOS teaching may be negated. Given these individuals lack self directedness, without outside support they will most likely draw from the traditional teaching ideology that is supplied by the school they are in. Consequently, they may frame their practice in the same traditional fashion. Another less likely option is they will feel torn between reform-based ideologies and traditional ideologies. Usually when this happens they will turn to the nearest “expert” and seek a decision. Unfortunately, the nearest “expert” may very well be a traditional teacher.

The end result for the few fourth order preservice teachers entering the teaching profession is equally bleak. Kegan (1994) explains because these individuals possess autonomy in their meaning making, they may feel violated when an opposing way of
knowing is forced upon them to solve issues. Considering educational institutions are rife with entities that impose traditional ideologies, fourth order teachers who seek to define their work as congruent with reform-based practices (including the NOS) will probably get frustrated. If their self directedness is violated enough, these teachers will probably either find a new teaching position or quit the profession all together.

Stakeholders such as preservice programs and induction and support groups can cohesively work together to help third to fourth and fourth order reform-based teachers thrive in traditional institutions. Third to fourth order teachers’ are in the direst need of support because of their lack of self-directedness. Stakeholders must continuously be available to augment the decision and meaning making of these teachers to help them maintain their reform-based and NOS teaching practices. Additionally, because as these individuals are approaching self directedness the chance of them feeling torn between reform-based ideologies and traditional ideologies increases. Considering this can be very emotionally taxing, stakeholders must also be available to provide emotional support and reassurance for these teachers.

As evidenced by this study fourth order reform-based teachers also need support from stakeholders. Participants in this study who operated from the fourth order expressed at times they grew tired of having to fight the same battles with more traditional teachers to implement reform-based and NOS teaching practices. Another sentiment was they felt like their rationales were not understood. Findings from this study indicate without support from “like minded” individuals these teachers may leave the teaching profession because of the constraints they experience. Stakeholders must be available for these teachers despite their
self directedness. This is crucial on two points. First, these teachers who are self directed and implement reform-based and NOS teaching practices may not tolerate their autonomous meaning making being violated by traditional institutions without support. Second, as evidenced in this study, these teachers provide a source of fourth order construction for the third to fourth order teachers they collaborate with.

**Further Study**

Recent literature has articulated the many synergetic factors involved in effective reform-based and NOS teaching practices (Craven & Penick, 2001; Clough, 2003; Backhus & Thompson, 2006; Clough, 2006; Clough et al., 2009) The first intention of this study was to take a naturalistic inquiry qualitative approach to identify factors associated with teachers’ implementation levels of the NOS. The second intention of this study was to propose a variable model (Figure 3) that illustrates how these factors may be linked together. With respect to these factors the following areas should be investigated:

1. More studies are warranted on how the factors proposed in Figure 3 are sequenced, interconnected, and interactive. These studies should range from those that take qualitative approaches such as this one to those that operate from advanced quantitative designs. Of particular interest is the reaffirmation of the order in which these variables in Figure 3 are presented. Through large scale quantitative studies that perform hierarchical analysis, an order of prediction of the variables can be determined (Tabachnick & Fidell, 2007). For instance, explicit/reflective NOS implementation may first be predicted with teachers’
abilities to implement reform-based practice as a whole which are preceded by their ability cope with teaching constraints. Then it may beneficial to determine if the level of support teachers are getting contributes to the predictability of their levels of NOS implementation over and above the way teachers cope with teaching constraints. After these variables are accounted for it may be determined if the degree of responsibility possessed by teachers adds to the predictability of NOS implementation. Suppose the order of consciousness teachers operate from does not add to the predictability of NOS implementation. This variable would be dropped from the model. Eventually through hierarchical multiple regression the variables presented in Figure 3 can be reduced to only those that contribute to the predictability of levels of NOS implementation. By understanding what factors hierarchically predict NOS implementation more informed recommendations can be made for preservice programs and professional development to increase effective NOS teaching.

2. To what extent does variance between preservice programs contribute to variance in teachers’ implementation levels of the NOS? Windschitl (2005, p. 525) states “serious questions have emerged over the past few years about whether the research communities that study teacher development have generated a reliable evidentiary base about the influence of preparation programs on the eventual practice of their graduates and the learning of their students.” This study focused exclusively on teachers from the ISU-STEP. As indicated before, this program affords more opportunities than other science teacher preparation programs to
learn reform-based and NOS teaching practices. The ultimate question is: Does this matter?

3. To what extent do characteristics preservice teachers bring with them to their preservice programs affect their NOS and reform-based instruction? Windschitl (2005) stated more needs to be known about the characteristics preservice teachers enter their programs with. Two potential variables (dissatisfaction and pre-preservice responsibility) are presented in Figure 3 and warrant further study. Although these variables were not the focus of this study several of the high and medium NOS implementers insinuated through statements these factors were associated with the way they taught.

4. To what extent can responsibility be taught to preservice teachers? In this study two types of responsibility were evident-intrinsic and extrinsic. Extrinsic responsibility motivating their reform-based and NOS teaching practices took the form of accountability to the ISU-STEP and their support networks and was manifested through feelings of guilt, embarrassment, and/or competition. Intrinsic responsibility was expressed as an internal source of accountability originating from the teacher to implement reform-based and NOS teaching practices. The ISU-STEP often teaches the moral epicenter of effective instruction. Of particular usefulness to teacher educators would be to know how possible it is to teach accountability and responsibility to implement reform-based and NOS teaching practices.
5. To what extent can preservice teachers’ self directedness be improved? Given most teachers leave preservice programs operating from third to fourth order their ability to frame and solve instructional decisions and problems often are at the mercy of the school they work in. Kegan (1994) explains the shift to increased self direction has nothing to do with self confidence or taking on new skills. Instead, teacher educators must ask their students to “change the whole way they understand themselves, their world, and the relation between the two” (Kegan 1994, p. 275). Kegan (1994, p. 275) points out what we are asking of students in this scenario is to objectively separate their “self” from the culture that which surrounds it—thus making them able to frame decisions independent of it. For new teachers to effectively teach from a reform-based ideology in institutions that subscribe from a traditional ideology it is imperative they are taught to be self directed.

