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The Effect of Teachers' Epistemological Beliefs on Practice

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by

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DEDICATION

To my parents, Milton Sr. and Melba Huling, thank you for everything.

I must also include my cousins, Judy and Evans Mank for their support and inspiration.

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Abstract

Unfortunately, for the most part, teachers do not teach the Nature of Science (NOS). Even when teachers have adequate NOS knowledge, their knowledge still does not make its way into practice. While there are various reasons for this happening, this study has isolated other, more typical, constraints to teaching in order to look more closely at the influence of personal epistemological beliefs, understandings of NOS, and their effects on practice. In an effort to minimize typical constraints of time for the teaching of NOS, a sixth grade physical science course was chosen as a way to minimize this constraint. Within this course there was a School District- mandated schedule for the teaching of NOS. This curriculum map included details of what NOS topics to teach and when to teach them. In *Phase One* of the study, correlational relationships between these understandings of NOS and personal epistemological beliefs were investigated. A *Pearson Correlation Coefficient* of 0.62 was calculated based on 28 sixth grade science teachers. In *Phase Two* of the research, eleven participants were chosen for a more in-depth analysis. Through the use of triangulation of interview data, classroom observations, artifact collection and survey scores to ascertain the constraints for each individual, even though few constraints could be verified that would affect instruction, only three of eleven participants taught NOS. Personal epistemological beliefs play a role in the way instruction is approached in either a constructivist or non-constructivist manner.

Chapter One

Introduction

Scientific literacy is now recognized throughout the world as a means of increasing both the economic and industrial development of a nation, as well as carrying out that progress in a socially and environmentally sustainable way (Fensham, 2008). Fensham notes that to meet these demands requires both identification and training of individuals who will enter the professions of science and technology. These professionals will direct the economics of the nation, while improving the personal health of its citizens. Equally important is the need for non-scientists to become scientifically literate in order to become informed consumers of information that is rich in science and technology, in order to support a more sustainable vision of growth (2008). Simultaneously, this vision enjoys support from varying international organizations (e.g., UNESCO [United Nations Educational, Scientific and Cultural Organization] and ICASE (International Council of Associations for Science Education) and has not escaped notice from organizations closer to home (National Science Board, 2006; National Academy of Science, 2007). The National Science Board (2006) reports that a host of stakeholders, from business and industry policy-makers to government agencies, proclaim that to increase this Nation's opportunities in a global marketplace, efforts to increase educational opportunities for all students must occur. These calls to action resonate in an environment where K-12 education has been challenged with its inadequacies, including accusations such as college readiness.

Currently, thirty percent of students entering post-secondary institutions require remedial coursework (National Academy of Science, 2007). Moreover, comparisons of scientific literacy against other industrialized nations (National Center for Education Statistics, 2004; Organization for Economic Co-operation and Development, 2007) reveal American students have fallen short of the mark.

It has been 30 years since the publication of *Nation at Risk* (National Commission on Excellence, 1983) with the dire prognosis of American education and its calls for reform. There is evidence to suggest many of the reforms recommended in the *Nation at Risk* document have come to fruition, including the emphasis on more rigorous core courses (such as science), accountability, and by some measures the addition of more qualified teachers (United States Department of Education, 2008). When the question is posed, “Have we done enough to ensure every student becomes scientifically literate?” international assessments suggest that answer is “No.” Furthermore, despite prior warnings sounded in *A Nation at Risk* (National Commission on Excellence, 1983) and the adoption of reform protocols, scientific literacy is not keeping pace with demands of the 21st century. The urgency of these issues applies to this nation’s immediate science and technological development. These same issues globally affect the future of all nations (Fensham, 2008).

Within the U.S., recent reports suggest that though much progress has been made in scientific literacy, considerable work remains undone (National Center for Education Statistics, 2004; Organization for Economic Co-operation and Development, 2009). According to the Programme for International Student Assessment,(PISA) which compared 15 year-olds on their math, reading and science skills in 34 of the world’s industrialized countries, U.S. students did not fare well (OECD, 2009). As a caveat, it should be noted that “scientific literacy” is a term often used in science education, but one that lacks a clear definition. At present, the science education landscape is a competition between two broad “visions” of scientific literacy (Roberts, 2007). The Organization for Economic Co-operation and Development (2009) defines scientific literacy as “an overarching competency comprising a set of three specific scientific competencies. A competency is more than just knowledge and skills (OECD, 2003) which includes the capacity to mobilize cognitive and non-cognitive resources in any given context (p. 126).” The PISA assessment, despite claims to the contrary, measures only the more de-contextualized concept of science, favoring facts and processes (Vision I) and measuring only Scientific Literacy within a narrow definition (Sadler and Zeidler, 2009). In contrast to Vision I, Vision II (Roberts 2007) embraces a more functional view of science, where students are exposed to contextualized socioscientific issues (SSI).

Administrators of the 2009 PISA announced the test would be designed to go beyond simple recall of scientific knowledge. Instead, the new test design would measure students’ ability to identify scientific issues, to explain phenomena scientifically, and to use scientific evidence in real life situations (OECD, 2007). Sadler and Zeidler (2009) criticized test items used in PISA as typical decontextualized (Vision I type) questions within an unnecessary background story. In contrast, Vision II favors a more contextualized vision of science that promotes personal decision-making. Through Vision II, science instruction moves away from the notion of decontextualized facts and processes students ought to know (being able to do science) toward one that embraces “real life” situations (being able to use science), where traditional boundaries of science become blurred within other social considerations (Sadler & Zeidler, 2009). This embedded nature of science, within a contextualized setting, establishes *relevance* for the learner and acts as a “watchword” for Vision II (Roberts, 2011).

First proposed by Zeidler (1984) and Zeidler & Schafer, (1984), a growing global cadre of science educators has expressed interest in expanding the definition of scientific literacy to include the moral and ethical aspects of science as a societal endeavor (Zeidler & Keefer, 2003; Zeidler, Sadler, Simmons, & Howes, 2005; Zeidler & Sadler, 2008). It has been argued (Zeidler & Sadler, 2008; Zeidler et al., 2005) that any vision of scientific literacy must consider morality and ethics. The study of socioscientific issues (SSI) elevates character development within the scientific literacy framework. In doing so, it provides opportunities for students to engage in discourse to consider moral, environmental and political aspects of science and their impact on society. SSI is mentioned here not just to provide a discussion of scientific literacy beyond what most consider Vision II, but also as part of the larger discussion about providing best practices for students. By providing these experiences, students are challenged by opportunities to develop their own knowledge using socioscientific reasoning (Zeidler & Sadler, 2011).

As debates are taking place in science education about how school science needs to look, PISA (OECD, 2009) (its limited SL scope notwithstanding), does provide one measure of students' achievement that should not be ignored, especially considering the current environment of accountability. On the three measures (reading, mathematics and science), American 15 year-old students placed in the middle half to lower third of the group. According to the 2009 results of PISA for scientific literacy, the United States ranked 17th (behind Poland, Belgium, Ireland, and Hungary) and only slightly above the mean. Miller's (2007) research on adults over the past 20 years has also yielded disparaging reports about scientific literacy. As of 2005, the highest level of scientific literacy, globally, was found in Sweden (35%), with the U.S. placing second with a scientific literacy rate of 28%. To place second provides little solace given the majority of U.S. citizens remain scientifically illiterate, despite two decades of gains. From 1988 to 2005, scientific literacy among adults in the U.S has increased from 10% to 28%, according to Miller (2007). Using a set of core knowledge and process questions, Miller and his colleagues tested adults in 27 European Union nations plus the United States, Canada, China, Japan, Korea, India, and New Zealand. The differences between scientific literacy levels of secondary students and adult respondents are credited to the American university system, which requires one year of science for all students, regardless of major (Hobson, 2008). While these increases are encouraging for those adults who matriculate through college coursework, they could hardly be considered a satisfactory level for living in a technological society (Hazen, 2002) and frankly reflect the urgency about scientific literacy felt by the science education community, both nationally and internationally.

For over twenty years, scientific literacy has continued to be a mainstay of global reform documents (AAAS, 1989, 1993, 1997, 2009; Achieve, Inc., 2013; McComas & Olson, 1998; Ministry of Education of the People's Republic of China, 2001; Zeidler & Sadler, 2011; NRC, 1996; NSTA, 2000; Turkish Ministry of National Education, 2005) and international assessments (National Center for Education Statistics, 2004; Organization for Economic Co-operation and Development, 2007). Scientific literacy is now viewed as an important outcome in science education and is enjoying worldwide caché (McEneaney, 2003) despite its definitional challenges.

During the last half century, much research has focused on learning about the nature of science (NOS), which distinguishes scientific knowledge from other knowledge and is a key component of scientific literacy (Lederman, N., & Lederman, J., 2004). This research, too, has provided an unsuitable outlook for education in terms of what students are expected to know and do in science classes.

Just as assessments on the broader scope of scientific literacy have provided a disparaging outlook, decades of research have also shown that neither teachers nor students are capable of expressing adequate understandings of NOS (Abd-El-Khalik & Lederman, 2000a; Duschl, 1990; Lederman, 1992, 2007; Schwartz & Lederman, 2002).

As research suggests (Abd-El-Khalik & Lederman, 1998), NOS is best learned through an explicit reflective approach. Through a set of subsequent research studies (e.g., Abd-El-Khalik, 2001, 2005; Abd-El-Khalik & Lederman, 2000b; Akerson, Abd-El-Khalik, & Lederman, 2000; Bell, Matkins, & Gansneder, 2011; Khishfe & Abd-El-Khalik, 2002) have demonstrated the greater effectiveness of these methods over previously attempted methods and make the point that explicit does not mean didactic, rather the intended understandings are planned for, as opposed to hope for as an artifact of instruction. Opportunities to reflect must be given to students so they may construct their own knowledge within a setting of student-centered activities, but the complexion of such activities, whether contextual or decontextualized, has become a topic of discussion amongst the science education community.

There has been recent criticism of methods of teaching NOS as a set of de-contextualized tenets used in previous research on explicit-reflective instruction (Allchin, 2011; Brickhouse, Dagher, Letts, & Shipman, 2000; Johnston & Southerland, 2002; Olson & Clough, 2001; Ryder, Leach, & Driver, 1999; Smith & Scharmann, 1999). A host of researchers (e.g., Brown, Collins, & Duguid, 1989; Metz, 1998; Roth, 1995; Wells, 1999) question the ability of students to recognize NOS concepts taught out of context, as an integral component of science and scientific issues. Clough (2003) has expressed concern that instructional attempts at teaching NOS without contextualization have contributed to the minimal effectiveness of explicit-reflective instructions.

More recent research suggests explicit-reflective instruction as a best practice regardless of the contextualized or decontextualized nature of NOS instruction (Bell, et al., 2011).

Clough (2003) maintains that employing explicit-reflective practices is only part of the necessary components to effective NOS instruction. From a review of research into how people learn, he promotes the case that beyond a contextualized setting, NOS requires “extensive scaffolding between a variety of NOS instructional contexts and [that] pedagogical strategies are important to promote a deep understanding of the NOS” (Herman, Olson & Clough, 2011, p.2). Explicit-reflective practice, whether as a threshold to best practice or as a practical method on its own, may remain at present, unresolved. More important is that, despite consensus within the science education community of effective practices of NOS instruction within the typical K-12 classroom, NOS instruction remains either absent or rarely and effectively addressed (Abd-El-Khalik, Bell, & Lederman, 1998; Clough, 2006; Lakin & Wellington, 1994; Lederman, 2007).

Though scientific literacy as a goal of reform has been embraced by national and international reform movements, desired classroom practices expected as a result of these reforms have met challenges. Along with the mandate for scientific literacy, teacher practice has been a popular topic of science education reform that favors a constructivist approach (Karakas, 2007), such as explicit-reflective instructional methods and scaffolding between NOS contexts. It is unfortunate that a schism now separates the educational theory of these student-centered reforms from the everyday practice of science teachers (e.g., Lederman, 2007; Tsai, 2002; Windschitl 2002). What is envisioned in science education reform expressed by what students are expected to do will require substantive change in the practice of science education from the way it is currently taught in K-12 classrooms (NRC, 1996). As an example of the importance of NOS, the *Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core*

Ideas (NRC, 2012) has included this statement: "…there is a strong consensus about characteristics of the scientific enterprise that should be understood by an educated citizen" (NRC, 2012, page 78). To acquire the experience necessary to carry out such a task requires students to practice with scientific issues. The skills required are not those that could be easily transferred from teacher to student. In fact, these are the same skills necessary to prepare students to become citizens in a world that will place ever-increasing demands on their abilities to think logically and critically about a myriad of scientific issues.

It is unfortunate that recent comparisons of scientific literacy in the US to other industrialized nations have not cast a favorable light upon this nation or its science education community. Thinking globally about science education and given the new requirements for the workplace in the 21st Century that can best be described as a *Knowledge Society* (Gilbert, 2005), scientific literacy education in all developed nations needs to be re-examined (Aikenhead, Orpwood, & Fensham, 2011). While a plethora of calls exist for the production of more mathematicians, scientists, and engineers in order to improve **our** economic outlook, this is only a part of a much larger global science education issue. As science and technology invade every aspect of life within the industrialized world, no one will escape the need to become scientifically literate and the science education community should promote worldwide scientific literacy (Bybee, 2008; Yore, Pimm, & Tuan, 2007).

The problematic nature of classroom practice is a serious matter for science education in its attempts to increase scientific literacy. The remainder of this chapter is aimed at defining scientific literacy, its association with NOS, and the psychological impediments to effective pedagogical practice that reside in personal epistemological beliefs.

Scientific Literacy

Despite being heralded as a world-wide educational outcome, scientific literacy lacks definitional consensus (McEneaney, 2003). Scientific literacy is fraught with multiple and sometimes contradictory meanings (Pearson, Moje & Greenleaf, 2010) reflective of its complex nature. Bybee, Fensham and Laurie (2009) note how deceptively simple scientific literacy may sound, masking its true complexity. As stated by Abd-El-Khalik and Akerson (2004), the development of coherent themes for science education reform, such as scientific literacy based upon previous reform frameworks (AAAS, 1989, NRC, 1996), can serve as an important general guide for student achievement; these reform documents nevertheless distort the vision that scientific literacy has a uniform definition. Roberts (2011) adds that despite the worldwide caché of scientific literacy, close scrutiny of policy documents and assessments programs do not promote a uniform vision. Differences exist between two philosophical camps which view scientific literacy as either the science itself (to include the products and processes of science) or as the manner in which science interacts with society (the relevance of science to society) (Miller, 2007; National Science Board, 2006; Roberts, 2011).

Zeidler and Sadler (2011) have proposed that Vision II of scientific literacy encompasses most socioscientific issues, though they argue that SSI may surpass the boundaries of Vision II framed by Roberts (2007), yet could be included in a more comprehensive view of Vision II. SSI seeks to provide students with instruction that includes real world and relevant issues to promote the decision-making process. It is the use of relevant issues that allows students to interact with issues that involve societal and scientific issues and could fall under a comprehensive Vision II framework for scientific literacy. In contrast, some aspects of SSI exceed the current Vision II framework. Zeidler and Sadler (2011) suggest any vision of scientific literacy is incomplete unless it includes moral and ethical considerations included within SSI. It is recommended (Zeidler & Sadler, 2011) that in order to move toward a more progressive view of scientific literacy, students will need to practice within a range of social, and ethical dimensions in order to make informed decisions (e.g. social justice, tolerance for dissenting voice, mutual respect for cultural differences, and making evidenced-driven decisions) and ask that Vision II become more inclusive to encompass SSI.

Miller (2007) argues that if a person can read an article that involves holes in the ozone layer of the atmosphere (Ozone Holes) or genetic engineering as easily as the sports or leisure page in the New York *Times*, then one could consider himself scientifically literate. In other words, a person knows enough to live in a society steeped in science and its related technology, but not enough to understand the jargon used by scientists and engineers in professional journals. These views are contrasted by those who believe that to be scientifically literate one must be exposed to and understand the mathematical rigors or grasp the complex and specific vocabulary (Hazen, 2002). Most students entering school will not become mathematicians, scientists, or engineers; nevertheless they will enter into a world that will demand an understanding of, and an ability to use, scientific information.

Despite the historical and ongoing definitional challenges of scientific literacy, what is needed to achieve either vision (Vision I or II) in terms of pedagogical practices enjoys a more or less universal vision. At present, the favored theoretical framework for science teaching within the science education community is rooted in constructivism (Abd-El-Khlaik & Akerson, 2009) as it mirrors the current consensus of what is known about the acquisition of human knowledge (Yang, Chang, & Hsu, 2008). Within a constructivist classroom, the practice of teaching should include hands-on and minds-on interactions that require critical and creative thought processes to solve problems. Instruction should **not** be founded upon memorization from textbooks or acquisition of a set of facts and vocabulary that is later tested using multiple choice assessments (NRC, 1996). Despite the calls to reform teacher practice, research has noted that many science classes are taught as reading classes (Britner, 2008), rather than using methods that support positive attitudes about science learning, such as those recognized as student-centered, hands-on (Anderson, 2007) including issues-oriented instruction (McComas & Moore, 1997). Most definite is the need to increase scientific literacy amongst the nation's students, but what hinders these attempts may be the teachers themselves. Teachers may not be prepared, either by District professional development or by schools of education, with the knowledge and skills to affect the change required by reform movements to increase the level of student's scientific literacy in ways that reflect a more progressive vision.

Within both Vision I and Vision II for scientific literacy, common ground exists and it is what is included in the reform documents that govern the direction of science education in the U.S. Scientific literacy is defined in the *National Science Education Standards* as the ability for students to make informed decisions dealing with science and scientific issues with a lesser emphasis on science as a collection of facts (NRC, 1996). Other, more recent reforms have also been introduced for English Language Arts that have ramifications for a literacy component specific to science (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010).

The Common Core State Standards Initiative (CCSSI), spurred on by National Governors Association Center for Best Practices and Council of Chief State School Officers (2010), has developed new sets of standards for English Language Arts and Mathematics. The goal of this initiative was to develop clear and concise standards that were relevant to real-world application.

Currently, 45 states have adopted the *Common Core State Standards* to include, *The Grades 6-12 Literacy in History/Social Studies, Science, and Technical Subjects* (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). For example, the following are excerpts of the *Common Core Literacy Standards* for grades 6-8 science:

- CCSS.ELA-Literacy.RST.6-8.8 Distinguish among facts, reasoned judgment based on research findings, and speculation in a text;
- CCSS.ELA-Literacy.RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

While designed to be specific to literacy, the goals of decision-making are similar to the standards for science previously mentioned (NRC, 1996) with regard to stressing decision-making requirements for student outcomes. These same constructs are also aligned with the recently released *Next Generation Science Standards* (Achieve, Inc., 2013). While these new science standards have been released in their final form, they have not yet been adopted by most states and no tests have been developed to align to them. For now, states continue to rely on the older *National Education Science Standards* (NRC, 1996) to base their curriculum. It is for this reason; discussion about science standards will be limited to the older standards.

To become scientifically literate requires that students learn the skills (processes and methods) of science (conducting observations, inferences, and conducting experiments), but this objective is only part of the picture. Individuals often conflate the process and methods of science with the knowledge construction component of science (Khishfe & Abd-El-Khalik, 2002).

Nature of Science

Over the past century, the nature of science has been a subject of much debate by philosophers, historians, science educators and sociologists. Giere (1988) points out that with the benefit of hindsight, the past century can be divided in two between positivism and constructivism with its center focused on Kuhn's (1962) *Structure of Scientific Revolution*. Since 1962, the nature of science and its importance to the science education community have undergone an abundance of debate and research.

The nature of science (NOS) can be thought of in a variety of ways: 1) the values and beliefs inherent to the individual's development of scientific knowledge (Lederman & Zeidler, 1987); 2) the epistemology of science, and 3) science as a way of knowing (Lederman, 1992). These differing definitions showcase "the multifaceted and complex nature of the human endeavor we call science" (Akerson et al., 2000, p.298). Simply put, NOS describes the characteristics of science, without which, science could not be distinguished clearly from many other disciplines that share some, but not all, of its characteristics. While the previous description of core attributes of science provides a partial and simplistic view, there are other attributes that require a greater depth of knowledge about science and that are still undergoing debate concerning the definitional properties of science. Just as scientific knowledge has changed through time, the concept of NOS has also changed throughout the past decades illustrating its own tentative and dynamic nature. These changes are reflective of the systematic thinking about the very nature and workings of NOS (Abd-El-Khalik, et al., 1998).

The latter half of the 20^{th} Century, thanks to Kuhn's (1962) influence, has been rich with debate about the philosophical nature of science. Though debates still exist, these debates remain mostly at the margins and outside the domain of school science. At present, there is a general consensus about its definition as it applies to science education. The current view of the nature of science can be thought of as how the scientific community passes judgment over what is accepted and what is not, or how much faith the community places on scientific knowledge (Marks & Eiks, 2009). To date, significant reform movements such as the *National Science Education Standards* (NRC, 1996), the *Benchmarks for Scientific Literacy: Project 2061* (AAAS, 2009), NSTA position statement: *Nature of Science* (2000), the newly-released *Next Generation Science Standards* (Achieve, Inc., 2013), plus the recent *Perth Declaration* (ICASE, 2007), emphasize the importance of the nature of science (NOS) as a key component to scientific literacy.

A benefit put forth for having an adequate understanding of NOS is that it enables the student (or citizen) to develop a better understanding of science content and provides him with the skills necessary to become a more informed decision-maker and better consumer of scientific information (McComas, Clough, Alamazroa, 1998). To help portray the importance of NOS on a global scale, this trend for increasing student understandings of NOS (as a part of scientific literacy) is not just limited to the United States (AAAS, 1990, 1993, 2009; Achieve, Inc. 2013; NRC, 1996; NSTA 2000), but has pervaded reform movements globally, from Europe to Asia (Matthews, 2009).

Though philosophers, historians, science educators, and sociologists still debate NOS these disagreements, for the most part, play a miniscule role in of NOS studied within the K-16 domain and remain largely at the margins. Most recently, there have been calls for a more inclusive form of NOS called "Whole Science," promoted by the noted philosopher Douglas Allchin (2011). These claims criticize the separation of NOS from its episodic event. While these criticisms have provided for lively debate within recent professional journals (Allchin, 2011, 2012; Schwartz, Lederman & Abd-El- Khalik, 2012), in terms of NOS within global reform movements, these discussions remain outside the scope of K-12 science. At present, a set of characteristics serve as a basis for most recent descriptions of NOS relevant to educational reform movements (Akerson et al., 2000); these include suggestions that scientific knowledge is:

- tentative (subject to change);
- empirically based (based on and/or derived from observations of the natural world);
- subjective (theory-laden);
- partly the product of human inference, imagination, and creativity (involves the invention of explanation);
- socially and culturally embedded;
- distinguishing between observations and inferences;
- promoting functions of and relationships between scientific theories and laws.

Despite the emphasis on NOS and its relevance within reform movements and the science education community, success toward student understanding of NOS has been largely absent. Research has consistently shown that student's comprehension of NOS is not on a par with the contemporary vision of the science education community (Duschl, 1990; Lederman, 1992, 2007). In addition, students see the value in learning about science as a process with an understanding of NOS (Adams & Chiappetta, 1998; Freedman, 2002; Gibson & Chase, 2002; Ryder et al., 1999; Siegel & Ranney, 2003; Tomanek & Cummings, 2000; Wenner, 1993).

Unfortunately, what students need and desire may not be what they get in the classroom. This discouraging, but perhaps expected revelation about student's NOS understandings comes as research reveals a shortfall with teacher's understandings about NOS (Abd-El-Khalik , 2005; Abd-El-Khalik , 2000; Akerson, Morrison, & McDuffie, 2006; Tsai, 2002).

Teaching the Nature of Science

For certain, teacher knowledge and specific pedagogy to teach NOS play an important role in a student's scientific literacy and research reveals that teachers are limited by their knowledge of NOS (e.g., Abd-El-Khalik , 2005; Abd-El-Khalik , 2000; Abd-El-Khalik & BouJaoude 1997; Carey & Strauss 1970; Pomeroy 1993). Colleges of Education typically require one methods course that would include as a part, NOS. Perhaps of little surprise, teachers have had little experience learning either what is NOS or the importance of NOS or learning to develop the skills necessary to teach NOS. It is now realized that more than one science methods course is needed (Roehrig & Luft, 2006). Teachers cannot be expected to teach what they themselves do not understand, but even when they do have adequate knowledge of NOS, challenges remain. The assumption that knowledge of NOS would translate into practice based on their general pedagogical skills has been shown to be fallacious (Abd-El-Khalik et al., 1998; Bell, Lederman, & Abd-El- Khalik, 2000; Lederman, 1992), or, that what they say about the NOS on surveys may not be reflected in their teaching practice (Brickhouse, 1990; Hodson, 1993; Taylor & Dana, 2003). Lederman (2007), in an extensive review of NOS research from the past 50 years, noted that students' and teachers' understandings of NOS have remained stagnant. Perhaps because of lack of exposure within methods courses, teachers' do not regard NOS equal to or certainly more important than traditional science content. Furthermore, even if teachers have adequate understandings of NOS, there is still no guarantee of its translation into practice. If teacher knowledge and skills were the only cause, the solution would be simple, but this issue seems to be an ongoing struggle for science education suggestive of a deeper rooted source.

According to Abd-El-Khalik & Akerson (2004), teachers must possess sufficient knowledge of NOS, they must possess the pedagogy to teach NOS, and they *must* value NOS as important, if not more so, than “traditional” subject matter. In other words, teachers must acquire the knowledge and skills, as well as be willing to change the day-to-day practice within their classroom. They must emphasize not just the subject matter itself, but also how scientific knowledge is constructed, but these changes can come with much resistance (Yang et al., 2008). Research has demonstrated (Tsai, 2002, 2007; Yang et al., 2008) that a teacher’s beliefs about how knowledge is constructed (e.g., their *epistemological beliefs*), are at odds with constructivist student-centered teaching practices. These epistemological beliefs are often more linked to the types of classroom instructional strategies than knowledge of content (Olafson & Shraw, 2010). Epistemological beliefs have also been linked to NOS retention (Akerson et al. 2006) and relationships of views held by teachers about NOS (Akerson, Buzzelli, Donnelly, 2008). Akerson, Buzzelli, & Donnelly (2010) suggest the need to continue this line of research between the potential relationship of epistemological beliefs and NOS instruction. Thus far, research into epistemological beliefs has focused on those beliefs associated with the knowledge and knowledge construction of science rather than the broader, more general view.

The main objective of this research is to investigate the relationship between the two epistemological beliefs, as they are associated with science, as well as with teachers’ more personal epistemological beliefs about general knowledge and knowledge construction. Perhaps the possible dynamic between the two realms of epistemological beliefs, the nature of science

(NOS) and broader epistemological beliefs and how these beliefs interact with other common barriers to instruction will shape this study. Though strong arguments exist for students to gain adequate understandings of NOS (Bell & Lederman, 2003), it may be first necessary to understand the role of the teacher's broader and more personal beliefs about knowledge and knowledge construction. It may be this knowledge that helps the scientific community make progress towards the goal of scientific literacy of students. Just as NOS can be defined as the epistemology of science, a broader scope of beliefs about knowledge and knowledge construction exist called "personal epistemological beliefs."

Personal Epistemological Beliefs

Personal epistemology can be thought of as one's own beliefs about the certainty, simplicity, and sources of knowledge, as well as the justification for knowing (Hofer, 2002). Personal epistemology is a seemingly related construct to NOS as they both involve the characteristics of knowledge and knowledge construction (Abd-El-Khalik, 2003). Most researchers now agree that personal epistemologies develop over time in a constructivist manner and that beliefs about learning may be a precursor to one's own beliefs about knowledge. Feucht and Bendixen (2010) describe more than four decades of historical development of the field that have brought a variety of frameworks. These frameworks designate personal epistemology as a cognitive developmental journey, "driven by a process of cognitive disequilibrium" (p. 5). If the goal for scientific literacy includes students' understanding of how scientific knowledge is constructed, and the science education community is interested in the situational learning opportunities of students, then a look at the broader field of personal epistemological beliefs would seem prudent.