6. To what extent does utility value for teaching the NOS change over time and how does that impact NOS implementation? Evidence from this study in respect to the association between utility value of teaching the NOS and NOS implementation was slightly discrepant with that stemming from the study conducted by Abd-El-Khalick et al. (1998). This study focused on inservice teachers whereas Abd-El-Khalick et al.’s (1998) study focused on preservice teacher with recent NOS instruction. Further research is needed to determine not only the role of utility value for teaching the NOS and how it impacts NOS implementation, but also how this utility value changes over time.
7. To what extent are preservice field experiences associated with teachers’ implementation of reform-based and NOS teaching? Windschitl (2005) claims the science education community needs to know how field experiences impact science teacher effectiveness. Anecdotal evidence derived from statements made by a few high and medium NOS implementers in this study indicated their preservice field experiences shaped their reform-based and NOS teaching practices.

8. To what extent does the Restructuring Science Activities course impact teachers’ NOS implementation? Three out of the four low NOS implementers did not take the Restructuring Science Activities course. Additionally, all medium and high NOS implementers completed this course. Furthermore, almost all individuals who took this course indicated it was the most beneficial courses taken as it helped them implement the NOS. Further research is needed to determine exactly what the impact of this course is on teachers’ NOS implementation practices.

9. Concern has been voiced about the use of questionnaires in educational studies. Reasons for this concern include their use can obscure important patterns and phenomena that may be more evident through employing qualitative methods (Lederman & O’Malley, 1990; Fraser, 2007). Several items on the VASSIST questionnaire in this study were problematic and not used (Table 4). Seemingly, this instrument did not allow the context surrounding why teachers were responding the way they were to become evident. Future studies may want
descriptive text, proctoring, or qualitative responses to accompany these sections of the VASSIST.

10. All teachers in this study faced teaching constraints to some degree over their teaching career. Additionally, the teachers had different ways of coping with these constraints. Because levels of constraints were indicated through self report in interviews, difficulties were encountered determining exactly how limiting constraints actually were to teachers’ NOS instructional practices. Future research should employ measures to determine constraints in a manner that are more objective and outside of participants’ perceptions.
REFERENCES


nature of science among junior high school students. *School Science and Mathematics, 81*, 221-226


APPENDIX A: INFORMED CONSENT DOCUMENTS

August 13, 2009

Dear [XXXXX],

My name is Ben Herman and I am a PhD. student at Iowa State University working with Dr. Michael Clough. We hope this greeting finds you well and that you have fond memories of the time you spent in the ISU Secondary Science Teacher Education Program (ISU-STEP).

Because you completed the ISU-STEP, we are inviting you to participate in a study we are conducting to determine the effectiveness of a portion of that program. Through more deeply understanding the impact of our program, we can develop recommendations for improving it and science teacher education programs beyond ISU’s.

If you agree to participate in this important study of our program, you may decide to take part in as many of the following as you wish:

- Complete a survey that will take approximately 30-45 minutes.
- Permit us to observe you teaching three science classes.
- Permit us to interview you between November 2009 and January 2010. The interview will take approximately 60 minutes. You could be asked to take part in a follow-up interview, but may choose not to do so.
- Provide us artifacts (e.g. course syllabus, lesson plans, assignments, exams, etc.) that would help us better understand the science education experience of your students.

This study is completely voluntary and you can elect to skip portions of the study or withdraw from any portion of the study at any time without penalty. Teachers who elect to participate in the study will, unfortunately, not be compensated for their time spent participating. However, future humankind may benefit from this study through the improvement of science teacher preparation programs.

There are no risks associated with this study. Pseudo names will be used so that participants and their schools cannot be identified. Questions, comments and any concerns with this study may be directed to Benjamin Herman, bcherman@iastate.edu, (515) 745-6697
Dr. Michael Clough, mclough@iastate.edu, (515) 294-1430

If you choose to participate in this study, please carefully read the enclosed informed consent form. If you decide to participate, please sign and return the consent form to me as soon as possible. Feel free to contact me or Dr. Clough with any questions you may have about the study. Thank you for your time and consideration!

Benjamin C. Herman, PhD. Student
September 09, 2009

To Whom It May Concern:

My name is Ben Herman and I am a PhD. student at Iowa State University working with Dr. Michael Clough. You are receiving this letter because XXXXX, a teacher in your district, has shown interest in participating in educational research that I am working on at Iowa State University. The goal of this research to determine the effectiveness of portions of the ISU Secondary Science Teacher Education Program (ISU-STEP) by looking at the practice of teachers who completed this program. Through more deeply understanding the impact of our program, we can develop recommendations for improving it and science teacher education programs beyond ISU’s.

If XXXXX agrees to participate in this important study of our program, XXXXX may decide to take part in as many of the following as XXXXX wishes:

- Complete a survey that will take approximately 30-45 minutes.
- Permit us to observe them teaching three science classes.
- Permit us to interview them between November 2009 and January 2010. The interview will take approximately 60 minutes. They could be asked to take part in a follow-up interview, but may choose not to do so.
- Provide us artifacts (e.g. course syllabus, lesson plans, assignments, exams, etc.) that would help us better understand the science education experience of their students.

This study is completely voluntary and XXXXX can elect to skip portions of the study or withdraw from any portion of the study at any time without penalty. Teachers who elect to participate in the study will, unfortunately, not be compensated for their time spent participating. However, future humankind may benefit from this study through the improvement of science teacher preparation programs.

There are no risks associated with this study. Pseudo names will be used so that participants and their schools cannot be identified. If your district approves with this teacher participating in this study, please sign the space provided below confirming your approval and return this letter to me in the self addressed stamped envelope provided. Questions, comments and any concerns with this study may be directed to Benjamin Herman, bcherman@iastate.edu, (515) 745-6697 or Dr. Michael Clough, mclough@iastate.edu, (515) 294-1430. Thank you for your time and consideration!

Benjamin C. Herman, PhD. Student

CONFIRMATION:
I have read the previous statements in this letter and give my consent for XXXXX to participate in the educational research Benjamin C. Herman is conducting with Iowa State University.

Signed:____________________  Printed:___________________  School:_______________
INFORMED CONSENT DOCUMENT

Title of Study: Investigating characteristics of, and factors affecting, the practice of secondary science teachers who completed the same pre-service teacher preparation program

Investigators: Benjamin C. Herman
Iowa State University, Department of Curriculum and Instruction.

This is a voluntary research study. Please take your time to decide if you would like to participate. Please feel free to contact me with questions or concerns at any time. My contact information is provided below.

INTRODUCTION

This research aims to determine how and why individuals who completed Iowa State Universities’ Science Teacher Education Program are similar and/or different in instructional practices. You are being selected because you completed your pre-service teaching experience at Iowa State University and you currently teach science.

DESCRIPTION OF PROCEDURES

To conduct this study, I am asking for your permission to conduct the following measurements on your practice:

1. Artifacts: Throughout the study, you will be asked to place artifacts from your teaching in an envelope as they are used in your teaching. Artifacts can include but are not limited to assignments, activities, handouts, book selections, lesson plans etc. I will collect these artifacts at the end of each week.

2. Observations: With your permission, I will observe classes three to five times throughout the duration of this study. The primary intent of observations is to provide a context to how artifacts are employed in your practice. During observations I will not be interacting with students, but will be taking field notes pertaining to activities they may be engaged in.

3. Questionnaire: During the final weeks of the study I will ask you to complete the Views on Science, Science Inquiry, and Science Teaching questionnaire (VASSIST). This instrument measures aspects such as your views about science and constraints you perceive that affect your teaching.

4. Interviews: During the final weeks of the study you will be asked to participate in 2-3 interviews. The purpose of these interviews is to discuss in depth with you aspects of your teaching as indicated by artifacts, observations, and questionnaire responses. In addition, you may be asked to provide feedback on how teacher preparation may have influenced your practice, or how it may be improved.
This study is completely voluntary and you can elect to withdraw from any portion of the study at any time without penalty. This includes skipping questions during interviews or questionnaire completion. In addition, measurements are completely anonymous, confidential and seen only by the participant and the primary researcher. Results from this study will also be anonymous with no traceability back to the originator of information.

RISKS

There are no anticipated risks associated with this study. Pseudonyms and identification numbers will be used so that participants and their schools cannot be identified.

BENEFITS

Teachers who participate in the study may directly benefit from this research. Teachers may show increases in teaching performance through their reflection process of their own teaching required in this research. In addition, teachers will be provided a summative reflection of their practice from the primary researcher if requested. Lastly, depending on the school district this may fulfill professional development requirements.

Future humankind may benefit from this study through the improvement of teaching, teacher education, and learning. If at any time you feel burdened or uncomfortable in this study, you may withdraw without risk or penalty.

COSTS AND COMPENSATION

No costs or compensation are associated with participation in this study.

PARTICIPANT RIGHTS

Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. If you decide to not participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which you or your child are otherwise entitled.

CONFIDENTIALITY

Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies, auditing departments of Iowa State University, and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis.
To ensure confidentiality to the extent permitted by law, the following measures will be taken:

Teachers will be assigned an identification number, and no one except the primary researcher will have access to any documents that identify the teacher by name. The audiotapes used in the study will be erased after transcription of the interview. All participant names on the questionnaires, writing reflections, and artifacts will be replaced with identification numbers once the documents are received. Because participants will be asked to participate in an interview after having completed the questionnaire, his or her responses will only be documented under the identification number of the questionnaire; the participant’s name will not be used. The surveys, transcripts, artifacts, and observation notes will be kept in a locked filed cabinet for seven years before they are destroyed. If the results are published, study participants’ school and individual identity will not be disclosed.

QUESTIONS OR PROBLEMS

You are encouraged to ask questions at any time during this study.

- For further information about the study contact Benjamin C. Herman at bcherman@iastate.edu or at (515) 745-6697
  Dr. Michael Clough at mclough@iastate.edu (515) 294-1430

- If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office of Research Assurances, Iowa State University, Ames, Iowa 50011.
PARTICIPANT SIGNATURE

Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study. If you decide to participate in the study, you may choose to withdraw from the study at anytime you wish.

Participant’s Name (printed) ____________________________________________

(Participant’s Signature) ________________________________________________  (Date)

(Signature of Parent/Guardian or Legally Authorized Representative)  (Date)

INVESTIGATOR STATEMENT

I certify that the participant has been given adequate time to read and learn about the study and all of their questions have been answered. It is my opinion that the participant understands the purpose, risks, benefits and the procedures that will be followed in this study and has voluntarily agreed to participate.

(Signature of Person Obtaining Informed Consent)  (Date)
APPENDIX B: CLASSROOM PRACTICE CODING TOOLS

(1) LSC Classroom Observation Protocol (COP)

I. Design

A. Ratings of Key Indicators

1. The design of the lesson incorporated tasks, roles, and interactions consistent with investigative mathematics/science
   
   Not at all  2  3  4  5  6  7

2. The design of the lesson reflected careful planning and organization
   
   Not at all  2  3  4  5  6  7

3. The instructional strategies and activities used in this lesson reflected attention to students' experience, preparedness, and/or learning styles.
   