The progressive development of personal epistemologies has been supported by evidence that suggests an evolving trend from young to older student in the development of beliefs about learning to beliefs of the nature of knowledge (Bendixen & Rule, 2004; Jehng, Johnson, & Anderson, 1993; Schommer, 1990; Schommer-Aikins, Mau, Brookhart, & Hutter, 2000). Both the original work of Perry (1970) and later work by King and Kitchener (1994) with their *Reflective Judgment Model* are categorized as late-onset developmental models that coincide with higher education (Chandler, Hawlett & Sokol, 2002). Both researchers suggest a link between epistemological development and critical thinking skills associated with the increased expectations of higher education (King & Kitchener, 1994; Perry, 1970). According to both the *Perry Model* (1970) and the *Reflective Judgment Model* (King & Kitchener, 1994) it is in late adolescence or emergent adulthood that individuals can develop a more sophisticated understanding of knowledge. Before late adolescence, epistemological beliefs formerly were assumed to remain absolutist. Current research has provided insight into qualitative differences about knowledge and knowing in Kindergarten children (Wildenger, Hofer, & Burr, 2010). These early onset changes about beliefs of knowledge should be of great interest to educators, especially given their intricate relationship with beliefs about learning (Elby, 2009) and achievement (Wood & Kardash, 2002). In their research, Wood and Kardash (2002) have found clear evidence that the most common factors associated with students' epistemological beliefs (with the exception of the *Attainability of Objective Truth*) have a strong correlation with academic aptitude on college readiness tests.

Perry (1970), in his original work at Harvard University, concluded that entering freshmen had views of knowledge as facts handed down from authority, whereas seniors believe knowledge to be tentative, derived from reason and empirical inquiry (Schommer-Aikens, 2004). More current conceptions of personal epistemology suggest the construct as a system of more-or-less independent beliefs developing in an asynchronous manner. It is important not to confuse the issue of the independence of beliefs (e.g., Beliefs about Learning, Beliefs about Knowledge) with their interrelationships with learning. Though some researchers have discomfort with this linkage (Schommer-Aikins, 2004; Chandler et al., 2002), the problem involves theory and not application. As described by Elby (2009), "they are clearly related, as one's beliefs about knowledge are likely to influence how one approaches learning, but they are definitely not the same" (p. 4). Therefore, regardless of the dichotomy in theory, "educational researchers agree that both students' conceptions of knowledge, as well as their conceptions of learning, develop progressively through educational experiences" (Loyens, Rikers, & Schmidt, 2009, p. 502). What is most important for this research is that researchers agree that beliefs about knowledge and knowledge construction (knowing) exist in what researchers refer to as "developmental stages" (Bendixen & Rule, 2004). Naïve epistemological beliefs (or more absolutist/positivist positions) can be thought of as absolute, from an authority figure, or certain and never changing. The other end of the spectrum would be considered as having beliefs about knowledge and knowledge construction (or constructivist positions) that are personally constructed, contextual, and tentative. In an ideal world, the science education community should hope students' and teachers' epistemological beliefs would be closer to sophisticated beliefs than naïve, tentative rather than fixed, and contextual instead of factual.

Studies of personal epistemologies and their relationship to other fields such as conceptual change, nature of science, and science education in general cannot be overlooked due to relationships with teacher practice (Feucht & Bendixen, 2010). Theoretical and empirical work has indicated the importance of teachers' personal epistemologies (or more specifically epistemic development) affect choices teachers make about their teaching practices; for instance: 1) how they choose teaching strategies; 2) how they choose teaching materials; 3) how they might accept education reform, and 4) how they view professional development (Feucht, 2008; Feucht & Bendixen, 2010, Patrick & Pintrich, 2001; Schraw & Olafson, 2002; Tsai, 2002). Feucht and Bendixen (2010) describe how teachers with absolutist mindsets tend to view knowledge as transferable from the expert teacher to the naïve passive learner. Teachers with evaluativist views about knowledge tend to encourage a more collaborative strategy, where students construct their own knowledge and justify their knowledge commitments. While the field of epistemology has seen robust research over the past forty years, it is only more recently that work with respect to teachers' personal epistemological beliefs and their relationships with educational practice have gained the attention of researchers. As teachers' epistemological beliefs are viewed as an influential factor in the classroom and these epistemological beliefs do affect practice (Olafson & Shraw, 2010), it would seem wise to include these factors in any research pertaining to science education.

With the knowledge that indicates that teachers' beliefs about the personal construction of knowledge (personal epistemologies) influences their classroom practice, the question must be asked, "How do these philosophical differences in teachers' affect practice?" As teachers move away from their more objective views on the nature of knowledge to one including an emphasis on the personal construction of knowledge, traditional classroom approaches no longer make sense. For teachers, this change in beliefs about knowledge is correlated to a shift in the philosophy of learning (Lorsbach, Tobin, Briscoe, & LaMaster, 1995; Tobin, 1990). Hopefully, this shift in their philosophy of learning will cause a change in classroom practices they employ. It is this shift from the objectivist beliefs (rooted in positivism) toward a more personal construction of knowledge (constructivism) that can change teachers' practices. There is much evidence to suggest personal epistemologies can be at odds with reform-minded philosophies associated with learning (Tsai, 2002). In recent research, relationships between teachers' understandings of how people learn, or construct knowledge, definitively correlate with how they teach NOS (Herman, Clough, & Olson, 2013). Other research (Akerson, Buzzelli, & Donnelly, 2010) has also looked at teachers' epistemological positions and how they correlate with a teacher's emphasis of (or value) NOS. It is important to note, the study by Akerson, et al. (2010) looked at preservice teachers during their internships, where effects from the supervising teacher dominated teacher practice. This leaves an open question about how personal epistemological beliefs (views consistent with either positivism or constructivism) might affect a practicing teacher.

Constructivism.

The constructivist epistemology, in a pedagogical sense as is used within this discussion, is either a way to make sense of how students learn or can be thought of as a theory of knowledge used to explain how and what we know (Lorsbach & Tobin, 1993). Constructivism is suggestive of a more sophisticated level within the personal epistemological framework, where knowledge is something the learner constructs and not something passed from omniscient authority to the naive passive learner (Feucht & Bendixen, 2010). A constructivist epistemology determines how teachers' view knowledge, including how it is created and used. These constructivist epistemologies are important because these ideals are necessary to drive the type of instruction called for in reforms and reflective of the type of instruction necessary for the development of sophisticated NOS understandings.

Constructivism, even with its worldwide acceptance in reform documents as a learning theory, is not without its critics (Solomon, 1994; Osborne, 1996; Jenkins, 2000). These critics have described constructivist pedagogy as relativist and even unscientific (Scerri, 2003). Much of the misunderstanding is rooted in that fact that constructivism is a theory of learning and not a theory of teaching. Some teachers and even some philosophers conflate constructivist practices with pedagogy solely associated with hands-on or discovery learning; where students develop their own knowledge through social interaction with little guidance from the instructor (Mayer, 2004). While hands-on learning can play a role in constructivist practices, its presence is not a sufficient condition. Discovery learning, while philosophically related to constructivist practices, is a more extreme version of constructivist pedagogy. Discovery, or implicit instruction, has fallen from favor as a best practice in lieu of a more explicit or guided approach.

The learning theory of constructivism comes directly out of the work of Piaget and Vygotsky (Slavin, 2000), though its influence can be traced back to the social pedagogical ideas of the educational philosophers Rousseau, Pestalozzi and Fröbel (Kornbeck & Jensen, 2009). Perhaps most well-known in American education is the work of Dewey in the early part of the 20th century. It was Dewey who put focus on the learner with his student-centered approach of education and who stated that "education is a constant reorganization or reconstructing of experience" (Dewey, 1916/1966, p. 89). Nearly a century since Dewey, while his ideas are commonplace within the halls of academia and modern learning theories, the true practice of constructivist teaching methods are observed on a much lesser degree. Too often, the practice of science teaching has succumbed to teachers' naïve personal epistemological beliefs, which conflict with constructivist beliefs about learning (Tsai, 2002). As suggested by Yang et al., these naive views of knowledge suggest positions that are "philosophically more like that of the positivist" (2008, p.13). It is here, where theory diverges from practice and as a result, students may suffer the consequences.

Positivism.

Positivism, a contrasting view of how knowledge is created, is a term that can have multiple meanings, from a commitment to social evolution, to a philosophical meaning involving logical positivism, or a methodological tradition within scientific practice (Riley, 2007), with the latter two having correlations to this discussion. Within a positivist methodology, or practice, all knowledge comes from single sense-data. Furthermore, theories are thought to be just human-made linkages between these single data (Alvesson & Skolberg, 2009). Science in a positivist tradition has its roots in empiricism, where socially constructed knowledge held no place and "truth" was believed to be obtainable. In the field of psychology in the mid-twentieth century, psychologists believed they could only study what could be measured and observed (Trochim, 2006); much like the scientists who held beliefs that science was only conducted by using the scientific method. Just as these ideals of one scientific method and objective truth conflict with modern views of the nature of science, so too does the notion of positivist pedagogy conflict with reform ideals for teaching science.

Ledoux and McHenry (2004) describe instructional methods and curriculum based in a constructivist framework a route to help students "develop conceptual models that will function as their own coding system for the to-be-known world" (p. 387). This is in contrast to a teacher having a more naïve understanding on Perry's scale (Perry, 1970) of knowledge and knowledge construction where "The objectives [of learning] are concrete and learning is observable and measureable" (p. 387). It is critical to realize the importance of teachers and their levels of understandings of knowledge and knowledge construction along a continuum of epistemological beliefs. It will be the teacher who will choose the types of strategies employed in the classroom. Will those strategies be student- or teacher-centered, focused on knowledge construction, or rooted in rote learning? Perhaps the more important questions might be: What role will the teacher's personal epistemologies play in the value placed on NOS instruction? How will that instruction look? and What other factors might influence either the epistemological beliefs or instruction practice?

Statement of Problem

While research supports the fact that teachers can learn NOS, this knowledge might not translate into practice (Abd-El-Khalik & Lederman, 2000; Lederman, 1999). Without the support of the teacher, student understandings of NOS as an outcome will stall. Intentions toward teaching NOS are critical (Lederman, Abd-El-Khalik, & Bell, 2001), especially given its importance within scientific literacy. Important questions that must be asked, therefore, include: "Why do science teachers not consider NOS to play a critical role in teaching? Even if teachers do understand its importance to scientific literacy, why are they not putting NOS into practice?" Research has shown how personal epistemologies relate to the types of classroom practices employed (Sinatra & Kardash, 2004; Tsai, 2002, 2007) by teachers. Epistemological beliefs associated with science (SEBs) also control the importance teachers' place on NOS (Tsai, 2002). Although NOS has been described as an epistemological belief, more recently these two constructs have been discussed as separate, but related constructs (Wu & Tsai, 2011). Scientific epistemological beliefs (SEBs) and NOS are similar in that they both address beliefs about scientific knowledge and knowing science. To differentiate SEBs from NOS, SEBs place more emphasis on beliefs about the nature of knowing science, justification of scientific knowledge, and decision-making on socioscientific issues. For example, SEBs place a focus on a person's beliefs about how scientific knowledge may be tentative or socially constructed, more so than the development of the knowledge during the scientific enterprise.

As Abd-El-Khlaik and Akerson (2004) suggest, this is where research should be focused. How teachers value NOS is a crucial factor in the teaching of NOS (Lederman et al., 2001) as these principles are what shape classroom behaviors (Bell & Pearson, 1992; Olafson & Shraw, 2010; Tsai, 2002). Gallagher (1991) found that science teachers holding epistemological beliefs centered in positivist view of science teaching either did not teach aspects of NOS, or they focused entirely on the scientific method and more traditional positivist views of the nature of science. Hashweh (1996) found a similar relationship where teachers' constructivist beliefs were associated with constructivist behaviors in science classrooms. Given the important association of teachers' epistemological beliefs on practice, it then seemed prudent to investigate the relationship between teachers' epistemological beliefs and how these beliefs about the broader scope of knowledge and knowledge construction affect NOS instruction.

Research Questions

To gain a better understanding of the relationship between teachers' intentions to teach NOS and their possible relationships with personal epistemological beliefs, the following questions were advanced:

Research Question 1

1. *In what ways do teachers' epistemological beliefs affect practice in the science classroom during NOS instruction?*

Question 1 Rationale

To overcome the hurdles of providing students with appropriate experiences to learn NOS, a host of known obstacles must be overcome. Recent research has provided evidence that epistemological beliefs strongly correlate with the ability to predict teacher practice (Olafson & Shraw, 2010). As epistemological beliefs are associated with teachers' views of NOS (Akerson et al., 2008), as well as classroom practice (Yang et al., 2008), it would seem prudent to investigate the intersection (of NOS, personal epistemological beliefs and practice).

Research Question 1a

a. *What is the nature of the relationship between personal epistemological beliefs and understandings of NOS?*

Question 1a Rationale

What is now emerging in epistemological theory is that there exists a tentative relationship between domain-specific epistemologies and more general epistemologies (Palma & Marra, 2008). New views of epistemology consider that domain-specific epistemological beliefs are nested under a larger, more general, epistemology (Buehl & Alexander, 2006; Hofer, 2006). Given the proposed relationship between these two constructs, in order to gain ground toward better understandings amongst teachers about NOS, it would seem imperative to further this research into this proposed relationship.

Research Question 1b

b. In what ways does the co-occurrence between NOS and personal epistemological beliefs affect the importance teachers place on NOS?

Question 1b Rationale

Recent research suggests a relationship between NOS and personal epistemological beliefs (Akerson, et al., 2006; Akerson, et al., 2008; Akerson et al., 2010). The latest research by Akerson, Buzzelli, and Donnelly (2010) has found that improved “intellectual levels” (referring to their epistemological sophistication) of teachers were associated with classroom practice associated with NOS instruction. The reason suggested as to why teachers chose not to teach NOS was they did not view NOS as important as other content. It seems quite rational to believe that better understanding of NOS must be a precursor to its gaining importance. This translation of knowledge of NOS into a teacher’s belief that NOS has importance is not automatic, suggesting other epistemological beliefs outside the context of NOS may play a role. Zeidler, Herman, Ruzek, Linder & Lin (2013) have identified classic utilitarianism as a factor influencing reasoning. By applying reasoning skills, one could expect a person to give the emphasis to that which would have the maximum benefit, or marginal utility. In Zeidler, et al., (2013) recent cross-cultural study of students' use of reasoning found that utility, at best, played a secondary role. Furthermore, this study supported the notion that a set of complex epistemological beliefs play a role in decisions about socioscientific issues, supporting other related research (Yang & Tsai, 2010; Zeidler, Sadler, Applebaum, & Callahan, 2009).

Question 1c

c. *In what ways does the co-occurrences between NOS and personal epistemological beliefs correlate with the classroom activities during NOS instruction?*

Question 1c Rationale

The effects of epistemological beliefs on practice have received much attention and are typically found to be at odds with reform-based (constructivist) practices (Tsai, 2002, 2007; Yang et al., 2008). Constructivist teaching practices also serve as the basis for NOS instruction (i.e., explicit-reflective instruction). Unfortunately, positivist pedagogy such as lecture still dominates classroom practice on a global scale (e.g., Hammer 1994; Lemke 1990; Tsai 2002; Poole 1994; Windschitl 2002). In a series of studies, Akerson et al. (2008, 2010), have reported how student teachers holding more constructivist views about knowledge and knowledge construction using the Perry Model (1970) held more sophisticated understandings of NOS.

These studies have also shown that understandings of knowledge construction more like that of a pedagogical constructivist were associated with better understandings of NOS, but, as previous research has suggested, this knowledge did not translate into practice. With the assumption that NOS instruction will occur due to a mandated District curriculum that includes NOS, this research hopes to investigate the type of NOS instruction that occurs as a result of differing views of knowledge and knowledge construction (i.e., epistemological beliefs).

Realizing that the NOS portion of the District's curriculum occupies on 25 of the 64 allotted days for the unit containing both NOS and the practice of science, NOS is clearly present. It is also important to realize, this question refers to the amount of instruction that should be present to cover the spectrum of NOS concepts included within the curriculum maps. These curriculum maps too where not designed for each teacher to be on the same page as others, but more so to act as a guide for instruction. NOS should appear within instruction for about 25 days and hopefully embedded within other sections to provide rich instruction for students. This question does not compare the amounts of instruction between practice and skills based on quantity, only how much NOS instruction that should be present given the District mandates. If NOS instruction is not present, then other factors beyond the curriculum are to blame.

Question 1d

d. What other factors are responsible for influencing teacher's choices they make about classroom instruction?

Question 1d Rationale

Recent research has suggested an intricate relationship among teachers' epistemological views, their classroom practice, and the institutional environment (Tsai, 2006). As colleges of education are charged with producing teachers equipped to handle the demands of the 21st Century classroom, it is important to distinguish between what research tells us about how epistemological beliefs have a strong correlation to practice and what teachers believe about what affects their practice. While beliefs are associated with classroom practices (e.g., Hashweh, 1996; Kang & Wallace, 2004) it is important to understand the different perspectives.

Question 2

In what ways do classroom practices differ between instruction of NOS and instruction of process skills?

Question 2 Rational

A plethora of research supports teachers' lack of NOS understandings (Abell & Smith, 1994; Akerson et al., 2006; King, 1991; Lakin & Wellington, 1994; Murcia & Schibeci, 1999; Smith & Anderson, 1999; Tsai, 2002), as well as social and institutional constraints for its lack of or inadequate teaching (Larkin, Seyforth & Lasky, 2009; Abd-El-Khalik & Lederman, 2000; Saka, Southerland & Brooks, 2009). If, as suggested (Hammrich, 1997, 1998; Lederman, 1992; Nott & Wellington, 1995; Tsai, 2006; Yang et al., 2008), epistemological beliefs are related to the types of classroom instruction, then logically instructional types (i.e., constructivist or positivist) would be independent of context (i.e., NOS or the practice and skills of science), but this may not be the case.

It is suggested (Driver, Newton & Osborne, 2000; Linn & Hsi, 2000) that individuals hold incoherent and non-cohesive views of scientific inquiry depending on context. This domain-specific view stands in contrast to the domain-general developmental models (Bell & Linn, 2002) derived from the work of Piaget and his stages of development (1968). Piaget extended his structured view of epistemological development to include "horizontal decalage" to accommodate context and task variation (Inhelder & Piaget, 1958; Piaget, 1968). This question is directed at how instruction looks for separate types of content (NOS and process skills) and how this instruction is effective by epistemological beliefs.

a. In what ways are these differences reflective of understandings of NOS?

Question 2a Rationale

Research into teachers NOS understandings has resulted in knowledge that, even if teachers have adequate knowledge of NOS, There is no guarantee that NOS will be reflected in practice (e.g., Bell, 1996; Duschl & Wright, 1989; Lederman, 1992; Lederman & Druger, 1985; Lederman & Zeidler, 1987). Knowing that typical instruction of traditional content is taught in a positivist fashion such as lecture or conformational laboratory investigations, Allchin's (2011) view of NOS tenets as a "positivist manifesto" could be realized. While most research has focused on whether or not NOS is introduced into the classroom, this research is distinct. This research is different from most research as the school district mandates a set of tenets of NOS that must be covered within the first 9 weeks of school.

b. In what ways are these differences reflective of personal epistemological beliefs?

Question 2b Rationale

Even within the discipline of science, non-coherent and non-cohesive epistemological views have been found. BouJoude (2000) found that biology teachers were more apt to hold positivist beliefs about learning than chemistry and physics. This finding suggests that even differing content strands within the same discipline may affect classroom practice that is independent of NOS understandings. By comparing personal epistemological beliefs of teachers with their classroom practice, this research hopes to further delineate the domain specificity between NOS content and traditional content as they compare to personal epistemological beliefs.

Importance of Study

While much has been learned about how NOS is taught and some about how it is learned, the struggle to increase students' scientific literacy continues. If teachers' personal epistemological beliefs encumber the value they place on NOS, then a better understanding of this relationship is needed. The goal of this research has been to investigate the obstacles that prevent teachers from fulfilling the visions of recent reforms with regard to NOS instruction. As these are the obstacles that stall improvements in student's understandings of NOS, which then affect their overall scientific literacy, this must become a matter of utmost importance within the science education community.

Summary

As the developed world now embraces science and technologically-based study for economic sustainability and growth, the need for science education to keep pace is critical (Akpan, 2010). There now exists a rich history of research about teaching and learning that has pervaded global reform movements. For instance, the recent draft of the *Australian National Teacher Standards* (ASTA, 2009) mentions how highly-accomplished teachers should communicate the strengths and weaknesses of science, through diverse practices, as well as ways of knowing. As scientific literacy, and its component of NOS, has gained a global caché (AAAS, 1989, 1993, 1997, 2009; Achieve, Inc., 2013; ASTA, 2007; McComas & Olson, 1998; NRC, 1996; NSTA, 2000; Ministry of Education of the People's Republic of China, 2001; Turkish Ministry of National Education, 2005), the struggle to improve student understandings remains. The science education community has played its role in providing an abundance of research about the teaching and learning of NOS. This research has taught us much about teachers' inadequacies when it comes to their own knowledge and pedagogical skills, but even this knowledge has left us short of the mark with respect to advancing the reform movement into classrooms. Perhaps something else has caused the headwind preventing the science education community from traversing the schism between theory and practice. If this "something else" is indeed the personal epistemological beliefs of the teachers, then a better understanding of these co-occurrences are needed.

Chapter Two: Review of Literature

Introduction

Scientific literacy, with NOS a major component, has been the emphasis of a copious amount of research for almost 60 years (Lederman, 2007). Through this extensive research into NOS, much has been learned about how NOS should be taught and how it is learned. Unfortunately, despite the abundance of research that pertains to instruction and learning of NOS, the bridge between pedagogical theory and practice has not yet been constructed. With scientific literacy now seemingly tied to the perception of educational systems and economic futures of nations, continued research into this pedagogical and theoretical schism should take center stage. As teachers are responsible for at least the majority of what happens in the classroom, research into the factors that inhibit such pedagogy would seem essential. While many teachers do lack an adequate understanding of NOS, some do have adequate knowledge and still; yet NOS has failed to become an emphasis in the typical science classroom. Teachers practice are affected by a host of reasons that include NOS (Hammrich, 1997; 1998; Lederman, 1992; Nott & Wellington, 1995,Tsai, 2007), personal epistemological beliefs (Yang et al., 2008), and a variety of social and institutional factors (Larkin et al., 2009, Lederman & Abd-El-Khalik, 2000; Saka et al., 2009). It is these unseen, but ever-present factors that control a teacher's actions and will become the focus of this research.

While inadequate understandings of NOS cannot be disregarded as an important reason why teachers' do not value NOS, other causes such as institutional factors and epistemological factors have both been shown to play a role (e.g., Larkin et al., 2009; Lederman & Abd-El-

Khalik, 2000; Yang et al., 2008; Saka et al., 2009). With NOS serving as the seminal benchmark for scientific literacy, it would seem essential to look at factors that affect the way NOS is taught and learned within the science classroom. With reform movements acting as a guide to instruction and given the rich research history about NOS learning, the schism that exists between reform and instruction is clearly dependent upon the teacher. It is here this research aims to look at the teacher as a barrier (or impediment) to the goals of scientific literacy, called for in science reform efforts.

Within current and past science reform initiatives is the requirement for the development of a scientifically literate citizenry (e.g., AAAS, 1989, 1993, 1997, 2009; Achieve, Inc., 2013; NRC, 1996; NSTA, 2000). To date, the global science education community holds firm to the belief that scientific literacy hinges upon students' gaining a sophisticated understanding of the nature of science (NOS), a principal component of scientific literacy (e.g., AAAS, 1989, 1993, 1997, 2009; Achieve, Inc., 2013; ASTA, 2007; McComas & Olson, 1998; NRC, 1996; NSTA, 2000; Ministry of Education of the People's Republic of China, 2001; Turkish Ministry of National Education, 2005). This trend for increasing student understandings of NOS is not just limited to the United States, but has pervaded reform movements globally, from Europe to Asia (Matthews, 2009). A copious amount of literature reflecting the belief that NOS instruction links decision-making ability within science and technology related issues (Carey & Smith, 1993; Collins & Shapin, 1986; Cotham & Smith, 1981; Driver, Leach, Millar, & Scott, 1996; Kuhn, Amsel & O'Loughlin, 1989; Lederman, 1983, 1999; Millar & Wynne, 1988; Shamos, 1995).

The general stance is that by having a sophisticated understanding of the way science knowledge is constructed, citizens will be better able to recognize pseudoscience claims, to distinguish good science from bad, and to have the ability to apply science within their everyday lives (Bell & Lederman, 2003). For the most part, the science education community knows a lot about how best to teach NOS and some about how it is learned, but the path has not yet been fully cleared to a point where we can be confident that students will have an adequate understandings of NOS when they leave school.

For decades, research has demonstrated the lack of NOS knowledge in both teacher and student (Abd-El-Khalik & BouJaoude 1997; Akerson & Hanuscin, 2007; Behnke 1950; Carey & Stauss 1970; Duschl, 1990; Lederman, 1992, 2007; Pomeroy 1993) and provided insight into how best to teach NOS (Abd-El-Khalik, 2001, 2005; Abd-El-Khalik & Lederman, 2000; Akerson et al., 2000; Khishfe & Abd-El-Khalik, 2002). This research has instilled a sense of urgency within science education departments for the development of coursework aimed at helping new teachers. It is unfortunate that little progress has been made toward this goal. This may indicate there are other factors inhibiting the progress towards citizens becoming scientifically literate.

Tsai (2007) suggests that a teacher's *scientific epistemological beliefs* (SEBs) – a construct related to NOS, but focused more on the knowledge construction – are responsible for and associated with classroom practices. Within his research, Tsai (2007) found SEBs do play a critical role in in the enactment of inquiry-based science instruction, something other researchers have previously suggested (Abd-El-Khalik, 2005; Roehrig & Luft 2004; Tsai, 2002). According to Tsai (2007), the theoretical positions of views of scientific knowledge aligned with either positivism or constructivism held a strong relationship with classroom practice. While there have been studies that reflect the role of SEBs on student learning, few studies have been undertaken a look at the role of a teachers' SEBs and their correlation with choices with regard to instructional practice. This is unfortunate as these SEBs are considered an important factor affecting instruction (Hammrich, 1997, 1998; Lederman, 1992; Nott & Wellington, 1995). In a recent research article by Yang, Chang and Hsu (2008), the idea of teachers' epistemological beliefs were expanded to include the teachers' broader beliefs about knowledge (personal epistemological beliefs) and were made clear when the authors stated, "Teachers' views concerning constructivist instruction were consistent with their epistemological beliefs towards knowledge and learning" (p. 17).

As research from various studies has shown (Akerson et al., 2006; Akerson &Volrich, 2006), there exists a relationship between a person's epistemological positions and their conceptualization of NOS. One study has provided evidence that suggests intellectual levels do predict how NOS is taught (Gallagher, 1991). Gallagher (1991) explains that secondary science teachers hold views of science as a body of knowledge with little emphasis on to the processes of science or how this scientific knowledge is constructed. Science teachers possessing epistemological beliefs centered in positivist view of science and favoring the transmission of ideas and concepts over student construction of knowledge either did not teach aspects of NOS, or focused entirely on the scientific method (Abd-El-Khalick & Lederman, 2000). A study by Tsai (2007) has highlighted teachers' epistemological beliefs as an important influencing factor of classroom climate and instruction. This brings forth the question as to how this might influence NOS instruction. It is this intersection of epistemological beliefs and NOS that may play a significant role in whether a teacher values NOS, and hence chooses to teach it.