   Not at all  2  3  4  5  6  7

4. The resources available in this lesson contributed to accomplishing the purposes of the instruction.
   
   Not at all  2  3  4  5  6  7

5. The instructional strategies and activities reflected attention to issues of access, equity, and diversity for students (e.g., cooperative learning, language appropriate strategies/materials).
   
   Not at all  2  3  4  5  6  7

6. The design of the lesson encouraged a collaborative approach to learning.
   
   Not at all  2  3  4  5  6  7

7. Adequate time and structure were provided for "sense-making."
   
   Not at all  2  3  4  5  6  7

8. Adequate time and structure were provided for wrap-up.
   
   Not at all  2  3  4  5  6  7

9. Formal assessments of students were consistent with investigative mathematics/science.
   
   Not at all  2  3  4  5  6  7

10. Design for future instruction takes into account what transpired in the lesson.
    
    Not at all  2  3  4  5  6  7

11. __________________________________
    
    Not at all  2  3  4  5  6  7

B. Synthesis Rating

1. Implementation of the lesson not at all reflective of best practice in mathematics/science education

2. 3. 4. 5.

   Implementation of the lesson not at all reflective of best practice in mathematics/science education

C. Supporting Evidence for Synthesis Rating
### II. Implementation

#### A. Ratings of Key Indicators

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1. The instruction was consistent with the underlying approach of the instructional materials designated for use by the LSC.

2. The instructional strategies were consistent with investigative mathematics/science.

3. The teacher appeared confident in his/her ability to teach mathematics/science.

4. The teacher's classroom management style/strategies enhanced the quality of the lesson.

5. The pace of the lesson was appropriate for the developmental levels/needs of the students and the purposes of the lesson.

6. The teacher was able to "read" the students' level of understanding and adjusted instruction accordingly.

7. The teacher's questioning strategies were likely to enhance the development of student conceptual understanding/problem solving (e.g., emphasized higher order questions, appropriately used "wait time," identified prior conceptions and misconceptions).

8. The lesson was modified as needed based on teacher questioning or other student assessments.

9. ______________________

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### B. Synthesis Rating

1. Implementation of the lesson not at all reflective of best practice in mathematics/science education

2. Implementation of the lesson not at all reflective of best practice in mathematics/science education

### C. Supporting Evidence for Synthesis Rating

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Don’t know</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all</td>
<td>To a great extent</td>
<td>Don’t know</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### III. Mathematics/Science Content

#### A. Ratings of Key Indicators

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>The mathematics/science content was significant and worthwhile</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>2.</td>
<td>The mathematics/science content was appropriate for the developmental levels of the students in this class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>3.</td>
<td>Students were intellectually engaged with important ideas relevant to the focus of the lesson.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>4.</td>
<td>Teacher-provided content information was accurate.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>5.</td>
<td>The teacher displayed an understanding of mathematics/science concepts (e.g., in his/her dialogue with students).</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>6.</td>
<td>Mathematics/science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation analysis, and/or proof/justification.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>7.</td>
<td>Elements of mathematical/science abstraction (e.g., symbolic representations, theory building) were included when it was important to do so.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>8.</td>
<td>Appropriate connections were made to other areas of mathematics/science, to other disciplines, and/or to real-world contexts.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>9.</td>
<td>The degree of &quot;sense-making&quot; of mathematics/science content within this lesson was appropriate for the developmental levels/needs of the students and the purposes of the lesson.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>10.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

#### B. Synthesis Rating

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Implementation of the lesson not at all reflective of best practice in mathematics/science education</td>
<td>Implementation of the lesson not at all reflective of best practice in mathematics/science education</td>
<td>2.</td>
<td>3.</td>
<td>4.</td>
<td>5.</td>
<td></td>
</tr>
</tbody>
</table>

#### C. Supporting Evidence for Synthesis Rating
IV. Classroom Culture

A. Ratings of Key Indicators

Not at all & To a great extent & Don’t know & N/A

1. Active participation of all was encouraged and valued. & 1 & 2 & 3 & 4 & 5 & 6 & 7
2. There was a climate of respect for students’ ideas, questions, and contributions & 1 & 2 & 3 & 4 & 5 & 6 & 7
3. Interactions reflected collegial working relationships among students (e.g., students worked together, talked with each other about the lesson). & 1 & 2 & 3 & 4 & 5 & 6 & 7
4. Interactions reflected collaborative working relationships between teacher and students. & 1 & 2 & 3 & 4 & 5 & 6 & 7
5. The climate of the lesson encouraged students to generate ideas, questions, conjectures, and/or propositions. & 1 & 2 & 3 & 4 & 5 & 6 & 7
6. Intellectual rigor, constructive criticism, and the challenging of ideas were evident. & 1 & 2 & 3 & 4 & 5 & 6 & 7

B. Synthesis Rating

1. Implementation of the lesson not at all reflective of best practice in mathematics/science education
2. 
3. 
4. Implementation of the lesson not at all reflective of best practice in mathematics/science education
5. 

C. Supporting Evidence for Synthesis Rating
A. Likely Impact of Instruction on Students' Understanding of Mathematics/Science

While the impact of a single lesson may well be limited in scope, it is important to judge whether the lesson is likely to help move students in the desired direction. For this series of ratings, consider all available information (i.e., your previous ratings of design, implementation, content, and classroom culture, and the pre- and post-observation interviews with the teacher) as you assess the likely impact of this lesson. Feel free to elaborate on ratings with comments in the space provided. Select the response that best describes your overall assessment of the likely effect of this lesson in each of the following areas.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Negative</th>
<th>Mixed/Neutral</th>
<th>Positive</th>
<th>D/K</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Students' understanding of mathematics/science as a dynamic body of knowledge generated and enriched by investigation.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. Students' understanding of important mathematics/science concepts.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3. Students' capacity to carry out their own inquiries.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. Students' ability to apply or generalize skills and concepts to other areas of mathematics/science, other disciplines, and/or real-life situations.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5. Students' self-confidence in doing mathematics/science.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. Students' interest in and/or appreciation for the discipline.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Comments:
B. Capsule Description of the Quality of the Lesson

In this final rating of the lesson, consider all available information about the lesson, its context and purpose, and your own judgment of the relative importance of the ratings you have made. Select the capsule description that best characterizes the lesson you observed. Keep in mind that this rating is not intended to be an average of all the previous ratings, but should encapsulate your overall assessment of the quality and likely impact of the lesson. Please provide a brief rationale for your final capsule description of the lesson in the space provided.

Level 1: Ineffective Instruction

There is little or no evidence of student thinking or engagement with important ideas of mathematics/science. Instruction is highly unlikely to enhance students' understanding of the discipline or to develop their capacity to successfully "do" mathematics/science. Lesson was characterized by either (select one below):

Passive "Learning"

Instruction is pedantic and uninspiring. Students are passive recipients of information from the teacher or textbook; material is presented in a way that is inaccessible to many of the students.

Activity for Activity's Sake

Students are involved in hands-on activities or other individual or group work, but it appears to be activity for activity's sake. Lesson lacks a clear sense of purpose and/or a clear link to conceptual development.

Level 2: Elements of Effective Instruction

Instruction contains some elements of effective practice, but there are serious problems in the design, implementation, content, and/or appropriateness for many students in the class. For example, the content may lack importance and/or appropriateness; instruction may not successfully address the difficulties that many students are experiencing, etc. Overall, the lesson is very limited in its likelihood to enhance students' understanding of the discipline or to develop their capacity to successfully "do" mathematics/science.

Level 3: Beginning Stages of Effective Instruction (Select one below.)

Low 3  Solid 3  High 3

Instruction is purposeful and characterized by quite a few elements of effective practice. Students are, at times, engaged in meaningful work, but there are weaknesses, ranging from substantial to fairly minor, in the design, implementation, or content of instruction. For example, the teacher may short-circuit a planned exploration by telling students what they "should have found"; instruction may not adequately address the needs of a number of students; or the classroom culture may limit the accessibility or effectiveness of the lesson. Overall, the lesson is somewhat limited in its likelihood to enhance students' understanding of the discipline or to develop their capacity to successfully "do" mathematics/science.
**Level 4: Accomplished, Effective Instruction**
Instruction is purposeful and engaging for most students. Students actively participate in meaningful work (e.g., investigations, teacher presentations, discussions with each other or the teacher, reading). The lesson is well-designed and the teacher implements it well, but adaptation of content or pedagogy in response to student needs and interests is limited. Instruction is *quite likely* to enhance most students' understanding of the discipline and to develop their capacity to successfully "do" mathematics/science.

**Level 5: Exemplary Instruction**
Instruction is purposeful and all students are highly engaged most or all of the time in meaningful work (e.g., investigation, teacher presentations, discussions with each other or the teacher, reading). The lesson is well-designed and artfully implemented, with flexibility and responsiveness to students' needs and interests. Instruction is *highly likely* to enhance most students' understanding of the discipline and to develop their capacity to successfully "do" mathematics/science.

Please provide your rationale for the rating:
(2) Nature of Science Classroom Observation and Artifact Protocol (NOS-COP)

Key indicators

<table>
<thead>
<tr>
<th>Not at All</th>
<th>To a Great Extent</th>
<th>Don’t Know</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Extent to which the lesson structure/artifacts has clear opportunities for accurately and explicitly addressing the NOS**

1. Science is taught through inquiry. 1 2 3 4 5 6 7

2. Historical/contemporary accurate examples of science and/or scientists are incorporated in the lesson. 1 2 3 4 5 6 7

3. Other (e.g.) 1 2 3 4 5 6 7

**Extent to which the instructor and/or lesson structure/artifacts explicitly and reflectively addressed the NOS**

4. NOS ideas addressed are accurate? 1 2 3 4 5 6 7

5. Students’ attention is explicitly and reflectively drawn to how classroom instructional practices reflect or distort the NOS. 1 2 3 4 5 6 7

6. Students’ attention is explicitly and reflectively drawn to the NOS in the context of science content being taught. 1 2 3 4 5 6 7

7. Students’ attention is explicitly and reflectively drawn to NOS ideas implicit in inquiry activities. 1 2 3 4 5 6 7

8. NOS ideas are explicitly and reflectively scaffolded back and forth along the decontextualized to contextualized NOS instructional continuum. 1 2 3 4 5 6 7

9. Students are required to reflect on explicitly identified NOS ideas in the lesson. 1 2 3 4 5 6 7

**Synthesis Rating:**

<table>
<thead>
<tr>
<th>Implementation of the NOS not at all reflective of best practices in science education</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation of the NOS extremely reflective of best practices in science education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX C: VIEWS ABOUT SCIENCE, SCIENTIFIC INQUIRY AND SCIENCE TEACHING (VASSIST)

Your answers are crucial in developing recommendations for teacher educators. Your honest personal view, not what you think we want to hear is of utmost importance. Your responses will only be seen by the primary researcher (Ben Herman) and your name will be immediately replaced with a number to ensure anonymity and confidentiality.

Please read EACH statement carefully, and then indicate the degree to which you agree or disagree with EACH statement by circling the appropriate choice to the right of each statement.