It would seem difficult if a teacher held a belief about knowledge centered in positivism, where knowledge was absolute with no inclusion of an individual's construction of knowledge, to expect the kind of practice necessary for good science instruction called for in reforms. Also, for a teacher possessing a positivist philosophy the notion of the modern vision NOS would be a difficult barrier to overcome with regard to the practice of teaching aligned with current reform movements and the goal of having a scientifically literate populace.

Chapter Two is arranged first to inform the reader about scientific literacy, how it is defined, its global importance and how the nature of science plays an integral role. Then, NOS is further explained in terms of its historical past in terms of philosophical changes over the past 100 years and research of teaching and learning NOS from the past 60 years. To follow, the philosophical and historical view of NOS, an explanation of known barriers to the teaching of NOS is discussed. Thereafter, related work from the field of educational psychology is reviewed to look at teachers' beliefs about knowledge and knowledge construction. This section explains how these beliefs about knowledge and knowledge construction are related to constructivism and positivism, both as philosophies of learning, as well as how these philosophies influence classroom practice. Recent work that relates studies of teaching and learning NOS and epistemological beliefs, both from a strictly science perspective and that of the broader category of personal epistemological beliefs, is then reviewed. It is this last section's review of recent research that will guide this research to further investigate these relationships.

Scientific Literacy and the Need for Nature of Science

With every passing day, citizens of the world are confronted with questions that to answer require knowledge of science. Lederman & Neiss (1997) describe science as divided into three parts: 1): the body of knowledge, 2) the processes and methods, and a 3; way of constructing reality (the nature of science). While the exact definition in terms of what it means for school science is still debated, scientific literacy is mostly assumed to mean the ability of students to engage issues concerning science. For instance, a scientifically literate person is one who uses scientific information and scientific ways of knowing for the purpose of making decisions concerning himself, as well as the general society, hence the "democratic argument" for scientific literacy (Driver et al., 1996). Roberts (2007), in an extensive recapitulation of the varying views of Scientific Literacy, developed a heuristic model to explain these varying views. Within his heuristic, Roberts (2007) describes how most visions of scientific literacy fall into two over-arching themes, referred to as Vision I and Vision II. Reflective of Vision I are some reform documents that articulate scientific concepts and what students should master (e.g., AAAS, 1990; AAAS, 1993). Within Vision I, the primary goal of science education is to promote scientific concepts and processes and to help students develop robust understandings of scientific findings. Vision One's decontextualized understanding of science is contrasted with Vision Two's contextualized understanding. With the prioritization of contextualized understandings, Vision II removes the traditional boundaries of science and, in turn, broadens the scope to include personal decision-making where science is embedded within real-life social, political, economic and ethical concerns. Zeidler and Sadler (2011) describe Vision II as a place where distinctions of scientific ideas end and social consideration begin to blur. Zeidler and Sadler (2011) succinctly describe the difference between Vision I and Vision II in terms of what is expected from a scientifically literate person as what they ought to know (Vision I) and be able to do (Vision II) with their understanding of science. Vision II, with its form of functional scientific literacy, considers that any science content learning without an inclusion of its application, to include sociomoral implications, is an artificial divorce (Zeidler & Sadler, 2008a). Beyond the discussion of contextualized and decontextualized learning, there exist another variant in understandings of scientific literacy that requires further description.

To become "scientifically" literate requires that students learn the skills (processes and methods) of science (conducting observations, inferences, and conducting experiments), but this objective is only part of the picture. Individuals often conflate the process and methods of science with the knowledge construction component of science (Khishfe & Abd-El-Khalik, 2002). This type of knowledge is deemed important in recent reform movements as essential for students to learn in order to meet the citizenry requirement of the reform movements (AAAS, 1989, 1993, 1997, 2009; Achieve, Inc., 2013; ASTA, 2007; McComas & Olson, 1998; NRC, 1996; NSTA, 2000; Ministry of Education of the People's Republic of China, 2001; Turkish Ministry of National Education).

Beyond science content knowledge, citizens must have appropriate thinking skills to process the types of information they encounter on a daily basis about socioscientific issues in a meaningful manner in order to make informed decisions. Through intelligent public discourse and debate, it will be the "collective judgment" of the American citizenry that will determine how resources are shared and tax monies spent on issues concerning science and technology (NRC, 1996, p. 11).

For this reason, it is of utmost importance that students gain an understanding of science as a “way of knowing” if decisions regarding real world issues are to be made. In other words, students of science must learn more than mere content knowledge and scientific processes; they must also learn about a part of the philosophy of science called the “nature of science” (NOS).

A major focus on NOS came as a result of a shift in the views of science during the middle of the last century from a more positivist view of science to a more constructivist viewpoint (Abd-El-Khalik & Lederman, 2000). It was only after this paradigm shift marked by Kuhn’s publication (1962) that NOS gained enthusiasm as a relevant discussion. It is unfortunate that despite its worldwide caché, little ground has been made toward increasing students’ understandings of this concept.

Nature of Science

The nature of science can be thought of as the epistemology of science, or science as a way of knowing. As described by Lederman and Zeidler (1987), the nature of science encompasses the values inherent to the individual’s development of scientific knowledge. It includes how the scientific community passes judgment on what is accepted and what is not, or how much faith the community places on scientific knowledge (Marks & Eiks, 2009).

All knowledge has a value and belief system associated with it that is integral to its development. Science has its own specific set of values and beliefs that characterizes it as “scientific (Lederman 1992).” It is through these characteristics of knowledge that science sets itself apart from other disciplines. While characteristics of NOS are still debated, there are established characteristics that serve as a basis for most recent descriptions of NOS applied to academic research and educational reform movements (Akerson et al., 2000), these include: 1.)

Scientific knowledge is: 1) tentative (subject to change); 2.) empirically based (based on and/or derived from observations of the natural world); 3.subjective (theory-laden); 4.) partly the product of human inference, imagination, and creativity (involves the invention of explanation); 5.) socially and culturally embedded; 6.) makes a distinction between observations and inferences; 7.) clarifies the functions of and relationships between scientific theories and laws.

Provided below is an example of Florida's standards (Florida Department of Education, 2012), which are reflective of the National Science Education Standards (NRC, 1996) characteristics of NOS:

- SC.6.N.1.2: Explain why scientific investigations should be replicable.
- SC.6.N.2.2: Explain that scientific knowledge is durable because it is open to change as new evidence or interpretations are encountered.
- SC.7.N.1.7: Explain that scientific knowledge is the result of a great deal of debate and confirmation within the science community.
- SC.7.N.2.1: Identify an instance from the history of science in which scientific knowledge has changed when new evidence or new interpretations are encountered.
- SC.7.N.3.1: Recognize and explain the difference between theories and laws and give several examples of scientific theories and the evidence that supports them.
- SC.8.N.3.2: Explain why theories may be modified but are rarely discarded.
- SC.8.N.4.2: Explain how political, social, and economic concerns can affect science, and vice versa.

Much like the Common Core Standards for ELA and mathematics now being adopted by 45 of the 50 States (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010), a new set of science standards has just been finalized that eventually may replace the current science standards (NRC, 1996). These new standards, much like the old, emphasize the importance of NOS and further support the focus on robust and relevant science education (Achieve, Inc., 2013). The purpose and goal of these new standards focus on the premise that:

> “*all* students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice (NSTA, 2012, p. ES-1)..” including (but not limited to) careers in science, engineering, and technology”

Throughout the past century, the views of the nature of science have changed as philosophers, historians, and educators of science have debated its precise account (Alters, 1997; Loving, 1997; Matthews, 1994). Abd-El-Khalik and Lederman (2000) describe how the nature of science has changed over the past century. The changes in NOS went through a large shift from the inclusion of the basic steps of science (Central Association for Science and Mathematics Teachers, 1907) toward how scientific knowledge itself is constructed through a process that includes the empirical roots of science, as well as the social and psychological factors. It is these social and psychological factors that are now deemed of great importance and are expected to take part of the more recent reform movements (e.g., AAAS, 1989, 1993, 1997, 2009; Achieve, Inc., 2013; NRC, 1996; NSTA, 2000), but these factors came as a result of what reads like an epic battle for supremacy. It was this shift from the more mechanical views of science toward one of social construction that perhaps best characterizes the dynamics of this period. Just as science itself is no longer characterized by a smooth transition of scientific knowledge, those who helped guide the definitional properties of the nature of science did not enjoy a peaceful transition.

The past century's struggles with defining the nature of science can be divided almost in half, marked by Kuhn's (1962) work, the *Structure of Scientific Revolutions* (Giere, 1988). While philosophers holding empiricist views of science attempted to justify the logical processes of science, a new regime that believed science contained social and psychological factors argued, from a historical perspective, that science was not always rational. Historical investigation revealed that science did not make smooth transitions which were often filled with what Kuhn called "revolutions" as one "paradigm" was replaced by another (Kuhn, 1962).

Just like the historical scientific revolutions described by Kuhn (1962), philosophers, historians, and educators of science and can be generally separated into two opposing camps (Giere, 1988). It was Popper (1959) who described how the logical empiricists described those who viewed science from this new perspective as irrational and committing the "sin of psychologism" (Abd-El-Khalik & Lederman, 2000, p. 666). Popper supported the notion that science should be described by its scientific claims through verifiable observation, rather than a more descriptive account of how science works in terms of a Kuhnian view of knowledge construction (Giere, 1988). Abd-El-Khalik and Lederman (2000) describe the logical empiricist argument as "conflating logic with psychology (p. 667)." Kuhn's work emphasized the social context of science as opposed to the more logical and empiricist views of the time.

Popper (1963) suggested that science advances through what he describes as conjectures and refutations. In this view, he proposes that science offers up a theory (conjecture) in the attempt to disprove it. Through this process, the absence of refutations is considered support. While theoretically this perspective is sound, there is no historical or current evidence that scientists or science in general operates in this manner (McComas, 2000). Popper's view also emphasized the philosophy of science centered upon empiricism as he considered any psychological and sociological foundation as external to science (Abd-El-Khalik & Lederman, 2000).

Thanks to Kuhn's (1962) analysis of the history of science, the understandings of NOS made a turn toward a new vision which included social and psychological factors. During the second half of the past century, the trend toward contextual considerations of scientific discovery emerged. Kuhn (1962) described science as a discipline not progressing systematically toward a better understanding of scientific concepts, but one that moves in surges, moving through what Kuhn described as "scientific paradigms." Kuhn (1962) continues to explain that anomalous (or inconsistent) data accumulates until which time the existing theory cannot be maintained and a new theory to better accommodate the anomalous data is sought. During these paradigm shifts, or times of crisis, the scientific community faced choices as a result of too much anomalous data that did not fit with the current understandings. In a mechanical system – as science was once thought to be – changes in understandings should occur slowly and meticulously as new information becomes available. Instead, science was observed to completely abandon its previous conceptions for new conceptions that better explained the anomalous data. It should be noted that these new conceptions should not be thought of as being closer to "truth." It would seem that no matter how much one wishes for science to be completely objective and rational, Kuhn's historical analysis of the history of science paints a different picture, one with science having an influential social component. Kuhn's view of the nature of science has helped expand science's original logical empirical viewpoint, toward its current view. Though the current conception of NOS retains the original empiricist roots, it now includes psychological and sociological characteristics. More recently, challenges to the NOS have come with the view that knowledge of a list of tenets are insufficient to fully appreciate and make judgments about scientific claims.

There are critics that make the claim the notion of divorcing the tenets of NOS from the episodic event it is associated with, is unwise. These recent criticisms of NOS (and its set of characteristics) refer to these NOS tenets as a post Positivistic manifesto (Allchin, 2011), referring to its exclusionary nature, devoid of a real-life contexts in which to gauge the reliability of claims. Allchin (2011) adds, the nature of science is not the same as the philosophy of science (AAAS, 2009, chap. 1), nor or the citizens capable of becoming philosophers. Well-informed citizens need to understand how evidence works (Allchin, 2011). The notion of "Whole Science" as described by Allchin (2011) does provide a more inclusive perspective of NOS, rather than the more exclusive list of the more traditional list of NOS tenets.

Allchin (2011) questions what is it that we expect students to be able to do? There are certainly limits to these expectations. Critics of Allchin's request for the broadening of the breadth of NOS, decry "Whole Science" blurs the lines between NOS and the skills of inquiry and misrepresents a large body of work towards the current epistemological underpinnings of NOS (Schwartz et al., 2012).

The problem that is raised is that it is possible to help students develop the ability to pass judgment on mature science with its clearer examples of right and wrong. In contrast, within cases of the new science that is still emerging, problems arise (Brickhouse et al., 2000; Driver, Leach, Millar, & Scott, 1996; Khishfe & Abd-El-Khalick, 2002; Ryder et al., 1999; Schwartz, Lederman, & Crawford, 2004). Herman et al., (2013) responds to this issue by providing a more moderate solution in that NOS experiences should be inclusive of the learners' prior experiences. In order to promote deeper and robust understandings of NOS, it may be necessary to utilize NOS instruction within a variety of contexts (Clough, 2006). Clough (2006) argues that NOS instruction also needs to include extensive scaffolds between contexts. It is argued (Herman et al., 2013) that NOS instruction should occur along a continuum from decontextualized to highly contextualized.

Though the importance of NOS may have become apparent early in the 20th century, it was not until the late 1950s to early 1960s that research into NOS increased. One of the first tracks of research was intended to investigate students' conceptions of NOS. The disparaging findings set in motion what is now a long history of research into the problematic nature of learning about the nature of science.

What Do We Know About Learning the Nature of Science?

In an extensive review of literature, Lederman (2007) explained that initial research painted a gloomy perspective of students' understandings of NOS. As mentioned by Abd-El-Khalik and Lederman (2000), no matter what the instrument used to judge students' understandings of NOS, results were consistent that students possessed incomplete understandings of NOS (e.g., Aikenhead, 1973; Broadhurst, 1970; Lederman & O'Mally, 1990;

Mackay, 1971; Rubba, 1977; Rubba, Horner, & Smith 1981; Tamir & Zohar 1991; Wilson 1954). As a consequence of this research about students' inadequate knowledge of NOS, what followed was an attempt to remedy this situation by means of new science curriculum. With large amounts of funding, curriculum writers developed numerous curricula designed to help students learn through inquiry. The "alphabet soup" curriculum named for the breadth of acronyms describing its content [e.g., BSCS (Biological Sciences Curriculum Study, PSSC (Physical Science Study Committee), ISCS (Intermediate Science Curriculum Study), IPS (Introductory Physical Science)] was produced by private publishers and various universities, with the purpose of increasing the role of hands-on activities within science classrooms. This implicit approach (as it is now aptly named), which referred to learning about science by using the processes and methods of science, became a mainstay of much of the curriculum designed in the 60s and 70s (Lawson, 1982; Rowe, 1974). While initial results proved promising, it was surmised that appropriate curriculum could be a successful tool in improving student understandings (Lederman, 1992). This enthusiasm proved short-lived, as Abd-El-Khalik and Lederman (2000) explain that "when variables such as pre-testing, teacher experience, and student prior knowledge were controlled for, confusing results emerged (p. 669)." This hands-on approach to having students perform the tasks of science in a procedural manner lacked the minds-on component called for in more recent reform movements (NRC, 1996). What is now called "cookbook" or procedure labs, with an emphasis on conformation science. Researchers concluded that curricula alone were not an adequate solution for students to gain adequate NOS understandings (Lederman, 1992).

Instilling understanding of how scientific knowledge is constructed through historical analysis was also attempted, though not without its critics. Duschl (1990) warned of the dangers of teaching what he called ‘final form science,’ because this approach avoided the ‘collective mind of science.’ It was hoped that by providing teacher training and curricula, students would then begin to develop adequate NOS understandings that were hoped for (Lederman 1992). These attempts at improving students’ conceptions about science through historical analysis proved at best inconclusive and at worst ineffective at producing the kinds of sophisticated understanding desired by science educators (e.g., Klopfer & Watson, 1957; Rutherford, Holton, & Watson, 1970). As Lederman et al. (2001) describe, neither method (implicit historical or implicit through the use of hands-on scientific inquiries) has proven to be consistently successful at developing students’ conceptions about NOS. The conclusion made by researchers (Lederman, 1992) was that teacher understandings of NOS were the main contributor to student learning and not curriculum, but that is not to say that much has not been learned about necessary pedagogy to teach NOS.

Research supports the view that NOS is more effective if taught in an explicit and reflective manner (Abd-El-Khalik et al., 1998; Abd-El-Khalik & Lederman 2000a; Akerson et al., 2000; Khishfe & Abd-El-Khalik, 2002). The explicit-reflective method provides a methodological approach to the instruction of NOS concepts that are planned for instead of wished for as some instructional side effect (Akindehin, 1988, p. 73). This intentional approach draws students into discussions, activities, investigations, historical examples, etc. for the purpose of engaging learners in a meaningful learning experience. Through planned interventions and subsequent reflection, students’ conceptions of NOS are improved in a manner superior to the two previous modes of instruction (Abd-El-Khalik, & Lederman, 1998). Abd-El-

Khalik and Lederman (1998), drawing upon a comprehensive review of literature, make the claim that a "functional understanding of NOS" can be elicited through an explicit-reflective approach (p. 137). Akerson, Abd-El-Khalik, & Lederman (2000) note the limitations of the studies that have used primarily preservice teachers as study participants. While convenient samples for most researchers, they may not be the best choice for research purposes. Both research on situated cognition (e.g., Brown, Collins, & Duguid, 1989) and on transfer of learning (e.g., Lanier & Little, 1986) suggests that methods courses may not be the optimal context for promoting sophisticated views of NOS, yet they remain a popular choice for researchers for obvious reasons. Students in their third, fourth or fifth year of college are perhaps more advanced epistemologically and their learning of NOS may be quite different than a typical high school student. On the other hand, those students within elementary methods courses may not have the science background necessary to fully integrate NOS into context for their own learning.

Also, in order to acknowledge the integration of instruction into a contextual setting versus the more typical decontextualized activities based situation (e.g., Mystery Tubes, Dinosaur Bones), research suggests that in either case, the differences in learning outcomes may have more to do with the type of instruction (explicit or implicit) than with the setting (contextualized and decontextualized) (Bell et al., 2011; Khishfe & Lederman, 2006). Bell et al. (2011) used classes of preservice secondary teachers to determine which of four types of instruction (implicit-contextual, explicit contextual, implicit decontextualized, & explicit decontextualized) provided the greatest learning outcome. Instruction for two groups contained a socioscientific issue (Global Climate Change/Global Warming), with one group having nature of science relationships explicitly tied back to the previous NOS activities completed earlier in the semester. The other two groups were exposed only to the traditional activities-based instruction more common to nature of science instruction (e.g., Mystery Tubes, Mystery Box, Dinosaur Bones, etc.), with only one having the important discussion and debriefing following the activity. It should be noted that all groups were exposed to the NOS activities. The results of Bell et al. (2011) are consistent with Khishfe & Lederman (2006) who observed positive outcomes from both groups receiving either integrated or non-integrated explicit instruction. In the research by Khishfe and Lederman (2006), it is important to point out the methodologies were quite similar to Bell et al. (2011), but perhaps more important is that the participants were ninth grade high schools students and not the typical preservice teacher. It is not incorrect to say that contextualizing is without merit and perhaps necessary to move beyond declarative knowledge of NOS and into conceptual understandings of NOS between different contexts (Clough, 2007).

From a review of literature into how people learn, Clough (2003) cites how explicit-reflective practices are not enough to promote deep understandings of NOS. For instruction to help students develop understandings of NOS, he proposes that in NOS instruction, in order to be successful, classroom experiences need to be scaffolded back and forth along a continuum. This continuum described by Clough (2003) can increase connections to the workings of science and attempts to avoid the potential for the student to dismiss NOS as extraneous to science. This scaffolding also is meant to help students make connections between NOS and different science content. As well, Bell et al. (2011) acknowledge their interest in finding opportunities to embed NOS learning into contextual setting through the use of socioscientific issues (SSI), especially given its implications for decision making.

In the past century, where NOS was merely viewed as one's understanding of the scientific method (Central Association for Science and Mathematics Teachers, 1907), has come far with respect to the formation of understandings of what is NOS and how it is best taught. A statistician named Karl Pearson (1937) proposed a series of common steps used by scientists to solve problems that has become one of the most entrenched misconceptions of science education. These steps of the scientific method generally include, 1.) define the problem, 2.) gather background information, 3.) form a hypothesis, 4.) make observations, 5.) test the hypothesis, 6.) draw conclusions, and 7.) communicate findings with other scientists (McComas, 1996). From research into the ways scientists perform their studies, it is found that there is no method universal to science. This list of steps that characterizes the scientific method has, until recently, pervaded most precollege textbooks, thereby further entrenching the myth that science is a linear set of steps that is always followed. Instead of a formal and algorithmic set of steps, research (Carey, 1994; Chalmers, 1990; Gibbs & Lawson, 1992; Gjertsen, 1989) has explained that scientists apply imagination, creativity, prior knowledge and perseverance, characteristics that all problem solvers apply. Fortunately, newer textbooks have changed to terms such as "methods of science" to better explain the process of a scientific inquiry.

Neither the historical nor the implicit hands-on approaches have provided the science educational community with effective practices for teaching NOS. Fortunately, the explicit-reflective approach has provided hope that the tide of student inadequate understandings of NOS can be turned. More recent efforts to move toward a method of instruction to contextualize NOS also hold great merit, as these methods begin to address the nature of learning.

What Do We Know about Teaching NOS?

From over a half century of research, the science education community knows much about how NOS is best learned, but what about how it is best taught? Implicit methods with outcomes that are merely hoped for as artifacts of instruction have not proven successful in providing appropriate student understandings of NOS. Why should NOS conceptions not be treated like any other misconception? If a student fails to understand the differences between potential and kinetic energy, we would address it, not merely chance that the student may pick this concept up from some other activity. While there are many activities the student could perform that would include a transformation of energy such as the dribbling of a basketball, science educators would not leave it to chance that this knowledge would be somehow gleaned through the process. Why would an educator leave something as important as NOS to chance? Instead, research points to the need for a targeted intervention to dispel students' misconceptions by intentionally drawing students' attention to NOS issues (Abd-El-Khalik & Lederman, 2000a; Akerson et al., 2000; Akindehin, 1988; Bell, Lederman, & Abd-El-Khalik, 2000; Clough, 1997, 1998, 2004; Khishfe & Abd-El-Khalik, 2002; Lederman, 1992; McComas, 2000).

The research provides evidence that for NOS instruction to be effective it may need to be, at a minimum, explicit and reflective. It is quite disparaging, but implicit approaches to instruction still find their way into the classroom. There are still many teachers who believe that the mere engagement of students in a scientific task will automatically translate into knowledge of NOS (Jelinek, 1998; McComas, 1993; Moss, Abrams & Kull, 1998). To be effective, teachers need to take the next step beyond the learning of the processes of science and beyond low-level (cookbook) inquiry. However, it would be a critical error to imply that inquiry is *not* essential to NOS instruction (Abd-El-Khalik, 2001). Khishfe and Lederman's (2006) conducted research on ninth graders (previously discussed) that included combinations of approaches ranging from implicit to explicit-contextualized during the six week intervention. Though explicit instruction was superior to implicit methods, scores were marginally better for the explicit-contextualized group versus the explicit-decontextualized group. In previous research, Khishfe and Abd-El-Khalik (2002) studied 62 sixth graders for 2.5 months looking at differences between explicit and implicit-inquiry methods of teaching NOS. Similar to the later research (e.g., Khishfe & Lederman, 2006; Bell et al., 2011), evidence supports the use of explicit reflective over the more implicit methodologies. Furthermore, it supports the use of explicit reflection across a broad age range from preservice to sixth grade, which has implications for this research.

Clough (2007) suggests the effectiveness of an explicit-reflective approach should have come as little surprise. He suggests that inappropriate understandings of NOS, just like the more traditional misconceptions of content, are highly resistant to change. Implicit approaches in these cases would be ineffective at providing the necessary situations for conceptual change. It makes little sense to believe that a highly resistant misconception of NOS would yield to self-discovery method, just as it would for more traditional content. Furthermore, Lederman, Schwartz, Abd-El-Khalik, & Bell (2001) discussed how NOS should be taught in a manner similar to any other content specific knowledge where the teacher plans for and expects an outcome from instruction. Simply put, it should be planned for, taught and assessed, and not just assumed it will occur as an artifact of instruction.

In defining explicit instruction, Abd-El-Khalik and Akerson (2009) point out that care must be taken, as explicit instruction can have varied meanings. Explicit does not mean “didactic,” but rather planned for within a curriculum. The term “reflective” inherently includes complex ideas, theories, & principles when applied to instructional practice.

Dewey (1933) defined reflection as a process requiring a learner to reconstruct and reorganize his understandings. In the view of Dewey, reflection is a rigorous process that is more disciplined than other types of thinking, such as: stream of consciousness, invention and belief. According to Dewey (1916), as students are challenged by a state of disequilibrium, their own curiosity becomes the motivational impetus to satisfy their unsettledness. Reflection does not have a consistent methodology for implementation, but is more typically associated with student-centered, inquiry based, active, or collaborative practices, all of which are considered constructivist methodologies.

Khishfe and Lederman (2007) researched whether or not NOS teachings are more effective when embedded (integrated versus non-integrated) within instructional units versus a stand-alone unit. Though Khishfe and Lederman (2007) use the terms integrated and non-integrated, they can be thought of as decontextualized and contextualized. One interesting note was that little discernible difference was observed amongst groups as both groups had positive outcomes, though the group using controversial issues had a slightly larger gain. Unlike the Khishfe and Abd-El-Khalik (2002) study, which studied sixth grade science students, Khishfe and Lederman's (2007) research again turned to preservice teachers. It is not to say this study is not important, as it most certainly is; it does suggest a relationship between college and K-12 students with regard to learning NOS that may or may not exist. This finding matches the findings of others, where it would seem that enabling students' opportunities to integrate science topics in a real life context may yield beneficial outcomes in terms of NOS understandings (Bentley & Fleury, 1998; Collins & Pinch, 1998; Sadler, Chambers, & Zeidler, 2002; Simmons & Zeidler, 2002; Zeidler et al., 2009).

Khishfe and Lederman (2007) also make a tentative claim, citing the need for further investigations along the lines of how integration may provide some efficiency in terms of time spent on NOS. In a climate of high stakes tests, time spent on NOS must be balanced with the rest of the curriculum needed to prepare students. If integration yields such efficiencies, it would seem logical to pursue this line of research. As noted previously, Bell et al., (2011) mentioned the use of SSI as intriguing due to its potential to increase the decision-making abilities of students. The use of SSI for the teaching of NOS would please many (e.g., Allchin, 2011; Brickhouse et al., 2000; Clough, 2003; Ryder et al., 1999; Zeidler & Sadler, 2008) who believe that NOS must be linked to science content. Zeidler and Sadler (2008) describe any separation between the context of science and its implications and applications involving society as an artificial divorce.

SSI is a theoretical framework that promotes the integration of student decision making on a current controversial issues steeped with social ramifications. It is through encounters with SSI issues that students are able "to make reasoned judgments of scientific data; they are challenged to consider what is right, which necessarily entails normative ethical 'oughts' and 'shoulds' (Zeidler & Sadler, 2008, p. 201)." It is through the experiences with these ill-structured problems that students are provided opportunities to make reasoned judgments based on evidence, which also include competing interests and expected outcomes (Duschl & Osborne, 2002). SSI also provides students a glimpse of how science is interrelated with their own lives and the lives of the greater community by giving students opportunities to reflect on these issues (Driver et al., 1996; Sadler, 2004; Zeidler & Keefer, 2003). Furthermore, SSI can provide a contextualized setting for the study of science content and for some NOS tenets (Abd-El-Khalik, 2003; Sadler et al., 2004; Zeidler et al., 2009; Zeidler, Walker, Ackett, & Simmons, 2002).