SD = Strongly Disagree
D = Disagree More Than Agree
U = Uncertain or Not Sure
A = Agree More Than Disagree
SA = Strongly Agree

1. Scientific Observations

<table>
<thead>
<tr>
<th></th>
<th>Scientific Observations of the same event may be different because the scientists’ prior knowledge may affect their observations.</th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Scientists’ observations of the same event will be the same because scientists are unbiased.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>C</td>
<td>Scientists’ observations of the same event will be the same because observations are facts.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>D</td>
<td>Scientists may make different interpretations based on the same observations.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
</tbody>
</table>

**With examples**, explain why you think scientists’ observations and interpretations are the same OR different.
2. Scientific Theories

<table>
<thead>
<tr>
<th></th>
<th>Scientific theories are subject to on-going testing and revision.</th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.</td>
<td>Scientific theories may be completely replaced by new theories in light of new evidence.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>C.</td>
<td>Scientific theories may be changed because scientists reinterpret existing observations.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>D.</td>
<td>Scientific theories based on accurate experimentation will not be changed.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
</tbody>
</table>

**With examples,** explain why you think scientific theories change OR do not change over time.

3. Scientific Laws Compared to Theories

<table>
<thead>
<tr>
<th></th>
<th>Scientific theories exist in the natural world and are uncovered through scientific investigations.</th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.</td>
<td>Unlike theories, scientific laws are not subject to change.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>C.</td>
<td>Scientific laws are theories that have been proven.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>D.</td>
<td>Scientific theories explain scientific laws.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
</tbody>
</table>

**Explain what scientific theories and laws are and how they are different,** and provide examples to illustrate your answer.
4. Social and Cultural Influences on Science

<table>
<thead>
<tr>
<th></th>
<th>Scientific research is not influenced by society and culture because scientists are trained to conduct pure, unbiased studies.</th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Cultural values and expectations influence what science is conducted and accepted.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>C</td>
<td>Cultural values and expectations influence how science is conducted and accepted.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>D</td>
<td>All cultures conduct scientific research the same way because science is universal and independent of society and culture.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
</tbody>
</table>

Explain how society and culture affect OR do not affect scientific research, and provide **examples to illustrate your answer.**

5. Imagination and Creativity in Scientific investigations

<table>
<thead>
<tr>
<th></th>
<th>Scientists use their imagination and creativity when they collect data.</th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Scientists use their imagination and creativity when they analyze and interpret data.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>C</td>
<td>Scientists do not use their imagination and creativity because these conflict with their logical reasoning.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>D</td>
<td>Scientists do not use their imagination and creativity because these can interfere with the need to be unbiased.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
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</tbody>
</table>

Explain why scientists use OR do not use imagination and creativity, and **provide examples to illustrate your answer.**
6. Methodology of Scientific Investigations

<p>| | | | | |</p>
<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Considering what scientists actually do, there really is no such thing as the scientific method.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
</tr>
<tr>
<td>B.</td>
<td>Scientists follow the same step-by-step scientific method.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
</tr>
<tr>
<td>C.</td>
<td>When scientists use the scientific method correctly, their results are true and accurate.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
</tr>
<tr>
<td>D.</td>
<td>Experiments are the only way scientists develop valid scientific knowledge when they investigating the natural world.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
</tr>
</tbody>
</table>

Explain whether scientists follow a single, universal scientific method OR use different types of methods, and **provide examples to illustrate your answer.**

7. Social Interaction among Scientific Researchers

<p>| | | | | |</p>
<table>
<thead>
<tr>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Scientists <strong>usually</strong> work collaboratively with other scientists when conducting research.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
</tr>
<tr>
<td>B.</td>
<td>Scientists <strong>usually</strong> work with other scientists, but only to share results.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
</tr>
<tr>
<td>C.</td>
<td>Scientists <strong>usually</strong> work alone when conducting research.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
</tr>
<tr>
<td>D.</td>
<td>Scientific knowledge usually emerges from discussions and social interactions among scientists.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
</tr>
</tbody>
</table>

Explain to what degree scientists work with other scientists when doing research, and **provide examples to illustrate your answer.**
8. Science and Religion

<p>| | | | | | |</p>
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<tr>
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</thead>
<tbody>
<tr>
<td>A.</td>
<td>Science and religion are usually in conflict with one another.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>B.</td>
<td>Supernatural explanations are not useful for helping scientists understand the natural world.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>C.</td>
<td>Science ideas that have religious implications usually set scientists who do believe in supernatural beings against those who do not believe in supernatural beings.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>D.</td>
<td>Scientists who will not use supernatural explanations when doing science can still believe in a supernatural being.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
</tbody>
</table>

Explain why supernatural explanations should OR should not be used in credible scientific ideas, and **provide examples to illustrate your answer.**

9. Development and Acceptance of Science Ideas

<p>| | | | | | |</p>
<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Credible scientific ideas are usually generated in a matter of days, weeks or months.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>B.</td>
<td>Scientific ideas usually come to be accepted by the scientific community in a matter of days, weeks or months.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>C.</td>
<td>Credible scientific ideas are usually generated over a period of years to decades.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>D.</td>
<td>Scientific ideas usually come to be accepted by the scientific community over a period of years to decades.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
</tbody>
</table>

Explain how much time is usually required for credible scientific ideas to be generated, and then accepted by the scientific community, and **provide examples to illustrate your answer.**
10. Discovery and Invention

**In responding to the four items below, assume that a gold miner "discovers" gold while an author "invents" a story.**

<table>
<thead>
<tr>
<th></th>
<th>Scientific theories (for example, atomic theory, plate-tectonic theory, gene theory) are discovered.</th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Scientific laws (for example, laws of planetary motion, gas laws, gravitational law, law of pendulum motion) are discovered.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>B</td>
<td>Scientific theories (for example, atomic theory, plate-tectonic theory, gene theory) are invented.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>C</td>
<td>Scientific laws (for example, laws of planetary motion, gas laws, gravitational law, law of pendulum motion) are invented.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
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Explain whether scientific laws and theories are invented OR discovered, and **provide examples to illustrate your answer.**
Your answers are crucial in developing recommendations for teacher educators. Your honest personal view, not what you think we want to hear is of utmost importance. Your responses will only be seen by the primary researcher (Ben Herman) and your name will be immediately replaced with a number to ensure anonymity and confidentiality.