The use of SSI to contextualize content or NOS has been shown to be effective (Khishfe & Lederman, 2006; Sadler et al., 2004; Zeidler et al., 2009), especially if the goal is toward a more functional view of science literacy. More recent research (Eastwood, Sadler, Zeidler, Lewis, Amiri, & Applebaum, 2012) reveals that while both explicit-reflective instruction of NOS within traditional content and SSI were quantitatively similar; in fact, qualitative improvements in the SSI group hold much promise. The group having the SSI treatment was able to consider multiple perspectives. Given that epistemological views appear to be context-dependent, the emergence of multiple perspectives gained through SSI within student's understandings of NOS may prove a benefit for the making of informed decisions, an ultimate goal of NOS.

It is unfortunate that assessing this type of progressive vision of scientific literacy in terms of NOS, by its inherent nature, is limited to extended responses (Khishfe & Lederman, 2006; Walker & Zeidler, 2007; Zeidler et al., 2002) or interviews (Zeidler et al., 2009), an impractical option for large scale studies or state tests. While the full benefits of this contextualized instruction provided by SSI cannot be fully assessed and appreciated in large-scale assessments, it does not diminish the fact that SSI does provide a viable option for NOS instruction and moves instruction beyond focusing on merely isolated NOS tenets. Providing students with opportunities to engage in authentic activities using socioscientific issues can and should become an important part of the strategies associated with explicit-reflective teaching methods. Research into explicit-reflective instruction has provided much knowledge of the benefits to student learning. Moreover, the explicit-reflective approach of providing students opportunities to interact with real life controversial issues also shows much promise. Unfortunately, what happens in the classroom has little to do with researched methods of instruction for various reasons and reform mandates.

Barriers to NOS instruction.

To formalize what the science education community understands about the teaching and learning of NOS, two basic conditions must be met. First, teachers need to possess their own adequate understandings of NOS. Second, they must feel NOS is an important part of science instruction in order to include it within instruction. Both of these conditions can be thought of as obstacles to NOS instruction. Even when these conditions are met, teachers are faced with other social and institutional barriers to overcome as part of general practice. These situational and institutional barriers constraints include: pressure to cover content, classroom management skills, constraints by cooperating teachers, etc. Looking at these in terms of thresholds that must be crossed, it is clear that teachers must first know the content.

Teacher knowledge of NOS.

A teacher's understanding of NOS is a necessary requirement, as teachers need to understand themselves what they are expected to teach. What is unfortunate is that teachers' conceptions of NOS are just as inadequate as students (e.g., Abd-El-Khalik & Lederman, 2000a; Duschl, 1990; Lederman, 1992, 2007; Schwartz & Lederman, 2002). Research has shown that over the past few decades that teachers have for the most part, picked up this knowledge of NOS either through their content specific coursework or their science education courses (Abd-El-Khalik & Lederman, 2000a; Duschl, 1990; Lederman, 1992, 2007; Schwartz & Lederman, 2002). For students to learn NOS, it would seem essential that teachers need to understand the humanistic manner of scientific work (Morrison, Raab, & Ingram, 2009).

As early as the 1960s, efforts were underway to improve science teachers' conceptions of NOS with little success (Gruber, 1960, 1963; Welch & Pella, 1967, 1968). Slightly more recent studies revealed that teachers' NOS conceptions seemed to be unrelated to many of the variables that one might assume important for gaining understandings of NOS: content knowledge (high school and college), science achievement, and academic achievement (Billeh & Hasan, 1975; Carey & Strauss, 1968, 1969, 1970; Olstad, 1969; Scharman, 1988a, 1988b; Wood, 1972). Therefore, the typical activities expected to encourage understandings of NOS, such as undergraduate coursework, in-service institutes, or even professional practice, did not accomplish the task of improving understandings of NOS. Should it be of any surprise that many teachers have inadequate understandings of NOS? This could be especially true for those teachers who have not been exposed to NOS through a university's preservice training program aimed at improving teacher conceptions of NOS before they enter the teaching profession. Despite a half century of NOS being emphasized as part of reform movements, to this day teachers still have inadequate understanding of it (Clough, 2006).

Science teachers tend to view science as value free and objective, devoid of uncertainty, and that any change from this focus on the facts of science (Larkin et al., 2009; Saka, 2009) would undermine this view. A host of reasons exist for why teachers have not picked up this knowledge. For many, it may be that they themselves ended up teaching science, not because they wanted to or were particularly qualified to do so; rather, it was due to the shortage of science teachers that are now available to schools. Due to recent teacher shortages in many states, schools have teachers who entered the occupation as teachers of science having little in the way of science coursework or science methods courses. For certain, in many school districts it can be regrettably uncommon to find teachers of science having the necessary pedigree to be called a “scientist.” With few having spent time doing science or having little experience in laboratory settings and/or interactions with actual scientists (Bransford & Donovan, 2005; Smith & Anderson, 1999), is it any wonder why teachers do not have a clear perspective as to the values held by scientists? They also do not understand the assumptions made by scientists as they construct their knowledge (Lederman, 1992). To teach science requires teachers to have a clear idea of what is the proper vision of science, but to complicate matters further, teachers lack the comprehensive science content knowledge, without which, NOS concepts cannot be adequately inserted (Lederman, 1992). Without this proper vision of NOS, it would seem obvious that teachers would struggle with teaching NOS, but even when NOS knowledge is present, there is no guarantee it will translate into classroom practice.

Situational and institutional barriers.

Lederman and Abd-El-Khalik (2000) discuss multiple potential influences on why NOS instruction is absent in most classroom environments beyond just teacher’s knowledge of NOS, such as institutional and curricular constraints as well as teacher intentions and experiences. These researchers go on to state that these relationships between teacher understandings of NOS and their classroom practice are more complex than previously assumed. A teacher’s understanding of NOS is essential for translating this knowledge to practice. On the other hand, a teacher’s NOS knowledge in itself is not a sufficient condition to expect changes in the classroom to appear solely due to its presence. Appropriate NOS instruction does not make it into the classroom for a variety of reason; only one of which is teachers’ inadequate understandings of NOS (Lederman & Abd-El-Khalik, 2000).

Research has provided the science education community with multiple reasons why NOS instruction is not evident in the classroom beyond teacher's knowledge of, and their perceived value of, NOS. Teachers' classroom management, classroom experience, and attitudes about students' abilities and motivations (Lederman, et al., 2001) have all been reasons cited for the lack of NOS instruction. Other factors discussed by Abd-El-Khalik (1998) that are more situational include pressure to cover content, constraints by cooperating teachers, as well as other institutional constraints. Teachers also believe they lack the essential skills to be able to introduce topics that would include discussions of topics that would paint a picture of science as a social endeavor (Lewis & Leach, 2006). Teachers may also struggle to find appropriate resources in which to teach NOS. It is sad to say that textbooks rarely include a satisfactory address of NOS despite the state mandates for its inclusion (Abd-El-Khalick, F., Waters, M. & Le, A.P. 2008; Lederman et al., 2001).

What the science education community does know is that teachers make choices about what happens in their classrooms. These choices are based upon institutional factors such as school resources, goals, and culture. Institutional factors such as accountability are focused on short term student achievement that favors the adoption of a teacher-centered pedagogy that targets rote knowledge gains (Saka et al., 2009). To many, the goal of today's science learning is to prepare students for the next level of science with the emphasis of the facts of science (Larkin et al., 2009) and not the understandings by which science constructs its knowledge. The notion that the importance of science lies within the facts and process and not the nature of those understandings is at the heart of the problem.

Importance teachers place on NOS.

Lederman & Niess (1997) express the need for teachers to develop the attitude that NOS has equal or higher status than traditional content. Teachers must also develop the attitude that the knowledge of NOS will enhance students' understandings of science content. Unfortunately, these understandings do not come naturally, nor can they be mandated. The teachers may not understand that "nature of science is not important JUST because reform documents say so. Rather, the reform documents emphasize the nature of science because IT IS important (p. 2)." This lack of knowledge about the values of scientists and science in general is certainly problematic, but this may not be the only reason NOS instruction is lacking in the classroom.

Research has found a disconnect between teacher knowledge and classroom practice (e.g., Bell, 1996; Duschl & Wright, 1989; Lederman, 1992; Lederman & Druger, 1985; Lederman & Zeidler, 1987), so that even if a teacher possesses adequate knowledge, it may not get transmitted to students. Lederman's (1995, 1999) case study research of experienced teachers determined that teachers' intentions were the most important factor affecting the teachers' translation of knowledge into practice. In Lederman's (1999) multi-case study of five high school biology teachers, no relationship was found between teacher and student conceptions of NOS. Regardless of teacher knowledge of NOS, students held naïve views. In a subsequent line of research Abd-El-Khalik et al. (1998) found that teachers' conceptions of NOS do not necessarily influence their practice. Abd-El-Khalik and his colleagues stated that beyond expanding the students' knowledge of NOS, an emphasis must be placed on its importance in order for the NOS to make its way into practice. Participants in this particular study were fourteen MAT students who had already received BS degrees in their field, but now sought teaching certification. Using pre- and post-test questionnaires to study their understanding of

NOS, students were tracked through their student teaching experience, where video-taped observations, field notes, classroom artifacts and supervisor's clinical observation notes were used to assess classroom practice. Following student teaching, a semi-structured interview was employed to generate in-depth views of participants as well as corroborate previously developed views from other data sources. Despite gains in understandings of NOS from almost all participants and the acknowledged importance of teaching this construct, little evidence was found to suggest it was taught.

Though the idea that intentions, beliefs, and attitudes play an important role in activating observable actions is not new (Collette & Chiapetta, 1994), it has more recently been associated with the importance placed on NOS. Abd-El-Khalik et al., (1998) research gave rise to the notion that the importance student teachers placed on NOS related positively to their intentions to teach NOS during their student teaching experience. In a subsequent study, Bell, Lederman, & Abd-El-Khalik (2000) state that teachers need to internalize the importance of NOS, and it is this internalization responsible for determining action within the classroom. This goes beyond whether the teacher holds NOS as an important construct, but where teachers rank NOS among the total of science knowledge. In other words, is NOS important enough to waste valuable class time on with all the other demands of the modern classroom? With most research focused on teachers' understandings of NOS, a lesser amount has been focused on other potential factors associated with teachers' understandings of NOS and translations into practices (Lederman, 2001). Bridging this schism is critical in moving toward the implementation of successful classroom practices. Lederman's research (2001) demonstrated that those teachers who did not view NOS as an important construct to be taught within their classroom were reluctant to do so.

While much research has been conducted to find ways to improve teachers' conceptions of NOS, for the most part these improvements have not made their way into the classroom practices (Lederman, 2007). Unfortunate is the belief that teachers' NOS knowledge, once developed, would translate into classroom practices (Abd-El-Khalik et al., 1998; Bell, Lederman, & Abd-El-Khalik, 2000, Lederman, 2007) as teachers would somehow equate NOS knowledge with NOS's importance. This lack of teacher internalization of the importance of NOS has hindered progress, but to overcome this barrier requires a better understanding of this internalization process and how it relates to practice.

NOS and Its Connection to Epistemological Beliefs

This internalization, or belief, that teachers place on NOS has recently developed into a new strain of research concerning epistemological beliefs, a seemingly similar, but slightly different construct than NOS. NOS is generally associated with the assumptions, values, and characteristics of scientific knowledge (Lederman, 2007, 1992; Tsai & Liu, 2005). It has also been used as a term to describe what is science, how science works, and the processes and skills employed by scientists (Clough and Olson 2008). Scientific epistemological beliefs (SEBs), on the other hand, refer to beliefs about the nature of scientific knowledge and beliefs about the nature of knowing science from a perspective associated with Hofer and Pintrich (1997). As Wu and Tsai (2011) explain, from this perspective, scientific epistemological beliefs are considered categories of personal epistemological beliefs.

Both SEBs and NOS address beliefs about scientific knowledge and knowing science. In contrast to NOS, SEBs place more emphasis on beliefs about the nature of knowing science, justification of scientific knowledge, and decision-making on socioscientific issues. For example, students who believe scientific knowledge is simple and not dependent on context may be less likely to believe that scientific knowledge is tentative (Cho, Lankford, & Westcott, 2011).

Whether or not the discussion pertains to scientific epistemological beliefs (the beliefs about the study of scientific knowledge) or NOS (related to the study of science as a way of knowing), it would seem logical that these two constructs are related (Wu & Tsai, 2011). It would also seem improbable to study one without the other. If you are studying how scientific knowledge is constructed, then you are studying NOS. If you are studying a person's scientific epistemological beliefs, then you are studying their views of NOS.

Just as personal epistemological beliefs influence how a person views knowledge and knowledge construction, looking toward these beliefs as a source, or influence, on similar or semi-related beliefs such as understandings of NOS or SEBs would seem in order.

Personal Epistemological Beliefs

For half a century, educational psychologists have researched beliefs about knowledge and knowledge construction in students with the most pivotal moment toward this line of research coming as a result of Perry's (1970) seminal work. Ever since the realization that the development of epistemological beliefs play a crucial role in the learning process, research has increased and expanded in scope over these past decades. Research in the field of knowledge and knowledge construction has uncovered relationships between epistemological beliefs and their effects upon such things as learning strategies (Schommer, Crouse, & Rhodes, 1992), motivation

(Buehl & Alexander, 2005), conceptual change (Mason, Gava, & Boldrin, 2008), and text comprehension (Schommer et al., 1992; Schraw & Olafson, 2002), just to name a few. Most important to this discussion is that research has also uncovered a relationship between these epistemological beliefs and science achievement of students (Bell & Linn, 2002; Edmondson & Novak, 1993; Roth & Roychoudhury, 1994; Ryder & Leach, 1999; Ryder et al., 1999; Tsai, 1998a; Westby & Samarapungavan, 2001).

The conceptions of NOS held by teachers are viewed along a spectrum from either a realist perspective or instrumentalist perspectives and have their roots in how teachers view the construction of, not just scientific knowledge, but all knowledge (Akerson, et al., 2006; Hagege, Dartnell, & Sallantin, 2007; Yang, et al., 2008). One view along the epistemological beliefs spectrum is associated with ideologies more like those of a realist, where scientific knowledge tells us about truth and how it is ultimately knowable (Hagege, Dartnell, & Sallantin, 2007). Postivism is a philosophical viewpoint where data is key to construction of knowledge. While both positivism, with its empirical roots and social constructivism being socially constructed and culturally moderated, can share some similarities, in that they both are independent of a philosophical realism. Though constructivism has been called unscientific for its reliance on the social construction of knowledge, Positivism too, shares the human element, requiring human constructed linkages of data. Neither philosophical position in itself guarantees truth, only how understandings arise. Critical realism attempts to bridge this gap by acknowledging there is a "to be known" world, regardless of whether or not humans are capable of understanding it or not. The difference, pedagogically speaking, is that positivist positions are most associated with views of knowledge as transferable as discrete units. These discrete units of knowledge to a more traditionalist teacher are accretive in nature, making that knowledge inherently transferable.

The characteristic of such knowledge is that new knowledge is added to old, with truth as its ultimate destination. Teachers holding views that knowledge is inherently transferable in discrete units view themselves and their purpose in the classroom as provider of knowledge (Hagege et al., 2007). Secondary teachers especially believe teaching to be the "maximum information transfer" and learning to be a concept associated with "every information absorption" (Boulton-Lewis, Smith, McCrindle, Burnett, & Campbell, 2001; Waeytens, Lens, &Vandenberghe, 2002). It is this approach to learning that distinguishes teachers into these two categories (positivist or constructivist), within these categories more like a positivist that are considered problematic and at odds with science education reform, but how do these epistemological positions affect how a teacher will teach NOS?

Just as an understanding of NOS plays a crucial role in explaining how scientific knowledge is assembled, epistemological beliefs play an equivalent role in how general knowledge is constructed in a broader context. While Schommer (1990) describes personal epistemologies as more or less independent dimensions where the structure, certainty, and sources of knowledge play important roles in the construction of knowledge, Hofer and Pintrich (1997) describe epistemological beliefs as one's own beliefs about learning and knowledge, one which is seemingly related to NOS (Abd-El-Khalik, 2003). To be clear, philosophical views are discussed to provide the reader a better understanding of how these beliefs are related, the focus of this research was concerned with pedagogical beliefs. It is important to realize these philosophical views discussed are different, but do share similarities or differences when related to the pedagogical beliefs associated with them.

Perry's initial efforts have continued to influence research throughout the past decades (King & Kitchner, 1994, 2002; Moore, 2002) and are now lending themselves to the issues inherent to teaching and learning NOS. Scientific literacy, a mainstay of recent reform under which current State standards are based (NRC, 1996), calls for the preparation of students to become effective decision makers about scientific issues, as well as non-scientific issues. To do so, science education researchers are looking at the effects of how epistemological beliefs determine teacher's instructional practices involving NOS (Akerson, et al., 2006; Yang, et al., 2008). Educational psychologists are looking at this from a broader perspective of epistemological beliefs into how students make choices involving ill-structured problems (those with no correct answer) concerning more general knowledge. These strands of research would seem to be similar and in fact add credence to the fact that these are related constructs and therefore, should be of great importance to science educators given the recursive nature of teachers' epistemological beliefs and the effects on students' beliefs about learning (Feucht & Bendixen, 2010).

Throughout this section, the reader will encounter two terms, epistemological beliefs and epistemic beliefs. These two terms, epistemic and epistemological beliefs, have been used in the literature to describe beliefs about knowledge and the processing of knowledge, with epistemological beliefs being the more common of these terms (Mason, 2010). It should be noted that some would prefer to distinguish one from the other based on whether or not the discussion pertains to epistemological beliefs (the beliefs about the study of knowledge) with epistemic beliefs related to the study of the beliefs about knowledge and knowing (Alexander & Sinatra, 2007; Murphy, Alexander, Green, & Edwards, 2007). Kitchener (2002) had previously favored this distinction, but it should be noted that this distinction comes from a researcher perspective, more so, than a distinction we need be concerned (Mason, 2010). Educational and developmental psychologists study epistemic beliefs as its focus is the more personal assumptions about knowledge, which differs from the study of knowledge itself. As Vosniadou (2007) points out, anyone who studies an individual's epistemic beliefs is really studying about epistemological beliefs. Perhaps the most important factor to consider when looking at epistemic or epistemological beliefs is their importance as a major factor in conceptual change, either as a resource or constraint (Mason, 2010). So as not to get entangled in semantics about linguistics of a person's beliefs of knowledge and knowledge construction, limitations will be placed on the discussion of these two related constructs, as these are well beyond the scope of this research. The terms epistemic and epistemological will be used interchangeably throughout this paper to reflect the sources of material, whether educational, developmental psychology, or science education, more so than any intentional separation of these distinct, but obviously related constructs. Within this next section, personal epistemological beliefs will be explained and relevance added to the argument for epistemological beliefs of teachers playing a role in their instructional practice. To be clear, philosophical views are presented to provide the reader a better understanding of these philosophical viewpoints that are relevant to the discussion of pedagogical beliefs.

History of Epistemological Research.

The most influential moment in the study of epistemological beliefs erupted during William Perry's studies (1970) at Harvard University during the 1950s and 60s. While the original intent of his studies was to investigate personality, these studies revealed a conceptual change in students' views of knowledge and knowledge construction as they matriculated through their undergraduate coursework. While educational psychologists remain uncertain about the causes of these changes, it is a common belief that increases in the sophistication of epistemological beliefs are related in some way to the educational process. Just as science education concentrates upon NOS as a tool to enrich reasoning skills, educational psychologists have been interested in broader epistemological beliefs for these same reasons.

Although grounded in elite western culture (i.e., Harvard University students), Perry's model is based upon an individual's cognitive development and states that true learning involves qualitative changes in the way students approach knowledge (Moore, 2002). Perry's (1970) work describes the levels of these developmental reasoning skills and the fact that they do develop, but what is perhaps more important is how they are tied to the student's educational experience itself (Susman, & Rogol, 2004). Perhaps a more important question for educational researchers is how these educational experiences influence this qualitative change in reasoning.

At the core of educational experiences is the desire for students to construct knowledge beyond that of content knowledge. This development of more complex forms of thought about the world requires qualitative changes in reasoning. This progression towards more sophisticated epistemological beliefs is at the heart of second nature influencing the first. Perry's (1970) model suggests that student's progress through levels of epistemological sophistication. These levels include: dualism (positions 1- 2), multiplicity (positions 3-4), and contextual relativism (position 5), toward a final goal of commitment within relativism (positions 6-9). It is at the more constructivist positions where the objective and subjective thought process are balanced, where one does not hold an upper hand to the other (Chandler, 1987, 1988). One important caveat is that an epistemologically sophisticated stage is reached only by a fairly small percentage of the population, usually reflective of advanced degrees (Kuhn, 1991).

While the lowest level of dualism, position one, is rarely found, it describes a view of knowledge as absolute and synonymous with "truth." Within this perspective, reasoning is from a perspective of black and white, with views being either right or wrong; with no tolerance for opposing viewpoints. While position two provides lip service to opposing points of view, judgments are still made from a point of view that knowledge is absolute and unquestionable; though other views may be acknowledged, they are still deemed undeniably wrong. Positions three and four are still considered dualistic in the nature of reasoning, though a progression can be ascertained through views that there is some knowledge that is "not yet known" (position 3) towards a view that "we may never know" (position 4) (Moore, 2002).

The transition between four and five is viewed as significant by Perry, perhaps due to the transcending of the *laissez faire* attitudes of position four, where attitudes of "do your own thing" or "anything goes" prevail (Moore, 2002). It is this boundary that this argument uses to differentiate the naïve from the sophisticated in terms of how knowledge is constructed. Beginning with position five, there is a shift in views about knowledge and knowledge construction that considers context as an important factor.

Position five describes a position where students have progressed through a series of position of dualism, and the potential for a growing numbers of exceptions to exist to one which includes the skills of contextualized reasoning. Within positions five and above, students now have the ability to consider alternate points of view as they acknowledge their own points of view.

This shift in epistemological stances is a major step in active meaning making, changing dramatically the conceptions of how one views knowledge and knowledge construction, even though the Perry model extends through positions six through nine and represents not epistemological changes, but ethical changes. Little work has been done on these upper reaches of sophistication as few college undergraduates are represented with the post-contextual-relativistic thinking.

From this description, it would seem that college-educated individuals should possess these more contextual and tentative views of knowledge, but in fact it is far from true. From research, it would appear that maturation alone has little, if any, effect on epistemological development (Alexander & Sinatra 2007; Hofer 2001). Rather, education can have the potential to provide the stimulus for epistemological development to occur (Hofer & Sinatra, 2010), but there are no guarantees. Hofer and Pintrich (1997) suggest that while the educational process plays a crucial role in the development of a "more sophisticated epistemological thinking" they make no claim that all students should be expected to attain this goal (p. 404). If we consider not every teacher should be expected to have contextual and tentative views of knowledge (epistemological beliefs), how does that personal view of learning and knowledge construction affect their philosophy of teaching and learning?

Teachers' Epistemological Beliefs and Their Effect on Practice

Pajares (1992) and more recently Tsai (2002, 2006) makes the point that teachers' beliefs, either implicitly or explicitly, affect students during their daily routines. These same teachers hold a host of views from beliefs about students' knowledge and knowledge construction, the role of schools, to curriculum (Levitt, 2001). While these beliefs, in turn, influence a wide variety of other cognitive processes (Pintrich, 1990). Perhaps the most important point to make is that teachers' beliefs are an important factor in determining the complex relationship of how these beliefs correlate to student outcomes (Hofer & Pintrich, 2002; Pajares, 1992; Schraw & Olafson, 2002). Even more striking is that an individual teacher's beliefs are a more predictive factor in determining the types of instruction practices he implements in his classroom than either content knowledge or instructional strategies (Jones & Carter, 2007; Pajares, 1992, Tsai, 2002, 2006). The next question that must be asked "Is the exercise of instructional practices of teachers and the relationship to teacher beliefs a common occurrence." According to both Tobin (1993) and Peterman (1993), instructional choices are the primary confirmation of the teacher's beliefs. They are also the most likely influence on instructional practice (Jones & Carter, 2007; Pajares, 1992, Tsai, 2002, 2006).

Kuhn, Cheney, and Weinstock (2000) discussed that the existing research on personal epistemology demonstrates that teachers' beliefs fall into three categories that describe a developmental continuum similar to Perry's levels of sophistication , absolutists, multiplisit, and evaluativist (in Feucht, 2010). The teacher holding absolutist views perceive teaching as transference of information from expert to naive learner. The research on passive or "received knower" as Belenky, Clinchy, Goldberger, and Tarule (1986) described in *Women's Ways of Knowing* is synonymous with Perry's (1970) dualist perception of knowledge. According to Clinchy (2002), to a "received knower," the world is black and white with one correct answer devoid of ambiguity. Truth is something that can be proven and an external factor of knowledge that is lying in the hands of authority/experts.

The “received knower” describes the learning characteristic common to absolutists views from the perspective of the learner. Feucht (2010) notes other labels have been applied from the teacher perspective to include: “objective learning models (Howard, McGee, Schwartz, & Purcell, 2000), monological discourse patterns (Johnston, Woodside-Iron, & Day, 2001), realist worldviews (Tsai, 2002), and departing absolutists (White, 2000)” (in Feucht, 2010, p.66).

In contrast to the epistemological viewpoints of absolutists, those with multiplistic views place importance on promoting a learning environment that allows students to construct their own knowledge. Resources that promote expert views are frowned upon, instead favoring a view of knowledge that is more subjective and tentative and promoting environments that encourage this type of behavior. Again, a host of terminologies have been applied to these approaches from “constructivist learning models (Howard et al., 2000), dialogical discourse patterns (Johnston et al., 2001), relativist worldviews (Schraw & Olafson, 2002), constructivist teacher beliefs (Tsai, 2002), and intuitive relativists and aspects of selective relativists (White, 2000)” (in Feucht, 2010, p.67).

Toward the other end of the continuum from the teacher’s epistemological views as an absolutist stands the evaluativist, where environments are favored promoting the collaborative construction of student’s knowledge versus the understandings of other people’s knowledge in the previous multiplistic view. Within these classrooms, teachers favor opportunities for students to explore additional sources of knowledge by complementing their classrooms with additional materials to include electronic sources and other materials generally existing outside the typical curriculum.

It is in this environment that knowledge is perceived as a context-dependent and tentative entity (Feucht, 2010). These views have also been labeled as contextualistic worldviews by Schraw and Olafson (2002), and reflective relativist and aspects of informed relativists by White (2000). It is here the question begs to be asked, “What proportion of teachers hold these epistemological views?”

According to King and Kitchener (1994), approximately 15% of college students view knowledge as uncertain and that require the cognitive efforts of reflection in order to uncover the possibilities and to contemplate and evaluate those possibilities in order to reach reasoned judgments. Baxter Magolda (2002) reported how the majority of college students in her research still fell into the transition category of knowing in their senior year of college. Transitional knowers in this study had a dichotomous view of knowledge. For some areas such as social studies and humanities they leaned more towards what Magolda (2002) described as “Independent Knowing,” whereas in the subjects of science and math, their views were more absolute with regard to the subject matter. Using these references as a benchmark, while the numbers of teachers possessing naïve epistemological views are suspect, whatever number that can be derived from this evidence is large and disturbing.

As teachers now come from numerous backgrounds and can have vastly different college experiences, it is difficult to say why specific teachers have these disparate epistemological views. One possible reason is the type of college experience: either from colleges of arts and science or colleges of education. Zeidler et. al. (2002) mention how differences in emphasis between these two camps are related to their own set of epistemological underpinnings. Regardless of the reasoning behind these differences, a more important question may need to be posed, “So what?”

Why teachers' epistemological beliefs are important.

In terms of the student, there is a growing body of research suggesting that personal epistemologies play a crucial role in learning, impacting argumentation, as well as problem solving skills (Feucht & Bendixen, 2010). Drawing from evidence on several empirical studies, it is clear that there is a relationship between epistemological beliefs and science achievement (Bell & Linn, 2002; Elder, 2002), but it is yet unclear which epistemological beliefs may be correlated with these factors (Feucht & Bendixen, 2010). Wood and Kardash (2002) discussed that all factors, with the exception of attainability of objective of truth, are positively and significantly associated with epistemological beliefs as correlated to academic aptitude, as measured by (self-reported) ACT scores. A study by Bakken, Thompson, Clark, Johnson and Dwyer (2001) looked at a group of fifth grade students who were not achieving well in math. Upon closer study, it was found that these students were capable of considering only one variable at a time. After remediation using a hands-on approach, their achievement levels increased significantly, with no improvement in the control group that received no intervention. While the investigator noted that systems affect each other (evaluation, instruction, and achievement), thereby making the point that teachers and their practices, in fact, do make a difference. This may suggest that if teacher practice is not aligned to create an environment rich in epistemological development (i.e., constructivist practices), the personal achievements of students will suffer as a result.

One important note is that this relationship is believed to be recursive (Feucht & Bendixen, 2010) as these epistemic developments encourage critical thinking abilities, such as self-directed, self-disciplined, self-monitored, and self-corrective thinking (Paul & Elder, 2008). It is this nurturing of critical thinking at elementary and secondary grades that fosters epistemic development and has become an important consideration for teacher practice (Barnes, 1970;

Paul, Binker, Jemsen, & Krelau, 1990). In contrast, environments that do not foster critical thinking can be counter-productive (Chandler, et al., 2002; Feucht, 2008; Walton, 2000), and it is the teacher holding epistemological beliefs (held subconsciously) who can have a major effect on student achievement (Calderhead, 1996) or who can adversely affect the students' epistemic beliefs (Bendixen & Rule, 2004).

So what could a classroom look like that adversely affects epistemic development, learning, and achievement of the students held in its ward? These types of classroom experiences would include teacher-centered classrooms, where knowledge was taught as absolute or assessed in a manner where factual recall is emphasized. Given the current practice in the majority of classrooms, this could suggest that the teacher role may be more important than suspected. A more common belief is that poor teaching was synonymous with no teaching, but clearly that may not be the case. Classroom environments that do not foster epistemic growth can be worse than not having experiences with knowledge that is aligned to tested curriculum. By not providing an environment that fosters epistemic development, the damage could be far worse than students missing facts and understandings. According to this line of research, teachers may be responsible for encumbering students' epistemic growth, thereby affecting future learning beyond the present. Certainly, this could be a far greater obstacle to academic achievement than a few skills or facts they may have missed during the school year. It is important to realize the role of the teacher goes beyond just the provider of knowledge.

If the goal is to help students grow epistemologically, it would seem prudent for teachers to allow students chances to exercise the limits of their knowing and knowledge in general. For the most part, this environment that must be created by the teacher should be epistemologically rich and prosperous for the students. For example, it should be one where the teacher takes on the role of facilitator and motivator; guiding discovery as students look for connections, reminding them that multiple answers may exist and always asking students “why?” It is these classroom traits that are believed to be associated with a classroom that is structured to enhance the personal epistemologies of students (Schommer-Aikins, Bird, & Bakken, 2010). Feucht (2010) discusses how theoretical frameworks exist that address epistemological aspects of learning. These theoretical frameworks include: 1) The model of life-problem-centered pedagogy (Westephal, 1990), 2) the model of educational restructuring (Kattmann, Duit, Gropengieber, & Komorek, 1996; Duit, Gropengieber, & Kattmann, 2005). 3) The working model of how epistemological theories influence classroom learning (Hofer, 2001), 4) the integrative model of personal epistemology (Bendixen & Rule, 2004). What has been found from analysis of these frameworks is the commonalities. Perhaps not surprising is that these frameworks have elements of constructivism and conceptual change learning in common (Kattman et al., 1996; Westphal, 1990). Brooks and Brooks (1993) firmly make the point that “In order for learning to take place in schools, teachers must become constructivists” (p.v). While this would suggest that if teachers were not constructivists no learning would take place, which is certainly not the case. The point to be made is that in regard to the modern mindset of educational researchers, good teaching is synonymous with constructivist teaching (Richardson, 2003), but what is constructivism and what is its opposite?

Definition and historical background of Constructivism and Positivism.

Philosophically, the constructivist learning theory is a way to make sense of how students learn (Lorsbach & Tobin, 1993, p.1). Ledoux and McHenry (2004) describe instructional methods and curriculum based in a constructivist framework (i.e., pedagogical constructivism) as one that helps students "develop conceptual models that will function as their own coding system for the to-be-known world" (p. 387).

Finding an explicit definition of constructivism is difficult because of the various forms of pedagogical constructivism that exist. Phillips (1995) describes three versions of constructivism as they apply to the learner. *Active learning* describes the role not as a passive participant such as reading or listening, but as a participant actively engaged in prediction, investigation and debate. *Social learning* would include group activities where students are engaged in dialogue, negotiation, and consensus building and understand that such things as historical perspectives are determined by the interest of the group. The creative learner, the third and final type that Phillips describes (1995), requires the learners to create and recreate knowledge for themselves. This type of learning surpasses active learning. For example, in creative learning, students may be challenged to rediscover theories and laws through exploration.

Two main types of pedagogical constructivism exist: personal, a theory of individual learning; and social constructivism, a learning theory concerning the origins of knowledge in a culture or group (Baviskar, Hartley, & Whitley, 2009, p. 542). These two concepts of personal and social constructivism were once thought to be irreconcilable (Marin et al., 2000). The outdated nature of personal constructivism was a common lament of those who rejected the Piagetian constructivism (Gilbert & Swift, 1985; Giordan & Deveechi, 1987; Posner, Strike, Hewson, & Gertzog, 1982), but while the debates continue over the different manifestations of constructivism ranging from Piaget's cognitive view to Vygotsky's social approach to constructivism, common ground can be found. Applefield, Huber, and Moallen (2001) describe four essential components of learning: (1) "learners construct their own learning; (2) new learning depends on students'' existing understandings; (3) social interaction/dialogue plays a critical role; (4) authentic learning tasks are needed to ensure meaningful learning" (as cited in Brophy, 2002, p. xi).

While many give credit for pedagogical constructivism as a learning theory to Piaget and Vygotsky (Slavin, 2000), the ideas of constructivism date back at least to the Dewey's work in the early part of the 20th century. It was Dewey who focused on the learner with his student-centered approach of education and who stated: "… education is a constant reorganization or reconstructing of experience" (Dewey, 1916, p. 89). Another view would be to have a philosophical standing residing in behaviorism. Behaviorism has its own meaning associated with it and a long historical component that is beyond the scope of this paper. It is included here as an alternate view to constructivism in that its views of knowledge construction are similar to the positivist perspective discussed previously. Behaviorism mostly assumes the learner is passive and dependent upon external stimulus to form his conceptual understandings (i.e., objective versus the subjective view of constructivists). In general, behaviorists also assume that the learner begins as an empty vessel to which knowledge can be delivered via transmission of facts.

By holding this philosophy, a teacher holds a belief that it is the educational system that needs to provide students with information that is preexisting and accepted rather than constructed by the individual using his prior knowledge as a base (Scheurman, 1998). This emphasis is placed on students' prior conceptions of knowledge as opposed to knowledge being external to the individual, only to be transmitted as needed to the student, which constitutes a major difference between constructivism and other views of teaching and learning.

While Dewey is now an icon within the education community, through the first half of the twentieth century, one could make the claim that Thorndike won and Dewey lost (Lagemann, 1989), describing the battle between early constructivism roots and behaviorism. Behaviorism was the prominent psychological theory until the 1950s when it was challenged by cognitive psychologists, and later by constructivists, but just as positivism still lingers in the conceptions of scientists and science educators, behaviorism and its objectivist ideals are not dead. Behaviorist conceptions of learning still influence instructional design in fundamental ways such as task analysis, behavioral objectives, and criterion-reference evaluation (Jonassen, 1991). While behaviorists were and are more interested in the quantitative measure of knowledge, constructivism contrasts this view, looking instead at the qualitative nature of knowledge. Constructivism involves the reorganization of initial structures of knowledge (Lonka, Joram, & Brysin, 1996) and how a person's conceptions can be changed as a result of knowledge assimilations (Strike & Posner, 1992). To be clear, constructivism is a philosophy of learning and a theory of learning, not a theory of teaching. In this manner, constructivism can be described as "a philosophy about teaching and learning rather than a specific method or approach" (Harris & Graham, 1996, p.135). The view of knowledge that comes from a constructivist perspective is individually created and influenced by social and cultural factors.

Positivism, a contrasting view of how knowledge is constructed, is a term that can have multiple meanings, from a commitment to social evolution, to a philosophical meaning involving logical positivism or a methodological tradition within scientific practice (Riley, 2007) with the latter two having correlations to this discussion. As discussed earlier, science in a positivist tradition has its origins rooted in empiricism, where socially constructed knowledge held no place. In the field of psychology in the mid-twentieth century, psychologists believed they could study only what could be measured and observed (Trochim, 2006), much like the scientists who held beliefs that science was only about the scientific method. Behaviorism and positivism, while distinct epistemologies, are seemingly similar in terms of the views of knowledge and knowledge construction perspectives they propose. These views all are at odds with the notion that knowledge is socially constructed and culturally moderated, placing them at the opposite end of the continuum of knowledge construction and far removed from constructivist epistemologies. It is important to note, although the discussions about difference in philosophical positions include the extremes, from a pedagogical perspective as they relate to this research, these differences are much more moderate.

With cognitive research supporting views about human knowledge construction, constructivism has become the major theoretical framework for science education (Staver, 1998; Fosnot, 1996); but this status has not granted constructivism sanctuary from its critics. In any philosophy, there exist extremes that must be guarded against, with constructivism being no exception. Michael Matthews voices concerns about the dangers of employing constructivist practices through implicit or discovery learning and about situations where students are not guided toward better ways of understandings, as these methods may lead to a public who views choices about science as relative. For instance, he suggests people may, when suffering from a serious disease or illness, choose experimental over tested treatments, paying little attention to scientific research (Matthews, 1998). While an interesting philosophical argument, the current tenets of NOS are much more moderate. NOS, as it exists in reform movements that serve as a foundation for many current state standards within the US, do concede that science has empirical roots based in logic and is not completely socially constructed, as clearly this would give the impression that anything goes in terms of scientific understandings. Science understandings are not completely a social construction. The current state of NOS proclaims only it has social and psychology factors associated with it, as it is fundamentally a human endeavor.

Much of the criticism comes from those who conflate pedagogy aligned to a constructivist learning theory with strictly hands-on or discovery learning; where students develop their own knowledge through social interaction, with little guidance from the instructor (Mayer, 2004). Kirschner, Sweller & Clark (2006) criticize the use of discovery learning in a critical review of constructivism and its practice. They regard practices based on constructivism (discovery learning, etc.) as a critical failure in terms of pedagogy, finding it regrettable that constructivism is epistemologically opposed to the presentation and explanation of knowledge.

For certain, extreme views exist in positivism as well as constructivism, but even the well-known proponent's philosophical views are not polar opposites. In terms of views of Realism (i.e., belief in a literal truth) and its opposite, anti-realism (instrumentalism), Loving (1991) describe philosophers such as Toulmin, Shapere & Laudan as having views of theory development based on their success as a predictive tool rather than truth based (i.e., anti-realist), with Laudan being the most vocal in terms of his anti-realist philosophy. Von Glaserfield (1990) makes the point that instrumentalists (i.e., those who view theories as models and base their status upon their ability as a predictive tool), are much less objectionable to most scientists

(Taber, 2009f). Even von Glaserfield's (1989, 1992) radical constructivist views do not deny a single reality, but are often criticized as a relativist villain. It is not that constructivists deny a reality may exist, but rather our ability to recognize that reality, for constructivism is a theory of learning, not of being (Glaserfield, 2001).

While many documents site the differences between Kuhn and Popper, these differences appear to be moderate in terms of Realism as compared to the extremes of Laudan. Kuhn makes the case that newly developed theories may not be necessarily closer to truth (1962). Popper's view is that though scientific theories evolve over time to bring us closer to truth, they are nevertheless not completely verifiable (1963). In terms of Realism or anti-Realism (instrumentalist view) there are admitted differences, but neither reaches the extremes (Loving, 1991). According to Loving's analysis of documents written by well-known philosophers, philosophical positions were not as large as one might expect considering the portrayal of both within the literature. Even the noted Philosopher Karl Popper, supporter of Positivism in his famous publication *Conjectures and Refutations* (1963), realized that observations were not something to be digested. They were instead, inventions. In other words, Popper amended positivism and acknowledged the human factor that is present within scientific investigation. Nevertheless, this new post positivist view still held onto the belief of an objective truth. This post positivist view may now be embraced by many in the critical realist camp, where reality exists regardless of whether or not it can be recognized or perceived. The extreme theoretical goal post for this notion that all knowledge is constructed and that we all have different realities, smacking of relativism, is one of the concerns about the constructivist philosophy and may extend into the pedagogical realm. This radical view of constructivism, where something exists only when there are people to perceive it (Devitt, 2001), is unrelated to the discussion of NOS and teachers' more mainstream views about knowledge and knowledge construction. While these discussions of views at the fringe serve as interesting critiques, there are few, if any, constructivists that have formally taken these radical stances (Devitt, 2001).

While clearly there are philosophical differences, the positions discussed in this research are far from a radical version of either positivism or constructivism. The pedagogical practices associated with constructivism that are deemed appropriate for the teaching of NOS are not synonymous with limited teacher intervention. So too, the discussion in this research is bounded by the continuum between pure logical and reasoning and knowledge as a social construction, with each serving as a goal post never to be reached except in the most extreme cases. Those opposed to constructivism still believe the notion that constructivists have embraced an ideology that is epistemologically opposed to the presentation and that the explanation of knowledge is problematic (Handelsman, Egert-May, Beichner, Bruns, Change, & DeHaan, R, 2004). It is these differences in epistemological stances more like that of a constructivism or more like that of a positivist that result in distinct classroom settings (Yang et al., 2008), with positivists favoring the transfer of knowledge (Windschitl 2002; Tsai 2002; Poole 1994; Hammer 1994; Lemke 1990). Neither of these epistemological positions should be regarded as radical or extreme, but there are distinct differences in classroom settings that do result from these two epistemologies. The important thing to consider is not how behaviorism and positivism differ from constructivist views, but how beliefs about these differing epistemologies affect the actions of teachers.

Why do teachers need to be constructivists?

The dominant situation in most classrooms has the teacher holding a view of knowledge that is objective (Yang, et al., 2008) and described as "outside the bodies of cognizing beings" (Lorsbach & Tobin, 1993, p. 1). This view places science as a quest for truth with science as its vehicle. To comprehend NOS requires one to understand that scientific knowledge has empirical roots, but it also has psychological and sociological components. It is a way of knowing, but not one that prescribes to the notion that truth is in any way knowable or absolute.

Teachers who employ the use of constructivist methods are able to implement a greater number of teaching strategies more effective at producing conceptual change (Hashweh, 1996). It is central to the constructivist teacher that students' prior knowledge be considered. Also, students themselves are "active and self-regulating" participants in the learning process (Harris & Graham, 1996, p.135). The constructivist considers how students' cognitive structures evolve as a result of the imposition of new knowledge within the assimilation process (Lord, 1998). By considering the evolutionary nature of knowledge, a constructivist teacher helps students develop ownership as well as a deeper understanding (Mercer, 1996). In terms of science learning, constructivism asks students to "arrive at reasonable solutions to problems, learn to gather, evaluate, and synthesize information" (p. 150), all criteria for scientific literacy (NRC, 1996).

Furthermore, when making comparisons between constructivist approaches (teaching for understanding) and the traditional approach (aimed at mere knowledge transmission), when it comes to teacher effectiveness, there are two choices. Fenstermacher and Richardson, (2000) establish that what is thought of as good teaching within many pedagogical paradigms is synonymous with constructivist teaching. Cohen (1990) states the root of the problem is most likely not that the teacher is ineffective at constructive practices; the problem is his deep rooted transmission beliefs. It would seem then that this goes beyond making teachers aware of particular activities or forms of instructions favored by constructivists. The choices teachers make about effective forms of instruction are mediated by the teachers' personal epistemological beliefs (Yang et al., 2008). Acknowledging the differences in teachers' worldviews between Taiwan and its more western counter-parts, this large scale study (n=690) demonstrated how personal epistemological beliefs were an important factor in the development of classroom environments. Each participant filled out a paper-pencil survey and a questionnaire designed to explore teacher's personal epistemology. Furthermore, the large sample enabled these colleagues to make well-supported claims that the educational system itself affected teachers in a negative manner. Teachers with more experience were more likely to be hold views about teaching and learning that were contrary to a constructivist viewpoint. While experience was portrayed as a negative factor for these teachers, teachers who received enrichment through professional development programs did have marginally more views more toward the constructivist perspective in terms of instructional methods from their peers. Yang et al. (2008) derive from this study that Taiwan needs a serious examination of its policies towards teacher education process within the higher education establishment (Yang et al., 2008). What is learned through this study and other works is that if the science education community changes in practice, then what is needed is a shift in teachers' epistemological beliefs, from positivist to constructivist (Yang, 2008).

Lorsbach & Tobin (1993) refer to the importance of the acceptance of the constructivist philosophy as an influence on a science educator's metamorphosis. This change transforms the teacher from one who places an emphasis on the history of science as a viable tool for NOS instruction toward one requiring the sequencing of instruction to better place NOS understandings at the forefront of instruction. Sequencing instruction for better understandings sounds much like explicit instruction, a required instructional component required for proper NOS instruction. Lorsbach and Tobin (1993) go on to describe how these implications for the acceptance of constructivism may also include the ability to shift roles from provider of information towards one that would allow students to speak freely in cooperative learning environments, and then to share these constructed ideas with the class as a whole. This shift in classroom environment could help students explore science misconceptions in more depth, resulting in deeper understandings. This latter focus of cooperative learning and constructing knowledge is seemingly similar to the factor of "reflective" as referred to in the explicit-reflective instruction of NOS. A science educator's constructivist mindset is intimately wedded with his interest in student's conceptions of NOS (Wheatley,1991), as well as their classroom and instructional approaches (Lorsbach & Tobin, 1993). Research has shown that characteristics about how teachers view their practice as either constructivist or postivist (Akerson & Buzzelli, 2007; Perry, 1970) influence the ways they conceptualize NOS.

From an initial pool of 40 and based upon scientific epistemological beliefs, Tsai (2007) purposely selected and interviewed 4 middle school science teachers. These teachers represented in this research were all from Taiwan raising transferability issues due to the potential of differing worldviews. Furthermore, the research only entailed a very small number of teachers (n = 4). In contrast to many studies of epistemological beliefs, either specific to scientific epistemological beliefs or personal epistemological beliefs, the participants were experienced teachers, lending credence to the reliability of the research. Through these interviews, Tsai (2007) found that teachers who held more positivist-oriented beliefs, lectured more, focused more on test scores, tutorial practice problems, and in-class testing. In contrast, Tsai (2007) found that teachers holding more constructivist–oriented beliefs held more interactive discussions, inquiry and in general focused on student-centered activities. Not surprising is that teacher's beliefs about knowledge are also related to their views of teaching science (Tsai, 2002, 2007).

Scientific Epistemological Beliefs

Tsai (2002) found a positive relationship between 21 of the 37 interview subjects to suggest close alignment between scientific epistemological beliefs (SEBs) and teachers' instruction and learning of science, what is referred to as "nested" epistemological beliefs. Teachers' beliefs were categorized based on their beliefs about teaching, learning and science into three categories: traditional, process, and constructivist. It was concluded that most (21 of 37) held views considered traditional. The study consisted of physics and chemistry teachers with bachelor's degrees in the respective disciplines. It is unclear if these teachers have experienced any coursework in teaching and learning. While there is uncertainty about where these beliefs stem from, it provides an important example of how epistemological beliefs about teaching and learning can and do affect classroom practice. These findings, as they relate to other research, also provide information about how empirical views of science transcend cultures and are perhaps related to teacher's own classroom experience (Aguirre, Haggerty, & Linder,1990; Donnelly, 1999; Gustafson, & Rowell, 1995; Koballa, Graber, Coleeman, & Kemp, 1990; Tsai, 2002).

If these beliefs about teaching and learning have such an effect on practice, clearly they deserve the attention of the science education community. This transfer of teacher belief (about the importance of NOS) to practice becomes abundantly important considering what happens when students develop their own belief system about science (scientific epistemological beliefs) as a result of instruction.

Student SEBs (or philosophical views toward science) affect students decision-making patterns with regard to scientific issues and their overall orientation toward learning about science (e.g., Bell & Lederman, 2003; Edmonson & Novak, 1993; Tsai, 2000a; Wallace, Tsoi, Calkin, & Darley, 2003). In comparing the two contrary belief structures, students holding views that science knowledge is discoverable and completely objective (positivist) have a less sophisticated understanding of science than students with SEBs leaning towards a more constructivist viewpoint with evidence, effects of the scientific paradigm of the time, and negotiation (Tsai, 1998a, 1998b,1999a, 2000b; Wallace et al., 2003).

In a similar manner, teachers' SEBs have been found to have positive relationship with practice. Hashweh's (1996) study of 35 science teachers revealed that teachers with SEBs related to a more constructivist belief about learning were more likely to take into consideration how students learn. He found through the use of questionnaires and survey data, that teachers with "constructivist-oriented views were more likely to consider students' alternative conceptions, have a richer repertoire of instructional strategies, use more effective ways for promoting student conceptual change, and report more frequent use of effective teaching strategies than did teachers with positivist-oriented" scientific epistemological views (p.45). Questions about the transferability of this study do raise concerns due to cultural and training differences between these participants versus their western counterparts. Teachers in Beirut may enter the classroom with as little as two years of college, but again, the large sample size and use of practicing teachers makes these important findings to consider. Furthermore, these findings match similar (Benson, 1989; Gallagher, 1991) and previous studies by the author (Hashweh, 1985) conducted in the US.

Recent research by Akerson et al. (2010) investigated how more general epistemological beliefs, through the use of epistemological positions (based on epistemological views about knowledge and knowledge construction) determine relationships with the practice of preservice teachers. The study's focus was on how these epistemological positions, with regard to how preservice teachers conceptualized NOS, affected practice during their internships. Perhaps not surprising, the biggest influence was that of the supervising teacher. To extend the work along this line of research, this research proposes to look beyond preservice teachers towards traditional teachers, who would not be bound by the influence of a supervising teacher. The research by Akerson et al. (2010) also extends the current boundaries of recent investigations to include, not just scientific epistemological beliefs, but the more general views about knowledge by individuals (i.e., personal epistemological beliefs)

Epistemological Positions and NOS

Epistemological positions and their effects upon NOS can be thought of as one's second nature affecting the first. It is unfortunate that these epistemological positions are not as easy to study as the refraction of light, a simple and are a somewhat isolated concept. Duell and Schommer-Aikins (2001) state that these epistemological beliefs are fragmented and complex in nature; but how are they responsible for affecting the importance placed on NOS?

Even after teachers have received explicit NOS instruction during their science education coursework, teachers struggle with conceptualizing NOS due to the level of sophistication of their personal epistemological beliefs (Akerson et al., 2006; Akerson & Volrich, 2006). A study by Akerson et al. (2006) looked at nineteen elementary preservice teachers in a preservice methods course and found that epistemological positions are related to the sustainability of learned NOS. Using the *Views of Nature of Science* version B (VNOS-B) (Lederman et al., 2002) and follow-up interviews, student understandings of seven common characteristics of NOS (Lederman & Abd-El-Khalik, 1998; NSTA, 2000) were determined. At the beginning of the methods course the VNOS-B was given to the students followed by a 45-minute interview to both confirm that the researchers' interpretations of the VNOS-B were correct in order to gain a more in-depth understanding of each student's beliefs. After the initial questionnaire and interview, students experienced what are common context-free activities. At the end of the semester, students again went through the process of questionnaire and interview process to determine changes in their understanding of NOS. It was at this time that students' understandings of the seven characteristics of NOS were aligned with their epistemological positions according to the Perry scheme. Five months after the course, students came back for one more set of questionnaires and interviews. Through the comparison of Post and Post-Post Tests, it was determined that epistemological positions played a role in retention of NOS views.

While this is an encouraging finding, it still begs the question of what happens after years of teaching, or what happens alongside the potential for continued epistemological growth of teachers. Also, there is a discouraging message within this research: if a teacher does not already have an epistemological position equal to a level 5 on the Perry Model, then long-term conceptualization of NOS does not occur (Akerson et al. 2010). Previous research (Yang et al., 2008) suggests an inverse relationship between experience and epistemological position.

A previous Akerson study (Akerson et al., 2008) found that teachers with more constructivist positions also held more sophisticated understandings of NOS. In a continuation of this strand of research into teacher's epistemological positions, these authors looked at how epistemological positions relate to NOS emphasis and classroom practice, using four elementary teachers (K-3) purposefully selected based on the adequate views of NOS. These intern teachers had varying epistemological positions based upon the Perry scheme. Through the use of observation, video-tape, lesson plans and field notes, data were collected during the preservice teacher's semester long internship. Two to four observations were made on each of the four teachers each lasting from 30 to 45 minutes. The findings of this study revealed that the factor impacting how often teachers infused NOS into the lessons was the facilitating teacher. A limiting factor of this study presented by its authors was that there were no explicit questions about NOS instruction during the pre- and post- interviews. What differentiates the study by Akerson et al. (2010) from others is that this is one of few studies that specifically looked at personal epistemological beliefs. Most previous studies, including Akerson et al., (2006) drew epistemological positions from understandings of NOS. In the study by Akerson et al. 2010, epistemological beliefs were garnered from an instrument (Kelton & Griffith, 1986) specifically designed to determine personal epistemological beliefs and relate them to Perry's scheme.

There is evidence to suggest how personal epistemological beliefs and their associated positivist or constructivist views affect instruction. It is more important to note that these positions can be at odds with philosophies associated with learning (Tsai, 2002). Teacher epistemologies have been shown to affect teachers' practices (Tsai, 2002). It is these same limitations of epistemological beliefs that may limit inquiry-based instruction (Roehrig & Luft, 2004). Research states that teachers' epistemological beliefs inhibit certain practices within the classroom (e.g. Akerson et al., 2010; Tsai, 2002). Just as a lack of NOS knowledge can affect a teachers' practices, there is no denying that social and institutional factors can play a role in what happens in the classroom (Larkin, Seyforth & Lasky, 2009; Abd-El-Khalik & Lederman, 2000; Saka, Southerland & Brooks, 2009); however, a teacher's beliefs assert a more major influence on classroom practices (Abd-El-Khalik, 2005; Roehrig & Luft 2004; Tsai, 2007, 2006, 2002). Where these practices originate from is also well known, in that teachers' realist conceptions of knowledge tend to produce teacher-centered practices of lecture and other activities more focused on knowledge transmission. Most teachers hold positivist views, where knowledge is objective and controlled by the authority figure. Those teachers holding these views emphasized the facts and concepts of science and NOS was limited to the teaching of the "scientific method" (Abd-El-Khalick & Lederman, 2000).

Conclusions

To date, the science education community supports belief that a student's sophisticated understanding of the nature of science (NOS) plays an important role in the development of scientific literacy. While much has been learned about how to teach the nature of science and some about how it is learned, the path has not been fully cleared to a point where science educators can be confident that students will have an adequate understanding of the nature of science before they leave school.