Please read EACH statement carefully, and then indicate the degree to which you agree or disagree with EACH statement by circling the appropriate choice to the right of each statement.

SD = Strongly Disagree
D = Disagree More Than Agree
U = Uncertain or Not Sure
A = Agree More Than Disagree
SA = Strongly Agree

In responding to particular statements, the phrase “nature of science” refers to what science is, how it works, how scientists operate as a social group and how society itself both directs, and reacts to, scientific endeavors. The study of the nature of science includes investigating scientists, the scientific community, and the processes of science by asking questions such as:

1. What, if anything demarcates science from other human endeavors?
2. In what sense is scientific knowledge invented? In what sense is it discovered?
3. How does the notion of a scientific method distort how science actually works? How does it accurately portray aspects of how science works??
4. In what sense are scientific laws and theories different types of knowledge? In what sense are they related?
5. To what extent are scientists and scientific knowledge subjective? To what extent can they be objective?

11. Classroom management

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<tbody>
<tr>
<td>A.</td>
<td>Classroom management issues frequently interrupt my ability to explicitly teach about the nature of science.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
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<tr>
<td>B.</td>
<td>I feel comfortable in handling a range of classroom management or discipline situations while explicitly teaching about the nature of science.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
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<tbody>
<tr>
<td>C.</td>
<td>Explicitly teaching about the nature of science is not possible in my classroom because of classroom management concerns.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
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<tbody>
<tr>
<td>D.</td>
<td>Classroom management issues generally do not affect my ability to incorporate laboratory and non-laboratory activities that explicitly address the nature of science.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
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</table>
### 12. Task Structures

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Score</th>
<th>Recommend</th>
<th>Agree</th>
<th>Undecided</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>I teach a specific unit that explicitly addresses what science is and how it works.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>I explicitly address the nature of science throughout the school year.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>I have too little time to explicitly integrate nature of science instruction throughout the school year because of tasks unrelated to teaching (e.g. taking attendance, announcements, assemblies, etc.).</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Teaching science content is more important and consumes my time and effort. Therefore, I rarely find time to explicitly integrate nature of science instruction throughout the year.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>I precisely plan far in advance the science lessons I teach and will not deviate from this.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
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### 13. Evaluation Structures

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Score</th>
<th>Recommend</th>
<th>Agree</th>
<th>Undecided</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>I tend to assess students with short answer/multiple choice items.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Because of my concern for students’ performance on standardized science assessments, I spend less time explicitly teaching the nature of science than I would like.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>I explicitly emphasize nature of science instruction throughout the year because students who understand the way science works will better understand science content and perform better on science content assessments.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>The format and substance of student assessment in my class deviates from what I know is best for my students.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Many of my exams throughout the school year include items that explicitly address students’ understanding of the nature of science.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
<td>SA</td>
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14. Classroom Decision-Making

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<tbody>
<tr>
<td>A.</td>
<td>I rely on the science textbook we use to teach students about the nature of science.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>B.</td>
<td>I create highly interactive discussions to explicitly draw my students’ attention to accurate nature of science ideas.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>C.</td>
<td>When teaching science content, I tend to use a lot of stories about how science ideas were developed and came to be accepted.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>D.</td>
<td>I explicitly consider what activities, materials, and strategies will most effectively help students understand the nature of science.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>E.</td>
<td>My instructional decision-making is based primarily on what my colleagues say and do.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
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15. Collaboration 1

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<tbody>
<tr>
<td>A.</td>
<td>Much of what, when, and how I teach is governed by my department and/or collaboration teams.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>B.</td>
<td>Having the same content, instructional sequence, activities, tests, etc. in a science department is important for fairly comparing students’ progress.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>C.</td>
<td>When my ideas regarding effective science teaching deviate from my colleagues, I feel uncomfortable sharing my views.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>D.</td>
<td>I feel comfortable standing up to my colleagues when I disagree with their ideas about science teaching.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>E.</td>
<td>I will teach in a manner that I feel is most effective even if it goes against views expressed by my colleagues.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
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16. Collaboration 2

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<tbody>
<tr>
<td>A.</td>
<td>I feel that my teaching practices are supported by my school administration.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>B.</td>
<td>Most of the time I feel accountable for teaching in a manner consistent with what my school administration expects.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>C.</td>
<td>The outcome expectations of my school administration limit the way I teach science.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>D.</td>
<td>My principal trusts and supports my teaching decisions even when they differ from my colleagues.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>E.</td>
<td>If I disagreed with an instructional decision encouraged by my administration, I would feel compelled to do it anyway.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
</tbody>
</table>
17. Coping

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Score Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>In most cases, I prefer to do what my colleagues do rather than make waves.</td>
<td>SD D U A SA</td>
</tr>
<tr>
<td>B</td>
<td>To avoid controversy, I don’t talk to my colleagues about what I do in my classroom.</td>
<td>SD D U A SA</td>
</tr>
<tr>
<td>C</td>
<td>I don’t mind <em>appearing</em> to do what everyone else is doing in order to teach the way I think is best in my classroom.</td>
<td>SD D U A SA</td>
</tr>
<tr>
<td>D</td>
<td>I define my success by the extent to which I meet the expectations that others I respect have for me.</td>
<td>SD D U A SA</td>
</tr>
<tr>
<td>E</td>
<td>When questioned about a pedagogical decision I made, I would feel uncomfortable explaining the research that supports my decision.</td>
<td>SD D U A SA</td>
</tr>
</tbody>
</table>

18. Parents and Students

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Score Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>I tend to give more fact based assignments/activities because parents and/or students desire them.</td>
<td>SD D U A SA</td>
</tr>
<tr>
<td>B</td>
<td>I maintain my research-based teaching practices even if parents and/or students express displeasure with my teaching.</td>
<td>SD D U A SA</td>
</tr>
<tr>
<td>C</td>
<td>If students and/or parents react negatively to my explicit nature of science instruction, I will reduce the time I spend on it.</td>
<td>SD D U A SA</td>
</tr>
<tr>
<td>D</td>
<td>Although I am the professional science teacher, I still feel uncomfortable expressing my rationale to parents and/or students about my instruction.</td>
<td>SD D U A SA</td>
</tr>
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19. Outlook on Teaching

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Score Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>The effort required to effectively teach science in this school is not worth the stress and disappointments.</td>
<td>SD D U A SA</td>
</tr>
<tr>
<td>B</td>
<td>I am passionate about reaching science education goals beyond what is expected of me.</td>
<td>SD D U A SA</td>
</tr>
<tr>
<td>C</td>
<td>I feel like my job is already defined for me and I am just meeting someone else’s expectations.</td>
<td>SD D U A SA</td>
</tr>
<tr>
<td>D</td>
<td>I don’t seem to have as much enthusiasm now as I did when I began teaching.</td>
<td>SD D U A SA</td>
</tr>
<tr>
<td>E</td>
<td>Research-based teaching practices are too idealistic and unrealistic.</td>
<td>SD D U A SA</td>
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</table>
20. Collaboration with others from Iowa State University Science Teacher Education Program (ISU-STEP).

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<tbody>
<tr>
<td>A.</td>
<td>I often communicate about teaching science with ISU-STEP program graduates and/or science education faculty.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>B.</td>
<td>My current teaching practices have been significantly influenced by my collaborations with ISU-STEP graduates and/or science education faculty.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>C.</td>
<td>I see little utility in keeping in contact with ISU-STEP program graduates and/or science education faculty once I began teaching.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>D.</td>
<td>Once began teaching, I did not collaborate much with ISU-STEP program graduates and/or science education faculty about my teaching.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>E.</td>
<td>Collaborations with ISU-STEP graduates and/or science education faculty were crucial during my first year of teaching.</td>
<td>SD</td>
<td>D</td>
<td>U</td>
<td>A</td>
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Please provide any additional comments you feel are necessary in relation to the way you answered the previous items. This can include any ways you feel the ISU-STEP can be improved. Please make sure to put the number of the item next to the comments.
APPENDIX D: SEMI-STRUCTURED INTERVIEW QUESTIONS

1. Variables targeted: View on learning, general teaching self reflection and responsibility

- How do you know when learning is occurring in your classroom?
  - How do you know when your students understand?
  - How do you maximize student learning in your classroom?
  - How do you decide when to move on to a new topic in your classroom?
  - Why do you think this approach is important?

2. Variables targeted: self reflection, self efficacy, and responsibility

- What do you perceive are your strengths and weaknesses in your teaching practices?
  - What actions do you take to improve?

3. Variables targeted: General and NOS teaching self reflection, understanding of NOS teaching, motivation to teach the NOS (self efficacy, utility value), teaching constraints, and responsibility

- To what extent do you teach the nature of science?
  - What are your reasons for teaching (or not teaching) the NOS?
  - What are the pros and cons of teaching the NOS?
  - How did you come to value or not value NOS teaching the way you do?
  - What factors impact your NOS teaching and why?
  - To what extent are you proficient in teaching the NOS?
  - What specific NOS themes do you teach and why?
  - How do you implement what you learned in the ISU-SSTEP NOS course into your teaching?
  - To what extent do you explicitly or not explicitly draw your student’ attention to NOS ideas.

4. Variables targeted: Teaching constraints (i.e. classroom management, institutional constraints), coping strategies in response to teaching constraints, responsibility, orders of consciousness, self reflection of general teaching practices.

- How much freedom do you have to instruct the way you want to?
  - What do you feel are the greatest influences on your decision making as a teacher?
    - During the first year? Now?
  - What factors impact your instructional practices and how do they do it?
  - How do you determine what and how to teach?
  - To what extent are you expected to teach like your colleagues?
5. Variables targeted: Orders of consciousness, teaching constraints, coping strategies in response to teaching constraints, and responsibility

- What do you perceive have been the most significant specific conflicts you have faced in your teaching career?
  - How did this issue start?
  - What was your role in the issue?
  - How did you handle this issue?

6. Variables targeted: Use of support from ISU-STEP, orders of consciousness, and self reflection

- To what extent have you kept in contact with ISU-STEP graduates or faculty?
  - How has this influenced your practice?
  - How would your practice be different if you had or hadn’t kept in contact?
  - Why did you choose or not choose to stay in contact with these people?

7. Variables targeted: Perceptions of the ISU-STEP, responsibility

- Based on your experience, what recommendations do you have for the ISU-STEP as a whole?
  - What do you perceive was effective and ineffective about the program based on what you have found with your own teaching practice?
  - What did you perceive was or ineffective of the NOS component of the ISU-STEP program?
  - What else if anything do you want to tell me about these issues or ISU-STEP?
ACKNOWLEDGEMENTS

I feel very fortunate for the mentorship provided to me by my major professors Dr. Michael Clough and Dr. Joanne Olson. The time and dedication they provide to their students is amazing and well above what is required and expected. I want to thank them specifically for modeling that a higher purpose can be served through this profession. Their self-sacrifice for others provided a great motivator for me to complete this work so I can serve others in a similar fashion.

I give many thanks to Dr. Jim Colbert, Dr. Amy Froelich, and Dr. E.J. Bang for their expertise and time. I feel so fortunate to have been supported by such a kind and caring POS committee. I would also like to thank the thirteen teachers that possessed enough courage to allow me into their world. They are among the true heroes of society who ensure future generations may succeed.

My undying gratitude goes to God and my family. They played a crucial role in the development of the person I am today. I feel very fortunate to have the talents, humility, and determination to do this work. Specifically, I feel very blessed to have my family’s constant support in this and other endeavors. I will always remember the words of encouragement and the laughs we shared. I hope many more good memories and laughs await us in the future. I love you all.