At present, it is disappointing that students and teachers both possess inadequate understandings of NOS, (Lederman, 2007), and this situation is unacceptable for both the profession of science teaching and the scientific literacy of our current and future students. We know from research that teachers can learn NOS, but this knowledge may not translate into practice (Abd-El-Khalik & Lederman, 2000; Lederman, 1999) for a host of reasons. One of those reasons may be the teachers' own personal epistemological beliefs. As research has shown, (Tsai, 2004) personal epistemologies correlate to the types of classroom practices as they are related to the importance teachers' place on NOS. Without the support of the teacher, student understandings of NOS as an outcome will stall as "intentions towards teaching NOS are critical" (Lederman, et al., 2001). The point to be made is clear: For teachers to be effective in the classroom**,** they must become constructivists (Brooks & Brooks, 1993). The mandate of reforms (NRC, 1996) suggests that a stronger constructivist approach be employed (Karakas, 2007) along which an acknowledgement that for NOS to be learned, it must be presented in an explicit-reflective manner (Lederman & Abd-El- Khlaik, 2000). Students must be allowed to seek out their own understandings and gain appreciation for uncertainty; both are important tenants and should play an important role in a constructivist classroom.

It is not just that teachers have inadequate views of NOS (admittedly this would be a limiting factor); it is also that even when teachers gain understanding of NOS, teachers' epistemological views may hinder the desired instruction. Yang et al. (2008) suggest that teachers' epistemological perspectives are often centered in what Perry (1970) described as the positions of dualists' or multiplicists' epistemological positions, which are not congruent with constructivism. As well, these views of knowledge suggest that these positions are "philosophically more like that of the positivist" (Yang et al., 2008, p.13). If teachers have a view centered in positivism, is it any wonder why difficulty arises as they attempt to teach the nature of science?

In conclusion, the problem may not that these teachers cannot be taught NOS; rather, it may be that these teachers may be encumbered by their epistemological perspectives rooted in positivism and are not *able* to teach NOS in an appropriate manner. They may be held back philosophically by their own personal epistemological beliefs and, as a result, so are their students. Just as intentions to teach NOS are a crucial factor in the teaching of NOS (Lederman et al., 2001), clearly additional research is required to investigate in what ways epistemological beliefs may affect teachers' practice.

Chapter Three: Methods

Introduction

This study was built on the premise that epistemological beliefs, whether aligned with constructivism or positivism, have an impact on teacher's pedagogical practice during NOS instruction. The methods used reflected the need to better understand the dynamic through the use of a mixed methodology. To understand this relationship as it applies to practice, it was necessary to employ a process by which a deep description of the classroom setting could be established (Bogdan & Biklen, 2003). In order to gain an understanding of the relationship between the two epistemological beliefs constructs and practice, the study employed an interpretative approach. This interpretive approach (Bogdan & Biklen, 2003) was used to track teachers' teaching of NOS and to relate their teaching to their epistemological beliefs and institutional barriers. To this end, the research design was a descriptive and interpretive approach to analyze both qualitative and quantitative methods.

The purpose of this mixed-methods study was to determine relationships between personal epistemological beliefs, NOS, and the values teachers place on NOS instruction. Research studies mentioned thus far have relied on survey data of multiple choice and extended response alone (Yang et al., 2008) or a combination of extended response, interviews and classroom observations (Akerson et al., 2006; Akerson et al., 2008; Akerson et al., 2010) and only looked at teachers' scientific epistemological beliefs with the exception of one. It was only the research conducted by Akerson et al. (2010) that looked specifically at personal epistemological beliefs. In order to gain a more clear understanding of the effects of these beliefs (personal and scientific) as they relate to teacher practice this investigation is comprised of both quantitative and qualitative measures, as well as both personal and NOS.

The primary goal of this study was to explore the relationship between these two epistemological beliefs and how these beliefs affect how teachers value NOS and how this valuation affects classroom practice. A secondary goal was to examine the role of other institutional-related barriers that inhibit the types of instruction teachers would prefer to implement. A third consideration was how these same beliefs transcend into the more general content of scientific practice and skills. A fourth consideration was how the instruction of "practices and skills" differs from what was observed during NOS instruction as they related to teacher beliefs. Practice and skills of science are defined as the processes necessary to conduct scientific inquiry (e.g. observe, predicting, measuring, interpreting, and controlling variables).

The questions guiding this research were derived from decades of research into the learning and teaching of NOS, namely that even when teachers possess an adequate knowledge of the NOS construct, translation into practice is not guaranteed (Abd-El-Khalik et al., 1998; Bell et al., 2000; Lederman, 1992). The research strand that guides this investigation has developed from the presupposition that epistemological beliefs affect classroom practice more so than knowledge of NOS (Olafson & Shraw, 2010), as well as how these beliefs affects teachers views of the importance of NOS (Akerson et al., 2008). The following research questions are offered:

Research Questions

1. *In what ways do teachers' epistemological beliefs affect practice in the science classroom during NOS instruction?*
   a. *What is the nature of the relationship between personal epistemological beliefs and understandings of NOS?*
   b. *In what ways does the co-occurrence between NOS and personal epistemological beliefs affect the importance teachers place on NOS?*
   c. *In what ways does the co-occurrence between NOS and personal epistemological beliefs affect the classroom activities during NOS instruction?*
   d. *What other factors are responsible for influencing the choices they make about classroom instruction?*
2. *In what ways do classroom practices differ between NOS instruction and instruction of scientific practices and skills?*
   a. *In what ways are these differences reflective of understandings of NOS?*
   b. *In what ways are these differences reflective of personal epistemological beliefs?*

Participants and Setting

A selection of sixth grade physical science teachers were asked to participate in this study. The choice of the sixth grade physical science was a purposeful selection, based upon curriculum with in-depth reasons to be explained later in this section. The selection of classrooms and teachers comes from a large suburban district (90,000+ students) located in the southeastern US between two major metropolitan cities. The participant teachers were drawn from the district's 18 traditional middle schools, giving this sample a broad scope from semi-urban to rural. The district's largest city has been listed as having one of the highest poverty rates in the country, according to the Brooking Institution (2010). Of the nearly 170 public schools within the district, 90 are designated as Title I. Of the 18 traditional middle schools where teacher participation was solicited, 15 are Title I. The district also consistently ranks in the bottom 20%, based on test scores within the state.

The teachers in this district possess a range of experience, from first year teachers to 30+ year veterans. They also come from various backgrounds, from career changers to life-long educators, and come with a broad range of science training. Most teachers in the district have had opportunities for exposure to NOS knowledge through written communications from the district office personnel (i.e., the principal investigator). At that time, I was the Secondary Science Coordinator for the School District and these communications were part of my duties. The purpose of these communications was to develop teachers' understandings through the use of humorous anecdotes describing the common misconceptions of NOS (e.g., theories do not turn into laws). These "Monday Misconceptions," as they became known, were sent to all secondary teachers throughout the 2010-2011 school year.

In terms of Highly Qualified Teachers (defined as passage of a content test), the district's percent of Highly Qualified Teachers (HQT) (95.1%) was above the state's average (93.9%) for the 2008-09 school year. The following year (2009-10) the district increased the percent of HQT to 97.3%, as compared to the state's average of 95.2%. In terms of educational status, 72% of the district's teachers held bachelor's degrees with almost 26% holding a master's degree (10% below the state average). The turnover rate for teachers within this district remains high, with an average over a three year period of almost 20%.

The demographics of the district's students ran the full gamut of race and socioeconomic status. Based on the 2009-2010 district data, the student population consisted of: White (49.60%), Black (23.60%), Hispanic (23.40%), and other (3.40%). In contrast, the instructional staff according to 2009-2010 data, report that teachers were primarily white (82.66%), with Black (11.26%) and hispanic (5.22%) teachers making up approximately 16% of the teacher force. While there was clearly much work to do within the district to raise the level of overall student achievement, the past 6 years have seen many changes taking place in an effort to move the district forward. Curriculum maps were put into place to ensure students would have access to the entire curriculum content to be tested on high stakes tests. Through this curriculum mapping process, it was decided to make every effort to ensure teachers would cover NOS content in a manner to which it was reflected on the state's high-stakes test. Currently, NOS knowledge accounts for almost 20% of a student's score on the state's high stakes test given to all 8th grade students. The first 9 weeks of the mandatory sixth grade course was designed to emphasize the importance of two related but differing concepts, the processes and skills of science and the NOS. As this situation was still present when this author assumed his role, first as the secondary science coordinator and now as elementary science coordinator for the district, it makes sense to use this as an opportunity to research teachers' practice over this extended time-frame. It is this first class in middle school (physical science) that provided the setting for this research.

During this timeframe of data collection, the researcher used a combination of "comp" time and vacation time to accommodate the observations. All time spent on research and job related tasks were carefully documented in the researcher's calendar. It should be noted the researcher's role as Elementary Science Coordinator having previously worked as the district's

Secondary Science Coordinator may have affected teacher behavior. Great care was taken to explain the reason for my visits especially that these observations were not evaluative from a District perspective and notes gained from these sessions would never be shared with school officials. Also, the voluntary participation of this research study may have taken away much of the wariness of teachers as only those who would have felt at ease with my dual role would have applied. With the exception of two participants, the researcher knew the participants and had previous opportunities to develop a level of trust. While classroom observations of any kind can be nerve wrecking for a teacher, those from District level staff especially so, at no time did the researcher feel his presence was affecting the research task.

The teachers were initially contacted about their potential participation in this study the first week of August 2012. Once preliminary agreements took place via email and IRB forms returned, participating teachers took an online version of the E*pistemological Belief Survey* (Wood & Kardash, 2002; See *Appendix A*) and the *SUSSI* survey (Liang, Chen, S., Chen, Kaya, Adams, Macklin, & Ebenezer, 2008; See *Appendix C*) before August 16th. In an effort to maintain transparency within this research, total scores of each epistemological instrument were provided to participants if they asked; however, none did. It was explained to teachers that these scores represented positions or views about knowledge and knowledge construction for both general knowledge and science knowledge. It is important to note that this survey and the subsequent one were given before observations may have had an effect on the classroom practice of the participants. It was also explained to the 28 original participants in Phase One that their selection into Phase Two was determined through the use of epistemological beliefs of both general and science knowledge. Other potential selection criteria were school location, years of experience, courses taught (e.g., regular or honors), number of science courses taken, and degree.

Using the epistemological beliefs survey as a guide, a purposeful sample was chosen to provide a range of epistemological beliefs. These select eleven teachers became participants in the second phase of this research study. They were extensively studied through interviews, observations and collections of classroom artifacts conducted throughout the first 9 weeks of school. Each of these eleven teacher participants completed two interviews throughout the instruction unit (pre and post) and as many as five observations.

Of the 28 participants who completed the initial surveys for Phase One of the Study all were Caucasian. They represented thirteen different middle schools, with all but one having Title One status. There was no obvious reason why there was a lack of representation by five of the traditional middle schools. All the District principals were contacted to ask permission to approach teachers for the research. Only one school voiced concern over the research and asked that their teachers not be contacted. As for as the other four schools, it may have been a combination of District restructuring of both administrators and teachers at that time that caused the message to get lost. It may also have been just a random occurrence that those teachers chose not to participate, but it was not due to a lack of research effort to include those schools. Another potential reason is that I have had more contact with some schools more so than others, resulting in a comfort issue to participate Years of experience ranged from several years of teaching to 30^{+}- year veterans. The Phase I participants were drawn from a larger pool of about 70-80 total teachers. The sample of participants represented a little over 35% of potential participants. The average teaching experience for the Phase One group was slightly higher (approx. 16 yrs.) than the Phase Two group (approx. 13 yrs.). The Phase Two group represented 10 of the original 13 schools from Phase One. Included in the Phase One portion were 6 males and 22 females. The Phase Two participant group was comprised of 4 males and 7 females.

The study was approved by the University of South Florida's Division of Research Integrity and Compliance as well as the Polk County Schools Office of Assessment. All participants received an overview of the study before taking the initial surveys, as well as contact information for additional questions.

Instructional Context

The study occurred during the first quarter (9 weeks) of a sixth grade physical science course, a compulsory course all sixth grade students take. Sixth grade physical science was the introductory course for secondary students who have had little exposure to science, especially hands-on activities, during their elementary years. From my previous role as Secondary Science Coordinator, many challenges existed to encourage the teaching of science within these early grades. As science is not annually assessed as are math and reading, its inclusion within the school day, especially for grades K-4, can be limited.

Currently, while science is state tested only at the fifth grade level, there are important benchmarks that are mandated throughout K-5 (FLDOE, 2012). With the priority on the tested benchmarks of reading and math at the earlier grades, it is difficult for schools and teachers to place a priority on science given the high stakes testing environment. The challenge to incorporate science into the classroom at these earlier grades remains an obstacle. The reality is that science does not become a priority until fifth grade. The problem with this practice is that benchmarks that are mandated for earlier grades that are not mentioned in the fifth grade benchmarks, leaving holes in students' understanding of certain concepts. From both informal and formal discussions with principals and teachers as the Senior Coordinator for Elementary Science, I know that in many cases, science was not taught with any fidelity until 5th grade. The quality of this one year of science is then dependent on individual teacher quality at that particular school, leaving further questions as to the quantity and quality of student understandings. It was this lack of knowledge of and about science that prompted my predecessor to establish a prominent unit in sixth grade to focus on NOS and skills and practices of science.

The first nine weeks are aimed at providing an introduction to science, the nature of science, and its methods. Throughout the first nine weeks, several content strands are purposeful for the instruction of NOS (See *Appendix B*). The reasoning behind this front-loading of NOS content was a deliberate attempt to make sure students were exposed to aspects of NOS before delving into years of content instruction. This curriculum arrangement was put into place, with the help of several teachers, myself included, by a previous science supervisor to help ensure NOS would be taught in a manner reflecting its importance on the state's high-stakes test. This was not to say that NOS should only be taught during this limited time period, only that this was a deliberate attempt to place NOS at the forefront and have a better chance that it would be interpreted as valuable within the curriculum. Though it is included within the teaching unit, there were no guarantees as to the quality of this instruction. There are no mandated activities for its instruction as choices about practice are left to the classroom teacher. This design, which was built into the School District's 6th grade physical science curriculum maps that teachers are expected to follow, has been in place for over six years. The District in which the investigation took place required teachers of science to teach NOS as part of the prescribed curriculum map and as mandated by Florida's *Next Generation Sunshine State Standards* (NGSSS). Specifically, the 6th grade physical science course requires nine weeks of NOS instruction as an attempt at front-loading NOS instruction and to better guarantee fidelity of this important construct.

Though the nine weeks was taught within a unit sequence commonly referred to as the NOS unit, much of it falls almost exclusively within the realm of scientific processes or skills (PS) as described by the District's curriculum maps as to what students should know at the end of the unit. The following table (See Table 1) represents the concepts to be taught within the district's curriculum maps. The second column that is included describes the concept as either involved directly with NOS or falls within the domain of the processes and skills of science. This separation between NOS and practice & skills is placed in this table (See Table 1) to help the reader understand how the curriculum maps define and limit the scope of what students need to understand at the end of the unit. It is important to note, these concepts are not differentiated within the curriculum maps as PS or NOS for the teacher.

Though many of these concepts could be taught within the NOS domain and some even had a minor NOS related component included, these items included on the district curriculum maps marked as "PS" fall mainly within the area of a process skills and not NOS. For example, the language used to describe scope of instruction within the *Empirical Evidence* portion of the curriculum map emphasized the practices and skills needed to do science, such as graphing, use of technology, and identification of variables more so than any philosophical underpinnings about science. This is not to say a teacher possessing a sophisticated understanding of NOS could not make these connections, but these connections are not obvious within the curriculum map language. Clearly, there is research to suggest the decontextualized tenets of NOS can be taught effectively through activities focused on practices and skills (Clough, 2006). As an example, the concept of *Models* has four subcomponents: 1). to discuss with students the types of models, 2). benefits and limitations of models, 3).how they are helpful to understanding how things work, and 4). useful in terms of describing findings. These subcomponents listed under the concept of models within the curriculum maps seem to focus mostly, with the exception of subcomponent four, on student's familiarity and skill involved in using models versus how models are related to theories as a predictive tool. Three of the four listed subcomponents were more directed at students' learning of a practice and skill; it is this emphasis that prompted the categorization of this concept as PS on Table 1.

The Law of Gravity in terms of a mathematical model serves as a predictive tool to describe interactions between any object having mass, yet this knowledge does not help us understand how the effect occurs, only that it is related to mass and distance. An example of instruction on models that would focus on the practice and skills rather than NOS, might include having students using a model, either mathematical or pictorial, to answer questions (e.g., gravitational forces between planets, finding a location on a map, etc.). Another example would be the common model of the atom. This model is extremely useful in determining interactions between other atoms, but conversations about the fact this model may have no resemblance to the way an atom actually looks was absent from the District's Curriculum Maps.

Table 1

Curriculum for First 64 Days of Class with Denotations of Purpose of Concepts

Concept:	NOS (NOS)/ Process and Skills (PS)	Recommended Days of Instruction
What is Science?	NOS	
What is Not Science?	NOS	15 days of instruction
Science Impacting Society	NOS	
Investigations and Experiments Scientific	PS	
Processes	PS	25 days of Instruction
Empirical Evidence	PS	
Pose a Question	PS	
Conduct Research	PS	
Develop a Hypothesis	PS	
Design an Experiment	PS	12 Days of Instruction
Conduct an Experiment	PS	
Analyze Data	PS	
Models	PS	
Theories	NOS	12 days of instruction
Laws	NOS	

Research Design and Methodology

The purpose of this study was to investigate teachers' epistemological beliefs and the influence of those beliefs on practice during NOS instruction, as well as how these beliefs interact with other more traditional barriers (e.g., accountability, pressure to cover content, constraints of cooperating teachers or administrators and perceived student abilities). Using an interpretative mixed-methods design, both qualitative and quantitative data were obtained in order to generate a better understanding of these relationships. Quantitative measures were used to determine relative levels of epistemological beliefs for both personal epistemological beliefs (EBs), NOS, and pedagogical practice. Qualitative measures were employed to look at potential relationships between teacher's SEBs, EBs, pedagogical practice and other impediments, such as social and institutional barriers, to teachers' practice.

The reasoning behind the use of quantitative measures was to gain a better understanding of potential associations between teachers NOS and personal epistemological beliefs. The idea behind the use of qualitative methods was to probe teachers' views of practice, whether teacher- or student-centered and relate those views to the importance teachers place on NOS, as well as to how these practices are reflected in their views of knowledge and knowledge construction. Fraenkel and Wallen (2003) describe the use of qualitative or descriptive methods as a starting point for most research. Patton (2002) on the other hand, describes these practices as "detailed descriptions of situations, events, people, observed behaviors, direct quotations from people about their experiences, attitudes, beliefs, and thoughts …" (p. 22). As epistemological beliefs of participating teachers are an important variable thought to effect instructional practice, garnering insights via a qualitative practice seemed of utmost importance. Through the use of these qualitative measures, teacher conceptions concerning NOS as an important construct, personal epistemological views, and choices about selected practices became evident and helped answer the questions concerning in what ways do these constructs affect practice.

Quantitative measures were employed to describe, compare and investigate the correlation between teachers' nature of understandings of personal epistemological beliefs versus their understandings of NOS. These descriptions, comparisons and investigation of correlations also extended to teachers' practices. Using *SPSS Version 17*, descriptive statistics were generated to ascertain the categorical groupings for the participants, descriptive statistics and correlational information were used to construct understandings about the variables that potentially could affect practice. As a result of applying a mixture of quota and maximum variation sampling (Miles & Huberman, 1994), participants' understandings of personal epistemological beliefs and NOS understandings were grouped into three categories (Low, Mixed [Transitional], High). Those participants scoring more than one standard deviation above the mean were categorized as "High." This rating of "High" further corresponded to a higher score on the epistemological beliefs survey. Participants scoring within one standard deviation of the mean were categorized as "Mixed." Mixed or transitional views represented the more typical view of epistemological beliefs as they related to the sampled group. Similar to the previous categorizations, participants scoring one standard deviation below the mean were categorized as "Low." The quantitative measures were used to help describe the relationship between practice and epistemological beliefs during NOS instruction as well as skills and practices instruction.

Quantitative data served as the determiner for teacher selection, as well as provided correlational information to answer *RQ1a*, “What is the nature of the relationship between personal epistemological beliefs and understandings of NOS?” All other quantitative data served the purpose of providing additional information to gain a deeper understanding of the epistemology beliefs and practice through the use of triangulation. In this sense, the quantitative data served as support for the qualitative analysis.

Beyond the qualitative interviews and quantitative data collection methods previously mentioned from the epistemological beliefs and the nature of science evaluations, classroom observations took place to better ascertain the teacher practice. Within these observations, which are part of the normal task of the researcher fulfilling the role of curriculum coordinator for the School District, observations took place and data collected in both a quantitative and qualitative manner. The types of data collected included a qualitative and quantitative collection of common practices associated with either constructivist or positivist practices. Additionally, a journal was kept to record the researchers thoughts about the classroom experience.

Instruments/Measures

Each of the outcome variables under consideration were evaluated using mixed methods. NOS was examined through the use of the *SUSSI* survey (Liang et al., 2008; See *Appendix C*), and an interview protocol developed by Herman et al., (2011).

Personal Epistemological beliefs were evaluated through the use of the *Epistemological Beliefs Survey* (*EBS*) created by Wood and Kardash (2002) (See *Appendix A*). Using an interview protocol developed by Herman et al., (2011), epistemological beliefs were probed as they related to the teaching of NOS. Classroom practices were evaluated through the use of the *NOS-COP* (Herman, Clough, & Olson, 2013; See *Appendix D*).

Table 2

Instruments used during the study

Construct	Quantitative	Qualitative
Nature of Science	Students Views of Science and Scientific Inquiry (*SUSSI)*	Students Views of Science and Scientific Inquiry (*SUSSI*) & Interview protocol
Personal Epistemological Beliefs	Epistemological Beliefs Survey (*EBS*)	Interview protocol
Other Barriers (e.g., institutional and social)	*NOS-COP* (walk-through form)	Classroom Observation Protocol
Pedagogical practices	*NOS-COP* (walk-through form)	Field Notes

***SUSSI*: Nature of science.**

Many students, and even teachers, are not able to express their views appropriately on an open-response format survey. It is common in these cases for the participant to respond with few words, leaving the researcher with few clues to base an inference (Liang et al., 2008). In contrast, the use of a solely quantitative survey has its own set of problems that have been addressed by Lederman, Wade and Bell, (1998). The *Student Understanding of Science and Scientific Inquiry* (SUSSI) was employed during this research in order to provide the triangulation. The *SUSSI*'s blend of Likert-type items and related open-ended questions allows participants to rank items on a five-point scale (i.e., strongly disagree=SD, disagree more than agree=D, uncertain/not sure=U, agree more than disagree=A, strongly agree=SA). After completion of the Likert questions, the SUSSI provided participants the chance to explain their reasons for their choices in an open-ended format. The quantitative Likert portion of the *SUSSI* also provided a quantitative means to compare NOS understandings of participants to other quantitative data on epistemological beliefs and classroom practice.

The SUSSI was developed in a three-phase process. First, national and international reform documents and related literature were analyzed to determine NOS characteristics to be included within the instrument. Within this first phase came the development of an instrument based upon previous NOS instruments (e.g., VOSTS [Aikenhead & Ryan, 1992] and VNOS [Lederman et al., 2002]) and piloted in both the US and China. The second phase consisted of a modified version, based upon expert analysis and data from pilot studies. Also in the second phase, students were interviewed to better clarify content conceptions. The third phase was conducted in order to establish validity and reliability within three countries (United States, Turkey, & China).

Analysis of Likert-scale responses using the American research participants revealed a Cronbach Alpha was 0.69. Furthermore, a taxonomy identified and used for classification of the 24 Likert-items was developed that categorizes open-ended response scores into four categories. Those with understandings commensurate with contemporary views of NOS were scored as informed views (score = “3”). Responses that included partially informed views or those with responses that failed to provide support for their statement were rated as transitional (score = “2”). Responses that included misconceptions about NOS were rated as naïve (score = “1”). A lack of response, or a response that included “I Don’t Know” are rated as not classifiable (score = NC) (Liang et al., 2008).

EBS: Personal epistemological beliefs.

To quantitatively evaluate the levels of sophistication of the participant's views of knowledge and knowledge construction, the 38-question *Epistemological Belief Survey* (Wood & Kardash, 2002) was employed. The Wood and Kardash version of the epistemological beliefs survey is a compilation of the Schommer's (1990) and Jehng el al.'s version (1993). While previous versions of this survey were rather lengthy, spanning 80+ items, Wood and Kardash retained 38 items representative of the 5 independent dimensions of epistemic beliefs (See *Appendix A*) for their version. The five factors included on the EBS survey include: Speed of Knowledge Acquisition, Structure of Knowledge, Knowledge Construction and Modification, Characteristics of Successful Students, and Attainability of Objective Truth. Similar to the SUSSI, the 38 question EBS survey uses a 5 point Likert scale (1= strongly disagree, 2= disagree, 3= unsure, 4= agree, 5= strongly). After appropriate coding methods were employed to accommodate the reverse scored items, a high score on the EBS represents more sophisticated epistemological beliefs. A lower score represents a less sophisticated or naïve understanding of epistemology. Internal consistency alpha coefficients of the five subscales were reposted as: 1.) 0.74 for Speed of Knowledge Acquisition, 2.) 0.72 for Structure of Knowledge, 3.) 0.66 for Knowledge Construction and Modification, 4.) 0.58 for Characteristics of Successful Students, and 5.) 0.54 for Attainability of Objective Truth (Wood and Kardash, 2002). The overall alpha reliability of this instrument is .86.

***NOS-COP*: Pedagogical practice.**

In order to gain a deep understanding of teachers' classroom practice, multiple means of measure were employed, from classroom walk-through rubrics, participant interview protocols, and analysis of classroom artifacts. This triangulation method was necessary to overcome challenges present within any individual technique. For instance, it would be difficult to judge the importance or relevance of an activity unless the observer was familiar with the goal of the lesson. Classroom artifacts and/or teacher interviews provided the necessary context for the observation.

The observation form that was used during this research was a modified version of the *Classroom Observation Protocol* (Horizon Research, 2000). The discussion that immediately follows describes the development and nature of the *Classroom Observation Protocol* (COP) and also provides information about the reliability and credibility of the instrument. The *Classroom Observation Protocol* (COP) was developed to measure the quality of an observed science and mathematics classroom lesson. The items included in the *COP* are based upon science standards found in the *National Science Education Standards* (NRC, 1996). The validation of the protocol was accomplished using approximately 60 science and mathematics educators (who served as principal investigators of the Local Systemic Change projects). Items were identified, revised, and returned for review several times until there was broad agreement with individual content items and integrity and completeness of the instrument. Using a set of trained observers, the Cronbach's alpha coefficients for the item sets were as follows:

Table 3

Classroom Observation Protocol Cronbach Data

Item	Number of Items	Cronbach alpha coefficient w/o synthesis rating
Lesson design	10 + 1*	0.96
Lesson design, alternative	9 + 1*	0.92
Lesson implementation	8 + 1*	0.94
Mathematics/science content	9 + 1*	0.93
Classroom culture	8 + 1*	0.93
Classroom culture, alternative	7 + 1*	0.92
Likely impact on students' understanding	6	0.94

*Synthesis Rating

Concerns exist about the reliability of this survey if certain shortcomings are not overcome. These concerns should hold true for any instrument that is based upon the *COP*, such as the *NOS-COP* (Herman et al., 2013), that was the version used for this research. To overcome these concerns with regard to time in the classroom and intention of teacher's lesson design and purpose, these issues were overcome in this research by the following of means: 1) the length of observation lasted the entire period, 2) classroom artifacts were collected, and 3) lesson plans were available to the observer.

As constructivism is a theory of learning and not teaching, defining what is and is not constructivist practice was not an easy task and involved extended classroom visits from the researcher. To determine types of pedagogical practices used within the teacher participant's classrooms, a series of classroom observations took place on average of one every other week and lasting at least one hour. Every participant's classroom was visited four to five times throughout the research period. Unfortunately, it was not possible to make it to all schools to see similar content, assuming they were following the curriculum map. It was the artifact collection and casual conversation that provided the rear and forward looking perspectives of each classroom to compare content coverage and in some case the type of instructional practices during that instruction.

The importance of pedagogical practice cannot be understated as it can serve as a gate-keeper to an effective NOS implementation (Herman et al., 2013). Using the *NOS-COP* observation rubric developed by Herman, et al., (2013), pedagogical practices were tracked in order to gain a sense of teacher practice. Field notes were also taken to provide further depth to any interpretation of data.

The NOS-COP is similar to the *COP* observation protocol instrument in that it consists of the previously discussed *COP* observational protocol, with the addition of slight modifications to assess specific NOS instructional pedagogy. Herman et al. (2013) based the change of the instrument on guidelines that credit a lesson (e.g., NOS accuracy, explicit referral to the NOS, and level of NOS contextualization) as being informed by contemporary and respected NOS science education literature (Abd-El-Khalik & Lederman, 2000; Khishfe & Abd-El-Khalik, 2002; Clough, 2006; Khishfe & Lederman, 2006).

The nine observational indicators that comprise the *NOS-COP* are graded on a Likert scale from (1) “Not at All” to (5) “A Great Extent” referring the amount each indicator was witnessed by the researcher/observer. Two additional scores of (6) D/K and (7) N/A are also included for each item.

Interview protocol.

Two times during the nine weeks (pre and post) participants were interviewed using a semi-structured format based upon responses from their *Student Understanding of Science and Scientific Inquiry* (*SUSSI*) questionnaire (Liang *et al.*, 2008), as well as a five-question interview protocol based upon the protocol developed and used by Herman et al., (2013) (See *Appendix E*). This five-question (multi-component) interview protocol looked at the following factors:

- View on learning, general teaching self-reflection and responsibility;
- General and NOS teaching self-reflection, understanding of NOS teaching, motivation to teach the NOS (value or compliance), and teaching constraints;
- Teaching constraints (i.e., classroom management, institutional constraints).

Data Collection

Teacher Selection.

Phase One- The researcher sent an open invitation to all sixth grade teachers in the district. Within this invitation, there was an explanation of the scope and process of this research, as well as the expectations of the participants. Permission of participants was gained through the use of an electronic questionnaire that included questions about: 1) school location, 2) years of experience, 3) courses taught (e.g., regular or honors), 4) number of science courses taken, and 5) degree. The electronic survey form included a consent form that required a click to agree to continue. Also, all participants were asked to sign a paper copy of the consent form before beginning research. The consent form included on the electronic survey provided a secondary source of security to ensure all participants were had been properly informed. This initial information helped further select the purposeful sample, as well as providing a deeper understanding of the teacher. Information about the role of anonymity for this research and of any publications that came from this research was also provided at that time.

Once the questionnaire was completed, teachers were asked to electronically complete the electronic version of the *EBS* and *SUSSI* survey. Once data was collected, a fellow doctoral student statistically sorted participants' data according to low, medium, and high levels of understanding, referring to their positions of epistemological understandings (i.e., epistemological positions). The fellow doctoral student provided names only of those participants who completed both surveys. These participants were contacted by the principal researcher to determine if the participants would still be available for Phase Two of the research. The researcher reported those names to the fellow doctoral student to make sure the range of participants met the original criteria of having a diverse participant pool. The researcher had no access to this survey data until all data had been collected to protect against bias during the collection period. The *SUSSI* served as an additional informational tool in case additional information was needed for selecting the study group. This purposeful sampling determined which participants moved into phase two of the research. For this research it was important to be able to look at teachers with disparate epistemological views and compare those views to their classroom practice. A wide variety of classrooms based on varying levels of courses (e.g., honors and regular) were sought out considering student readiness has been noted as a potential barrier to the types of instruction employed. In the event there were only small differences within the epistemological beliefs of teachers, there remained the potential to select teachers based upon their understandings of NOS using the *SUSSI* instrument. Other potential selection criteria were years of experience, courses taught (e.g., regular or honors), and educational background (e.g., courses, degree). In the unlikely event that differences could not be found in either of these domains, or other listed differences, teachers would have been selected at random. Fortunately, between the EBS and participants either being still able to participate because of transfers and in one case a new school administration that viewed research as a distraction identification was managed without additional information. This additional information was useful when constructing teacher profiles.

Collection of Participant Data.

Phase One- The initial phase of the research consisted of every potential participant taking an online version of the *EBS* and the *SUSSI*. A Moodle site was constructed for the sole purpose of collecting this electronic data. Moodle is similar to BlackBoard, a learning management system used at many major universities. Moodle is a secure portal where tests and surveys can be given and scored automatically and confidentially. It was from this site that the doctoral student that was helping to facilitate this research, gathered and sort the for participant data. Throughout the data collection phase, the researcher did not have access to this site.

Phase Two – After the *EBS, SUSSI* data had been collected and sorted, eleven participants were selected for the purposeful sample needed for phase two. The goal was to select a minimum of three teachers from each of the three levels of epistemological understandings (low, mixed and high) based upon the standard deviation scores. More positivist positions were participants with scores one standard deviation below the mean. More constructivist positions are those participants with scores on the *EBS* of one standard deviation above the mean. It was important to note, these relative levels of understanding did not always correspond to epistemological beliefs position on the Perry Model (1970) such as Naïve, Transitional, and Sophisticated views about knowledge as used in other research to describe the philosophical or epistemological belief of the participant.

The rationale for classify teacher practice or epistemological beliefs in a range from more positivist to constructivist was based on historical and recent research on epistemological beliefs and practice. For example, Yang et al., recognized naive views of knowledge are "philosophically more like that of the positivist" (2008, p.13). In contrast, Tsai (2007) found that teachers holding more constructivist–oriented beliefs held more interactive discussions, inquiry and in general focused on student-centered activities. Historically, research has reported that for teachers to be effective in the classroom**,** they must become constructivists (Brooks & Brooks, 1993). It is this emphasis included in science education reforms (NRC, 1996) that suggest stronger constructivist approaches be employed (Karakas, 2007). Given the importance of the constructivism and its association with what is now recognized as a best practice, the choice was made to use this continuum between positivist and constructivist practices.

Following selection, these eleven participants were interviewed using a modified version of the interview protocol designed by Herman (2013) to probe their purpose of teaching, the value they place on NOS, as well as other factors they view as impediments to their practice. Starting in the second week of school, regular period long observations with a minimum of once every other week took place to provide information about the participants teaching practice. At the same time, additional artifacts were collected to provide additional insight into typical classroom practices of the participant. These artifacts included lesson plans and examples of student work. Two interviews were conducted with each participant (Pre, and Post) using a modified version of Herman's interview protocol (2013). Each interview was recorded and transcribed to act as a guide and member check (Guba & Lincoln, 1985) for future interviews. Interviews were planned to be 45 to 60 minutes long corresponding to teacher planning periods. There was an acknowledgement that it would not be possible to hold all interviews during the school hours, so alternate hours, either before or after school were utilized as needed. All interviews were performed by the researcher, and each was recorded and transcribed. All transcription and coding of interview data was done by the researcher. Care was taken to maintain confidentiality of the participants: all the documentation was stored within a locked cabinet inside a locked office.

Data from the *SUSSI* and *EBS* served as the basis for comparison between understandings of NOS, personal epistemological views, and classroom practice. The rationale to use total scores and not individual category scores was deliberate and was an attempt to gauge the overall belief structure of the participants and provide insight into their beliefs about knowledge and knowledge construction. Using empirical data from the *EBS, SUSSI*, and *NOS-COP*, descriptive and correlational data (from the 28 participants from Phase One) were used to build a deeper understanding of the constructs under study and to compare the relationships between each.

Descriptive statistics from the *EBS* provided information for the initial and purposeful selection of teachers used for intense study. Correlational data were also analyzed to determine what, if any, relationships exists between the *EBS* and *SUSSI* scores of teachers, EBS scores and the importance teachers place on NOS, as well as any relationship that existed between teacher's classroom practice. The *EBS* surveys were scored according to the developer's protocol (Wood & Kardash, 2002).

The *SUSSI* survey was utilized to provide a basis for quantitative comparison between other quantitative measures, such as the *EBS* and *NOS-COP*. As discussed in the previous paragraph, the *SUSSI* provided a quantitative means for correlational comparisons between the teachers' knowledge of NOS and their personal epistemological beliefs. The data from the SUSSI surveys were scored according to the developer's protocol (Liang et al., 2008). Open-ended responses within the *SUSSI* also provide added power to confirm understandings of NOS. These open-ended responses were used, along with the interview protocol responses, to help enhance the development of teacher profiles, as well as to add and/or detract support for understandings provided by the quantitative data obtained through the *SUSSI* survey instrument.

The *NOS-COP* was employed by the researcher to score classroom activities during observations. These data were available to compare teachers' personal epistemology and NOS understandings. The *NOS-COP* provided a critical piece in looking at how epistemological beliefs correlate to practice, during both NOS instruction and instruction of the practice during the NOS instruction. It was through the *NOS-COP* that types and levels (quality) of practices were measured. This quantitative data can be used both descriptively and as a variable in correlation between personal epistemological beliefs and NOS beliefs. Qualitative data were drawn from four main sources: interviews, classroom artifacts, *SUSSI* open-ended responses, and field notes.

As this research involves a timeframe where both NOS and scientific practices and skills are being taught, comparisons between NOS instruction and general content instruction were discerned as they compared to teacher beliefs. Through the use of the interviews, the teachers brought forward views of impediments to instruction that are outside epistemological beliefs. These impediments also provided important insights into science instruction.

Timeframe for the Study

Potential participants were contacted by August 1st, providing a month before the start of the school year. Upon agreement to become a part of the study, participants were asked to take the EBS, and SUSSI electronically, as well as to participate in one introductory interview, before the start of the school year. Because the first week of school was filled with distractions of many types, the hour-long observation and follow-up interviews were postponed until the second week of school. A minimum of one observation every two or three weeks took place for each of the eleven participants. The total time span of this research lasted approximately nine weeks depending on the pace of the teachers with regard to the School District's curriculum pace chart. In all, each participant completed two interviews (pre and post) that lasted approximately one hour. These interviews were recorded and transcribed by the researcher.

Table 4

Research Schedule

Date	Tasks	
August 1st	Teachers were solicited to participate in study.	Phase One Began
Before August 26	Teachers responded to *EBS*, *SUSS*I, and personal survey via Moodle	
August 26th through September 7th	Pre-instructional interview	Phase Two Began
Week of September 3rd	Instructional unit started	Observations began
Week of October 21st	Instructional unit ended	Observations ended
Week of October 29th	Post-instructional interviews started	
Week of November 12th	Post-instructional interviews ended	

Analysis of Results

Interviews, collected artifacts (lessons, test, and activities), and observation data were analyzed in order to identify common themes. These common themes were identified and were then used as codes to compare interview data with walk-through data from the *NOS-COP* and quantitative measures of epistemological positions. With the exception of *RQ1*, which was answered using strictly quantitative methods, the remaining questions were answered using an interpretive design. Furthermore, as the focus was on the processes that affect classroom practice, a lived experience for the teacher, teacher profiles were constructed in an effort to help organize, interpret and make meaning of these lived experiences.

The emergent design employed by this research was dependent on the initial information gained from survey instruments and pre-instruction interviews. This initial information served as a guide for the constant comparative method of data analysis (Glaser and Strauss, 1967). The basic premise of comparative analysis was constantly to compare data throughout the analytical process (Merriam, 1998). Staying true to the guidelines of comparative analysis, the collected qualitative data (i.e., *SUSSI* open-ended response, interviews & collected artifacts) were coded to and analyzed for emergent themes that explained the relationships among the variables.

Quantitative analysis.

The quantitative portion of the *SUSSI* and the *EBS* score served as the basis for answering the initial question (RQ1a) about the relationship between personal epistemological beliefs and NOS beliefs. Using the total scores from each phase one participant's survey, a calculation of the product moment correlation coefficient served to show the relationship between these two constructs. *Pearson's r*, as it is sometimes called, is a measure of the linear correlation between two variables, in this case the *EBS* and *SUSSI* scores. Values ranging between +1 and −1 give the degree of dependence of the two variables. A *Pearson r* of 0 represents no correlation whereas a score of +1 (positive correlation) or -1 (negative correlation) represents a high correlation. Using the correlational coefficient (r), the strength and direction of the relationship were described. The statistical software *SPSS Version 17* was used for all calculations throughout this research. The *EBS* was scored according to the developer's protocol (Wood & Kardash, 2002). The data from the *SUSSI* survey was scored according to its developer's protocol (Liang et al., 2008). Answering the other research questions (i.e., 1b-d & 2a-b) involved more depth of understanding than quantitative measures. A separate process for analyzing the qualitative data was used and was compared to the previous quantitative data.

Qualitative analysis.

Coding qualitative data is a process of analyzing data to develop categories and relationships (Strauss & Corbin, 1990), which in this research occurred at two levels. First, teacher profiles were developed using common emerging themes. Second, interpretations were made between the group of teachers and their respective epistemological beliefs and their classroom practices. Interviews were one source of qualitative data about teachers' beliefs. The interviews were transcribed, coded, and analyzed to look for categories of emergent themes. The teacher profiles, that now serve the purpose of providing the reader a context, as they emerged, served as the framework to construct the emergent themes.

Based on interview data, survey scores, observation data and collected artifacts, prototype profiles were constructed. These emergent profiles helped in revealing common themes across the participants. For example, time is now listed as a barrier, but this barrier had many sources (e.g., meetings, testing, schedules). By using the constant comparative method of analysis the common barrier of time emerged, even though it may not have been directly stated.

Observations and artifact collections were another source of important information to compare teacher beliefs to classroom practice. Both interviews and observations provided opportunities to further delineate a deeper understanding of each teacher's specific profile as it pertained to epistemological beliefs and its respective classroom practice. An additional source of evidence with which to build a teacher belief profile came from the initial surveys (*EBS* & *SUSSI [to include the extended response section]*). Through analysis of individual categories of each instrument, information was gleaned that enhanced the understandings being constructed about the teacher's beliefs and their effects on practice. Through the use of multiple data sources, triangulation techniques were utilized to construct a rich understanding, an important consideration for establishing credibility (Denzin, 1970). By cross-checking the quantitative data of *EBS* and *SUSSI* survey with interview transcriptions, extended responses from the SUSSI, the *NOS-COP* observation data, regularities from these multiple sources of data were sought.

Development of teacher profiles.

The pre-instruction interview using the semi-structured interview protocol served as a starting point for the generation of a teacher profile of their understandings of epistemological beliefs and how these beliefs corresponded to teachers' conceptions about instruction. The interview questions allowed for probes into teacher beliefs about types of instruction practices, how teachers value NOS, and potential institutional barriers to instruction. This information helped discern whether or not the participants who do teach NOS were doing so because it was required by a district mandate or because they value NOS, or both. To be clear, some teachers taught NOS because they felt they must, not because they felt that it had importance beyond curriculum compliance. After the second (post) interview, when quantitative scores were available to the researcher and observations had occurred, it was possible to determine a more robust understanding of teachers' attitude and beliefs about NOS. Through the use of triangulation, orientations became evident in terms of teaching NOS for compliance, rather than from a belief in its importance, and how NOS was taught may not have been reflective of NOS understanding. For instance, a teacher may have had a good understanding of NOS (*SUSSI*) and a low epistemological belief score (*EBS*). This situation could represent a case where compliance may take place (indicated by observations) because the teacher understands NOS, but may not value it based upon their epistemological position. This potential for compliance was found through the first interview. For instance, co-planning (where grade level teachers are expected to plan lessons together in order to improve the quality of the lessons and also to ensure consistency across the grade level) where one teacher dictates what and how topics were taught could be a dominant factor in practice, minimizing epistemological factors. The post interview became an importance piece of data to probe these differences for clarity.

Any additional information from the extended response section of the *SUSSI* was also used to enhance the teacher profile. Each teacher's extended responses were analyzed and coded by the researcher. Levels of sophistication were determined through this analysis to determine teachers understandings of NOS and whether the written responses differ from the beliefs gained from the quantitative portion of the instrument.

The questionnaires were read and analyzed thoroughly through a holistic lens to look for patterns, given that answers to one question may be contained within another questions response. These extended responses were included with the interview responses along with the quantitative responses for triangulation of beliefs and used to develop the teacher profiles.

Generations of categories of teacher beliefs were drawn from emergent themes that developed from the two surveys and the interviews. These themes were set against a benchmark of pedagogical views of positivism and constructivism, as it was these philosophical positions that frame this research. During each consecutive interview (teacher to teacher) with each teacher, summaries of patterns were checked against previous category findings to determine if they are contradictory, with categories of findings to be modified accordingly. It was this constant comparative method that was employed for the analysis of the qualitative data in order to investigate the understandings/beliefs teachers have constructed. A basic premise of constant comparative is to constantly compare (Merriam, 1998); each interview was transcribed and coded to add evidence for emerging conceptions, as well as to serve as a springboard for further guide questioning during the interview process. For instance, if a theme emerged about what teachers' peers discuss during common planning periods, a question was posed about these potential effects on the participant's own practice. Member checks, as a means to establish credibility, played an important role in the research process (Lincoln & Guba, 1985). After each interview session, my interpretation of the interviews was emailed to the participant to make sure the understanding I had gained matched the intentions the participant wanted to convey. Although most responses were limited to a polite, "Thank you," or other salutation, some did add to the conversation. These were included into the template used for analysis that included the original interview responses and my analysis of comments.

While there were only to interviews, pre-post) there were many causal conversations during, before, or after my observations. Notes of these conversations were documented into my log. Teacher profiles also emerged from this same analysis.

In addition to teacher interviews, a series of observations and artifact collections were conducted using the *NOS-COP*. The information gained from each observation and artifact collection was analyzed to search out supportive or contradictory themes that were gathered through the interview process. As in the process used for subsequent interviews when dissonant themes occur, these incongruences became the source of further questions during interviews with that same participant. Observation information, like evidence from interviews, was also observed for emergent themes and categories to guide the development of an understanding of teachers' classroom practice. As much of the observation protocol was quantitative in the form of a Likert Scale, descriptive statistics were used to bring a more qualitative meaning to this quantitative data.

To answer the different research questions, a variety of instruments were used to construct the teacher profiles. These teacher profiles were then used to compare against one another to look for emergent trends in terms of classroom practice. As discussed previously, research question 1a was addressed quantitatively through analysis of the *EBS* and *SUSSI* instrument. It was only *RQ-1a* that was addressed through the use of only two instruments and in a strictly quantitative manner. All other research questions were addressed through a minimum of three instruments with understandings developing from the triangulation of these instruments. In *RQ-1b*, which pertains to the effects of epistemological beliefs and the importance a teacher places on NOS, data from the two epistemological beliefs surveys were used in addition to interview data to address the question. In *RQ-1c*, where classroom practice is investigated as to its potential relationship with epistemological beliefs, the *NOS-COP* classroom observation protocol replaced the interview data as the main source of information for determining relationships. Classroom artifacts supplied additional information to support any understandings that are constructed for *RQ-1c*. Unfortunately, though required by the District, lesson plans were not always available. Fortunately, teachers are asked to post an agenda and this became a valuable resource for determining what had been or would be taught. These agendas often became sources of questions to the teacher. Artifacts that were collected regularity, either directly, photographed, or notes taken about, were any type of worksheet, lab document, articles, and anything else that would give an idea of what was happening in the classroom when I was not present. In terms of "other factors" addressed in *RQ-1d* that are responsible for practice, it was the interviews that supplied the main source of information, with artifact collection supporting the meaning-making.

The next main question (*RQ-2*) and its sub-components investigated classroom practice and whether it differs between when teachers teach NOS and more "skills and practices" types of content. As the first nine weeks of instruction were a combination of NOS and *skills and practices*, some observations naturally occurred during each of these instruction units. To answer *RQ-2a*, which refers to the NOS and classroom practices between the two constructs (NOS & *skills and practice*), the *SUSSI*, *NOS-COP*, interviews and classroom artifacts served as the informational sources. For *RQ-2b*, the *EBS* replaces the *SUSSI* with the previous mixture of data sources.

Table 5

Instruments used for each research question

RQ Number	EBS	SUSSI	NOS-COP data	Interviews	Type of Analysis	Classroom Artifacts
1a	X	X			Quantitative	
1b	X	X		X	Mixed Methods	
1c	X	X	X	X	Mixed Methods	X
1d			X	X	Mixed Methods	X
2a	X		X	X	Mixed Methods	X
2b		X	X	X	Mixed Methods	X

Comparison between teachers.

After all interviews, observations and artifact collection had been completed, a detailed profile of each teacher was constructed. It was only after individual teacher profiles had been constructed that a comparison of teachers and the respective practices could be analyzed. Through a careful analysis, again looking for common themes, a summary of the teachers was constructed to explain the relationship between epistemological beliefs and practice. Through the use of an Excel spreadsheet, themes were matched with participants to gain an overview of epistemological beliefs and how these beliefs relate to other evidence, such as field notes from observations, artifacts, and data from the observation form. As these comparisons between beliefs and practices took place, corresponding information from interviews guided the interpretation to answer the research questions (with the exception of RQ 1a, which was purely quantitative).

Credibility was achieved by prolonged time spent doing observations (one-hour biweekly visits) as well as extensive interviews to include member checking. Dependability was achieved through the use of careful coding until which time clear patterns emerged, as well as the use of triangulation from the various instruments.

Summary

A mixed-methods approach was employed in this study with the purpose of exploring the relationship between teachers' NOS beliefs, personal epistemological beliefs, and classroom practice either during NOS instruction or practice and skills.

Research was conducted during the nine weeks of instruction that included NOS as well as the practices and processes of science. These nine weeks are considered by the School District as an integral part of instruction as these concepts form the basis of further science instruction throughout their secondary careers. Before the start of the school year, teachers' epistemological beliefs were assessed using two separate instruments (*EBS & SUSSI*). These two instruments were used to define teachers' epistemological positions in science, as well as the relative relation to more general knowledge. These were independently compared to teachers' practices during NOS instruction and instruction concerning science practice and skills. Using an observational survey form (*NOS-COP*) and accompanied with interview data, common themes were developed to ascertain what relationships, if any, exist between these epistemological beliefs and how other barriers that teachers associate as major impediments to instruction.

Chapter Four: Results

Introduction

The purpose of this study was to explore the effects of teachers' epistemological beliefs on practice. Specifically, this study sought to investigate two overarching questions:

1) *In what ways do teachers' epistemological beliefs affect practice in the science classroom during NOS instruction?*

2) *In what ways do classroom practices differ between instruction of NOS and instruction of process skills?*

Both overarching questions contain subcomponents. The initial subcomponent of the first overarching question was answered by looking at one large group, while the other subcomponents were answered by looking at a sub-group of the large group, referred to as *Phase One* and *Phase Two* groups. To this end, either quantitative or a combination of both qualitative and quantitative were used to answer the research questions.

First, quantitative measures will be discussed for the *Phase One* portion of the study to answer RQ1a, "What is the nature of the relationship between personal epistemological beliefs and understandings of NOS?"As the goal of this study is to build individual teacher profiles and then compare and contrast those profiles, the section before *RQ1b* will be devoted to participant profiles. These profiles will help give the reader a context in which to place the further discussion necessary to answer the remaining questions. After the section describing the teacher (participant) profiles, the remaining research questions will be addressed in the order of the remaining research questions.

Research Questions 1a - What is the nature of the relationship between personal epistemological beliefs and NOS beliefs?

This research question sought to examine the potential relationship between these two seemingly similar epistemological belief structures. The study employed the use of the 38 question *Epistemological Beliefs Survey* as well as the *SUSSI* survey in order to determine the overall depth of teacher understandings. The average total score of each instrument was calculated and then correlated to gain a better understanding of this potential relationship. Of the 37 participants who participated in *Phase One* of the study, which consisted of the *EBS* and *SUSSI* surveys, 28 individuals completed both surveys. The following results were derived from those participants.

For the epistemological beliefs survey, the mean score was 140.86, with a standard deviation of 10.18. The skewness and kurtosis placed the data well within the range of normality (Sk= .46; Ku = .08). The range of 42 revealed different dimensions of beliefs considering the potential scores for the survey range were of 38 to 190. With a score of 72 marking the midway point between lowest and highest potential score, the participants scored on the higher end of the range based on the test mid-point. This should be expected based on the relationship between education and epistemological beliefs (King & Kitchener, 1994; Perry, 1970). Also, true absolutists, who would presumably represent the lowest potential test score, are rarely if ever seen, in research (Moore, 2002).

Table 6

Epistemological Beliefs Descriptive Statistics

N=28	Mean	S.D	Skew	Ku	Range
	140.86	10.18	0.46	0.08	42

Data from the 40 item *SUSSI* survey revealed a similar result in that the mean and standard deviation (M = 141.5, S.D. = 10.81). The skewness and kurtosis were higher than that of the EBS, but the sample remains within the model of a normal distribution based on the random selection of participants and large sample size.

Table 7

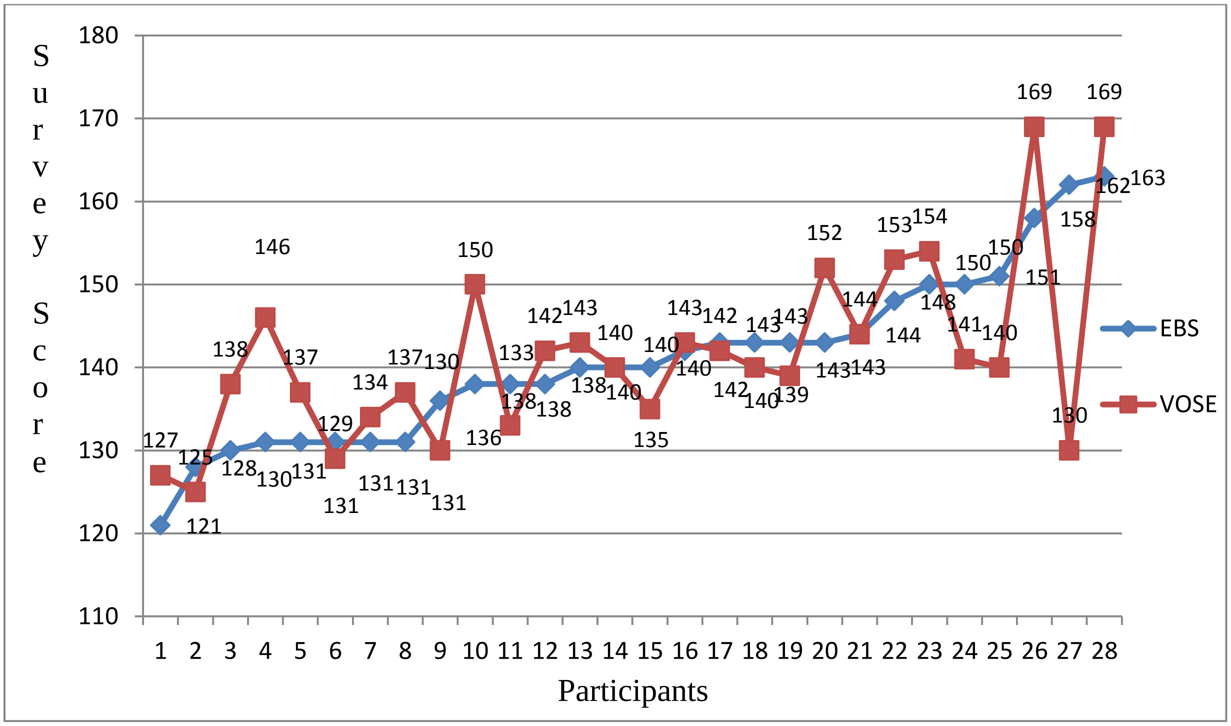
SUSSI Descriptive Statistics

N= 28	Mean	S.D	Skew	Ku	Range
	141.5	10.809	1.0374	1.3538	44

The *Pearson Correlation Coefficient* between the *EBS* and *SUSSI* instrument was determined to be 0.63, a moderately strong relationship. The p-value was 0.00033 (two-tailed) indicating statistical significance beyond the 0.05 level and should not be considered random.. What is notable is that one participant has an extreme disparity between the scores on the *EBS* and *SUSSI*. By removing this one participant, the relationship increases dramatically to R = 0.80. This participant provides an interesting dynamic between these two epistemological constructs. More about this participant will be discussed within the teacher profile section of this paper, as well as the discussion section for each research question. To answer the immediate question (1a), it would seem there should be few surprises given the suggested relationships already proposed with various research (Abd-El-Khalik, 2003).

Table 8

Correlation between EBS and SUSSI Overall Scores



Evidence supports the relationship between the NOS and personal epistemological beliefs. This relationship is not surprising as both involve the characteristics of knowledge and knowledge construction (Abd-El-Khalik, 2003). This relationship is important due to epistemological beliefs implications on practice (Feucht, 2008; Feucht & Bendixen, 2010; Patrick & Pintrich, 2001; Schraw & Olafson, 2002; Tsai, 2002), but there has been scant quantitative research about this relationship. Having confirmed a rather strong relationship between the two epistemological beliefs amongst the participants in *Phase One*, the next sections of this paper provide the reader with a profile of the eleven participants that took part in *Phase Two*.

Phase Two of the study was designed to deeply probe the beliefs and practices of eleven of the twenty-eight original participants. This was accomplished through classroom observation, interviews and artifact collection of eleven of the original 28 participants. The eleven participants were chosen based on epistemological beliefs scores to represent a broad range of orientations. After these profiles are presented, the remaining research questions are addressed.

Teacher profiles.

Of the 28 participants who completed both surveys, eleven participants agreed to be part of *Phase Two*. The goal was to have participants from the larger *Phase One* sample represent a range of epistemological beliefs. These levels were determined based upon the epistemological beliefs survey's standard deviation scores. Five of the selected participants fell below one standard deviation from the mean. Four selected participants were within one standard deviation from the mean (+/-10.1) and two held *EBS* scores above one standard deviation from the mean. It should be noted that the majority of those selected that held scores within one standard deviation from the mean were in a very tight range on the boundary of the first standard deviation level. This situation of a tightly-grouped set of participants occurred not because of choice, but rather was based on who agreed to participate in *Phase Two*. Even though every attempt was made to make choices based strictly on the score, other events such as changing teachers' roles and willingness to participate influenced the final choice of participants. In the end, the sample represented a large range of scores with participants who provided rich dialogue (discussed later within the profiles and discussion of findings sections).

Phase Two participants' scores were similar to the larger group of 28 participants used for *Phase One* of this study. The average EBS scores for the *Phase Two* group were 141.5 versus

140.9 for the larger group. The range for the *Phase Two* group was 34 compared to 42 of the larger group. Seven points of this increased range can be attributed to one participant on the low end of the scale. In terms of the SUSSI survey, a similar situation occurred with regard to range, but this increased range was attributed to high scores from the *Phase One* group. The SUSSI average score for the *Phase Two* group was 139.2 compared to 141.5 from *Phase One*. The SUSSI scores had a similar range disparity as the EBS scores. Phase Two participants had a 29 point range while participants in *Phase One* had a 44-point range. It should be noted that one of these two high scores (169) on the *SUSSI* was a former student of my major professor and had gained knowledge of NOS through the required science education coursework. The other high score was from one of the District's top teacher/trainers. Interestingly, these same two *Phase One* participants had nearly equal EBS scores as one other participant found in *Phase Two* participants. The *Phase Two* participant that had this nearly equal score proved to be one of the most interesting cases in the study. He was unlike the two from *Phase One* who had equally high scores on both surveys; instead, his survey scores were quite disparate. As will be discussed further, this disparity proved to be quite interesting in its affect on teacher practice. It was unfortunate that I was not able to include the participants with the highest *SUSSI* scores from *Phase One*, but role changes and administration reservations did not permit the inclusion of either candidate. I was not able to conduct research, other than the after-hours survey, in one school because the administrator felt time would be better spent on school improvement. With many schools now undergoing state oversight, this would appear to be a legitimate concern.

A common thread running through all participants of *Phase Two* was that they all cared deeply for their students. This strong feeling was perhaps due to self-selection for this research more than to factors associated with the research itself. I was also fortunate to have participants willing to openly express their concerns and struggles in the classroom.

To better understand the participants, this next section provides a profile of each participant that came from the constant comparative analysis methodology. This profile provides general as well as specific information about each teacher. This research was fortunate to have such a variety to provide a wide range of years of experience, backgrounds, content knowledge, and personal & pedagogical differences. From interviews, casual conversation, and classroom observations, it was noted that each participant displayed the exemplary characteristics of good teachers, such as caring for students and a belief that their efforts could make a difference in their students' lives. These aspects may have had an association with who was willing to participate in research versus any characteristic measured to select the *Phase Two* participants. Whatever the reason, having teachers with these characteristics made the research easier, as now a focus could be placed on pedagogical differences instead of beliefs about their views of the educational system or students. The following descriptions provide the general profiles of each participant. The participants have been assigned a number based on the score from the *EBS* instrument (e.g., *Participant One*, *Participant Two*, etc.). The following table (See Table 9) provides an *EBS* total and SUSSI total score for each participant. The scores are listed from low to high according to their personal epistemological belief score in an effort to assist the reader.

It should not be assumed that the specific scores (e.g., 139 & 140) are necessarily associated with different practices or that they guarantee any given epistemological beliefs level. Relating actual scores to outcomes such as practices may be beyond the current tools available. Hofer and Sinatra (2010) mention ways the use of a dichotomous scale to capture a non-dichotomous construct may be problematic.

Included in the teacher profiles are *EBS* and *SUSSI* scores to provide a sense of how the participant may view knowledge and knowledge construction and their understandings of NOS respectively. Other data used were derived from interviews, observations, artifact collection and information from the survey as to years of teaching, background if not originally teaching, etc. It should be noted that there are no discernable trends between years of teaching experience and scores on either the EBS or SUSSI survey. It was unfortunate that most teachers completed only the multiple choice section of the SUSSI. The interviews were often times running longer than promised, as was the electronic survey itself even without the completion of the extended response. To go through the extended response questions within the interview process in order to gain additional information could have added another hour onto an interview. Out of respect for teacher's time, a decision was made to not pursue answers to these questions. Though many of the participants would have gladly sacrificed the time, some had other obligations. As all participants could not share their understandings equally, pursuing only some information may not have been beneficial and ran the risk of placing bias within the research. All in all, with the addition of the casual conversations, the researchers prior relationship with most participants, additional information was gained that may have not otherwise been attainable. In total, there was adequate information to paint an accurate profile of the participants. The profiles helped in organizing main themes as they related to this research.

Table 9

Epistemological Scores of Phase Two Participants

Participant	EBS/SUSSI Score	Title I (Y/N)	Years Teaching (avg. 13.7 yrs.)	Sex M/F
One	128/125	Y	5	F
Two	131/146	Y	18	M
Three	131/137	Y	14	M
Four	131/129	N	3	F
Five	131/134	Y	12	F
Six	143/142	Y	17	M
Seven	148/153	Y	24	F
Eight	150/154	N	9	F
Nine	150/154	Y	25	F
Ten	151/140	Y	17	F
Eleven	162/130	Y	7	M

Participant One.

Participant One has the lowest score on both the *EBS* (128) and *SUSSI* (125) survey. *Participant One* teaches at one of the District's lowest performing schools. Despite these challenges, her classroom organization and control were typical of a teacher with well-established rules.

Her management is reflective of her responses to interview questions that asked: What does the classroom practice of the most successful science teacher look like? Her response was, "Good classroom management, able to keep her children focused, is highly organized and well prepared." This teacher clearly practices what she feels is most important. There is no wasted time between the moments students enter her class and the time they leave. The agenda for the day was clearly present on the board so that students understood what was required of them. At no time did I see a variation from this schedule.

She understands the role of facilitator, but feels it necessary to maintain a bit more control than one would traditionally expect from the definition. As she stated in an interview, “I try to be a facilitator, but I'm also like a director. I would say I am a *facilitator-director*.” It would seem, from her answers to my interview questions, she would like to move toward the role of facilitator, but feels pressured to maintain classroom control because of the types of students in her class. The reference to director in this case is synonymous with teacher and one who is in complete charge of the learning, whereas facilitator gives more responsibility to the students and the teacher acts as an assistant within the process. .

In a follow-up question based on my observations of her teaching, I asked why she talked more than her students. She replied, “I do more talking in an effort to cover the information and I repeat myself quite often because of inattention.” I then asked, “If students were well-behaved, as well as ready and willing to learn, how would your classroom look? She replied,

> *“I believe it would be a much more productive class. I would be able to not only cover the required material, but also broaden the scope to related topics. We would also be able to work on more complicated and involved labs.”*

Given that observation, lesson plans, or artifacts revealed no labs occurring of any type, it is unclear if these labs, if they were to take place would be procedural or involve a higher level of inquiry.

In terms of NOS, *Participant One* was quite honest when she mentioned, “The nature of science confuses me. I try to teach all the components that I think that are important.” From the SUSSI survey score and interviews, it was clear that her understanding of NOS was limited. It should be noted that, although she had the lowest score, it was only lower by a few points than five other participants. Despite the lowest score, she was using some activities to instruct her students in NOS and not just lecturing.

Given the comments about NOS confusion, I was surprised that she was using an activity from the University of Indiana ENSI website. The website includes many NOS activities. She used two activities from the site: *Science versus Non-science* and *Sunset, Souls and Senses*. Both activities were designed to explore the realm and limits of science. *Participant One* used these activities to help students distinguish science from non-science. This seemed to be a topic the teacher felt was important. It is also a topic included in the District's curriculum maps. In this case, the teacher felt the topic had value. When it came to other NOS topics, there was no evidence those topics were taught during the nine week grading period from lesson plans or classroom artifacts. It is not to say they may not have been mentioned within a lecture, but there were no planned or documented activities or readings on the topic. In this teacher's case, the reason they were not carried out may have been two-fold. First, she clearly had limited knowledge of NOS, despite the explicit explanations written into the District curriculum maps. Second, I witnessed school site restrictions that limited her freedom to teach what she wanted: those restrictions too may have played some role. She mentioned, "They [School Administration] expect us to teach very similarly. I think it's a high expectation for us to do very similar things. They want to see consistency between us." *Participant One* also mentions the school change from a block schedule (90 minute classes) to 50 minute periods as having a major impact on what she does in the classroom. When asked about variables that impact instruction, she mentioned, "The first year I was here we had block scheduling and I felt like I could at least get a lab accomplished."

The factor of a time constraint may explain the lack of hands-on experiences, but not the topics for instruction during these nine weeks. Within this time span, instruction was mostly centered on lab safety and the scientific method, not NOS. As she reports, “I do a lot of worksheets. I do the *Sunsets and Souls* from the University of Indiana. I do a cartoon on how you proceed through solving a problem and the steps of the scientific method. I try to go over the CONPTT ideas also from the University of Indiana.” CONPTT is an acronym for the six criteria of science: **C**onsistent, **O**bservable, **N**atural, **P**redictable, **T**estable, and **T**entative and is associated with the Science and Non-Science activity previously mentioned. I did not observe during visits or find evidence of student work posted on bulletin boards or in student journals of anything other than the *Sunsets and Souls* and *Science versus Non-science* activity. Collection of or taking notes about artifacts was a typical procedure during these visits. Unfortunately, in this case, as in many others, little to no evidence could be found of NOS instruction occurring between my visits either in student journals, lesson plans, posted in the room, etc.

Her responses during interviews seemed to indicate she placed some value on NOS and was not teaching it just because it was on the District curriculum maps. Unfortunately, it appeared her chosen method of instruction and lack of NOS understanding limited this instruction. While other influences, from administration and other teachers with whom she planned, may have played a role in her classroom choices, given her SUSSI and EBS score, it was likely her own epistemological beliefs and lack of knowledge were influential limiting factors for NOS instruction. Both her personal epistemological beliefs and NOS survey scores ranked amongst the lowest of the group. She also admitted confusion about NOS. Clearly, a lack of NOS knowledge would affect choices or lack of choices of instruction to cover the mandated topics. Even when she did find some appropriate lesson materials, they were used as a worksheet with right or wrong answers and not a springboard for discussion about NOS topics.

Participant Two.

Participant Two was quite an interesting case. This participant has a PhD from a prominent western university in the field of science and his score on the SUSSI survey was relatively high (146). This score places this participant ninth of eleven participants in terms of levels of NOS understandings. In contrast, his score on the EBS score ranked as one of the lowest (131).

It was clear from observing his classroom and from the interview process that he placed great value on education. His classroom management was governed by well-established rules and norms. It was also obvious he had established a good rapport with students. He spoke to each and every student as if they were his own child. As one might expect from a man with his knowledge of science, his descriptions to students were marvelous. He was able to place every science term or topic into context to help students paint a mental image. His approach to teaching was much like a grandfather telling stories to his grandchildren. He even referred to these frequent occasions where he included his verbal imaginary as, "My Stories." He mentioned in the first interview, "A lot of times I can hook with one of those stories. That really helps a lot."

He credits his knowledge of science that enables him to manipulate the District's curriculum maps to his needs. As he puts it, "I will take the general unit and combine certain topics together." The District's curriculum maps use "learning essential questions" to divide the content into chunks. Mastery of content is then judged by how well students have assimilated the information that would enable them to answer the lesson essential question (LEQ).

There are also discrete topics that must be covered for students to be able to answer the LEQ at the end of the topic. Certainly, many teachers approach these discrete topics separately, providing few connections for students. *Participant Two's* vast knowledge of content enabled him to link these seemingly discrete topics into a more coherent set of knowledge. While this provided him with some freedom to design his lessons, he still felt confined by the rigid structure mandated by the District.

When asked about these constraints, he answered, "People telling me how to teach and what to teach and I don't have the freedom to take the ideas and run with them." A follow up question was asked to determine where the bulk of these constraints come from. "Number one comes from the State, with a large part of our teacher evaluations now having to do with the test results." Clearly, the large part of the frustration is believed to be from the State on what and how content is to be taught. Also, to some degree, teaching constraints come from the District with its curriculum maps. He did make it clear that his administration allowed a great degree of freedom to its teachers, so this was not a constraint at that time. While internal constraints are limited, external (beyond the school) constraints existed and even extended to the students' homes.

It was also made very clear during the interviews that this teacher felt that parents' roles in the students' academics need to be improved. He felt a major constraint was that parents do not see the value of additional practice. "Kids don't have to do homework," he responded to a question about teaching constraints. "As a result, schools and Districts are at a disadvantage." Perhaps because of his strong background in science, he clearly demonstrated passion for science education. Unfortunately, the types of knowledge expected of students were not always reflected in the types of practices chosen. While he spoke of what students should be able to do, tasks were limited to the lowest level of inquiry.

While this participant's content knowledge about both traditional content and the nature of science were more than adequate, the stark differences in the *EBS* score and the *SUSSI* score were telling. He clearly valued the student understanding of scientific knowledge and the major role it played in their life. Despite his knowledge of science, a question could be posed as to the effect of the low *EBS* score on his practice. Within every observation, students were either doing, or preparing to do, some type of investigation or experiment. When asked about how much he spoke compared to students he responded,

> *"It varies. Some days I'll talk quite a bit. If I'm introducing materials I'll be asking for feedback and further questions asking what they think and different things like that. On certain days we are doing cooperative learning, I won't say a word.*
> *Sometimes I do a project or lab work on a topic and give them some latitude to design their experiment. We talk about the scientific method. For example, I have the students pick three different balls, drop them from three different heights and they get the information that satisfies the scientific method."*

It became obvious during classroom observations; students were given all the key information before they designed their experiment. It was here that the lower *EBS* score with its reference to authoritarian knowledge became visible in practice. During each observed class period, it was clear who held and dispensed the knowledge to the students.

NOS instruction was limited to the scientific method, or discussed via a story; but it was never explicitly mentioned during the observations. There were no contextualized or decontextualized activities employed to teach NOS, only the scientific method.

In observations outside the timeframe of District mandated NOS instruction, there were also no signs of NOS inclusions heard or verifiable artifacts found to validate the coverage of most NOS topics other than the scientific method.

In summary, *Participant Two* has a vast knowledge of traditional content and of NOS, undoubtedly because of his years spent doing science as a researcher. He was one of few who could list the majority of the NOS concepts without prompting, yet few if any mentions of NOS were heard or artifacts found to verify its instruction.

Participant Three.

Participant Three teaches at a school rated C last year by the state. The previous year it had been rated a B. Unlike many of the District's middle school teachers, he has a biology degree. This background was evident during discussions with his class. Like other participants, his rapport with students was excellent and his belief in being a good role model was first and foremost in his mind. He made it quite clear during interviews and casual conversation how much he was devoted to his students. Like *Participant Two*, his *EBS* score is 131. His SUSSI score (137) and is slightly below the group average of 141.5.

Participant Three, when asked what he envisioned the best science teacher would look like, responded, "Look professional and motivate their students to the highest learning levels possible through lesson plans and activities. He should make all students feel successful. Should not leave any student behind and finds ways to make all students feel they want to learn." He went on to state, "Students should follow directions, listen to what the teacher has to say closely and take ownership of the learning process."

When asked about how he viewed his role, he replied, "Make sure that I deliver the material and instruction in an appropriate manner. Hopefully, I do this as cost-effective as possible and keep their interest level high." The comment that includes "I deliver" was well documented within the observations. *Participant Three* was always in front of the class. Student talk was limited to answering questions about previously covered materials. The common delivery method was didactic using a PowerPoint (PPt). Students took notes verbatim from the PPt. His response clearly illustrates this interpretation:

> *"During direct instruction I always allow students to participate with responses to questions pertaining to vocabulary meanings. It keeps their attention and makes them feel they are owners in the learning process."*

Not surprisingly, hands-on activities or any type of inquiry appeared to be quite limited. He gave few examples of when his students were exposed to hands-on activities, always referring to previous years. Throughout the observations, I was unable to find any evidence of hands-on activities. As he elaborated about instruction during the interviews, it seemed clear that hands-on was seen something additional, not essential to learning science. He stated, "I usually start the lesson with the brainstorming activity, go over and discuss the ideas, a graphic organizer, and maybe some hands-on."

In terms of NOS, he responded, "I always tried to emphasize, 'Guys, this is really performing one of the steps scientific method and scientific inquiry,' because I emphasize both and the differences between them. It's important that they understand the steps." There is a clear emphasis on the scientific method both from the interviews and classroom observation. The observation and artifact collection yielded only coverage of the scientific method and variables. No other evidence was found to support the coverage of any other NOS topic.

Despite his biology degree, there was also a lack of understanding of certain NOS concepts. For instance, when asked about different concepts of NOS and which he focused on, explicitly or not explicitly, an immediate answer was not forthcoming. A prompt was eventually required in order to gain an answer. After the prompt of "theories and laws," he responded,

> *"If looking at the difference between theory and law I certainly make sure they understand the process of going from the point of the hypothesis to the theory and then to a law. I also let students know that accepted theories are subject to change due to the fact of the available technology at the time scientists completed their research."*

When asked about institutional constraints to teaching, there seemed to be few, if any. He responded to a question about these constraints in the following way, "I feel like we have a lot of freedom to choose. We are not dictated to at all. They want us to stick with the curriculum map absolutely as far as the concepts, but as far as the activities we choose, I feel like I have as much freedom as I want."

Overall, *Participant Three* was a very hard working teacher who is devoted to students. He mentioned that he spends many hours after school planning lessons to share with his students. Unfortunately, these lessons rarely included hands-on activities and are limited to PPT's and worksheets. There was an obvious lack of the knowledge of and pedagogy required to teach NOS.

Participant Four.

Participant Four teaches at a K-8 Academy that has been rated as a B school by the State grading guidelines. The school is known for using instructional methods based upon the latest research. The school was the first in the District to incorporate non-fiction text (mostly science) into the elementary reading blocks. The goal was to provide background so that students would enter the middle grades able to apply their knowledge.

Participant Four was the youngest of the participants, yet had superb management skills, that would be more expected of veteran and rapport with her students. She emphasized in discussion how she placed a priority on caring for her students. This caring and nurturing environment was quite obvious to an observer. She professes to make every attempt to provide students with engaging hands-on experiences, but at the same time, does not exclude those learners who have different strengths for learning, such as technology. She also explained how she places an emphasis on scientific thinking within the teaching of NOS. She confided she has few, if any, teaching constraints from her school's administration. Her only complaint for being able to do what she wanted in the classroom was the length of classes. "Fifty-five minutes is so hard to do labs," she recounted.

Although she had taught less than five years, she already had attained a master's degree in education from a local private college. During the interviews, she fondly recalled what she had learned about the practice of teaching and how she attempted to apply these methods. She explained, "I was taught to use the book as a guideline and not a Bible, and use the information, but don't drill and kill." It was surprising that *Participant Four* held the ideals of a constructivist in high regard, yet had one of the lowest scores on the *EBS* (131). From her actions in the classroom, it was obvious that the skills of constructivist teaching were emerging, but were not yet always present. She does use inquiry methods; on one of my visits she explained how she had just finished a classic inquiry of having students see how many drops of water can be placed on a penny. The goal of her lesson was to have students learn about the "scientific method" and to report and summarize data. It was not intended to teach the concept of cohesion.

She also made a point to tell me how it was necessary to cover material in three ways to correspond to the different learning styles of her students. From the discussion, I concluded that she almost, but not quite, understood how students need to construct their own knowledge. At present, the use of the multiple learning styles is meant to help students learn the facts and skills of science. In other words, it is a way for students to learn a teacher's knowledge, not construct their own.

In terms of NOS, this was more predictable, having an identical score as participants 2 & 3 on the EBS, and the second to lowest on the *SUSSI* survey (129). She did stress that NOS was extremely important on the State Standards and mentioned how they were assessed on every State exam. While she clearly recognized NOS's importance, she glaringly omitted anything other than the scientific method or the difference between the scientific method and methods of inquiry. The focus was mostly targeted at the hypothesis, variables and conclusions that are either correct or incorrect. There was no indication either from observation, interviews or artifacts concerning the knowledge construction processes of NOS. This was perhaps not surprising, as her background was in elementary education, and she had just recently moved to sixth grade science. Nevertheless, her science background was strong when compared to a science major or minor. What she did have in abundance is an enthusiasm for and love of science.

Her teaching constraints, beyond the lack of NOS knowledge, were minimal. Her administration gave teachers the option to try new things. She was the only sixth grade science teacher in this school, so co-planning was never an issue. She did mention that her colleagues had been a great help. Clearly, her beliefs about knowledge construction were still emerging. Furthermore, her use of hands-on activities for science was a step in the right direction and beyond what was witnessed from other participants. Being new to sixth grade science may have impacted her knowledge of available resources for the teaching of NOS.

Participant Five.

Much like *Participant Four*, *Participant Five* came to the secondary classroom from an elementary background. Her *EBS* scores were equal to participants two through four (131). *Participant Five* worked at one of the District's low performing schools. The school has consistently been challenged in finding quality teachers. *Participant Five* was a spirited teacher who wanted desperately to have her students achieve academically. She made every effort to make her class interesting and cutting edge by asking unique questions. I observed her one day turn a question about the antics of her cat into an exercise for developing an experiment to test a hypothesis.

It was these types of creativity that set her apart from other teachers at her school. Unfortunately, it was this creativity that she felt was stifled by her colleagues as she co-planned. She explained that it is not that she doesn't want to draw on others' creativity; instead, she wanted the freedom to pick and choose the best ideas to provide the best possible instruction for her students.

Within every conversation, whether formal or informal, *Participant Five* indicated that she valued having students see the big picture and learn how to not just learn science, but to apply it. In one interview response, she included the following statement in response to a question regarding the perfect science classroom:

It would be inquiry-based, such as presenting an issue or a problem to the student. This method engages students and forces them to problem solve. I think it helps. I think the students learn more that way and they learn it deeper. It also sticks more.

While the answer sounds profound, I saw little evidence of this style of teaching in the classroom, at least those that would be directed at the State Standards that involve NOS, with one exception, during a District-mandated activity that she seemed to resist. The resistance was interesting as it was evident her students were able to apply their knowledge while engaged in this activity. This District-mandated activity resembled socioscientific issues SSI, a method now thought to improve some aspects of NOS knowledge. *SSI* also provides opportunities for students to develop their own knowledge (Zeidler & Sadler, 2011). In fact, as I was scheduling her visit, she asked me to not come on that day as she felt the activity was not worthwhile. On the contrary, it was one of the better days, but it was not clear even after the activity that she came to the same conclusion.

There was inquiry present within her instruction, but unfortunately, the inquiry was typically directed at topics unrelated to the District's curriculum or the State's standards. One such research project was on scientists with disabilities. I found exemplars of this particular project posted on her room's bulletin board. While the lesson had value, its focus was biographical and covered social, not scientific topics with a purpose more about collecting facts versus using it as an issue related to science. On another day, I observed her class doing the activity she discussed in the interview.

"I had students research a scientist and I allowed them to choose any scientist at all and gave them some training on how to search for one that meets their criteria. For example, they may have chosen a "Hispanic Female Astronaut."

Again, though the assignment had merit, its focus did not meet any of the intended instructional targets for the unit she was covering. While she did have exciting ideas, they were not always directed towards the intended District goals, which were based on *National Science Education Standards (NRC, 1996)*.

In terms of NOS, this knowledge was, as might be expected from a social science major, low. The SUSSI score was 134, placing her at the lowest reaches of the one standard deviation mark. It is obvious when speaking with her that she wanted to learn science and how to best teach it. I appreciated her honesty: when I asked about her explicitness of NOS instruction, she proclaimed:

> *For the lab part the scientific method, it is explicit. The other types of things are implicit. Honestly, have mostly just talked about that. I mostly just touch on it and give examples, (this year, they watched videos of scientists at work gathering data, making observations, etc. and we talked about what they were doing.*

It would seem clear; the scientific method is the main and perhaps only focus and not always in a hands-on manner. If other NOS topics other than the scientific method were discussed in class, I was not present, nor was there evidence from artifacts. She freely admits she had spent too much time in the past on topics such as distinguishing between dependent and independent variables. While these are critical in order to carry out experiments, doing so out of context and as vocabulary is often difficult.

Her biggest challenge might not be traditional content knowledge or knowledge of NOS, but result from some constraints derived from co-planning. I was able to observe one of the planning sessions and it was clear that her co-worker also lacked NOS content, but did not want to do the additional research required to develop a good lesson. *Participant Five*'s frustration was visible during this planning session, and was also mentioned in the interview,

> *They should also be willing to learn if they lack background knowledge. Some people aren't as willing to learn and take it as a personal insult if they make an error and it's brought to their attention. For example, my degree is in social sciences. For the first few years teaching science, I was like a sponge and tried to learn all I could from my co-workers, textbooks, workshops, and reading books on my own. I allow students to take limited decisions within the context of the curriculum. Unfortunately, I feel restricted by time, resources, and the curriculum when it comes to doing this more.*

What did give me great hope for *Participant Five* is that she was eager to learn. On a curious note, after the observations and interviews were finished, I sent a summary and the transcriptions with a couple of follow up questions. As I had done this with other participants and received great results, what I got back from her was a surprise. She not only added the answers to my follow-up question, she also added to her original answers. Unlike the other participants, it was obvious that she had done extensive reading in order to add to the original questions. While her answers were not of immediate value because of her still new-found knowledge, it was interesting to see the understanding of NOS develop.

Participant Six.

Participant Six's *EBS* score (143) placed him ten points above the previous group of participants and two points above the mean score for all participants. His *SUSSI* total score of 142 placed him as the fourth highest of the *Phase Two* group. *Participant Six* has been teaching for many years, originally teaching in a neighboring District. He is now teaching at a middle school known for high quality instruction despite having a large immigrant population. One of the feeder elementary schools received a D rating from the State for the past two years. Despite this handicap, the school grades have remained fairly high. I have previous knowledge of this school, and know it to be one where collaboration between teachers is very common and the administration very supportive of their science program.

Two of this research project's teachers were also from this school (six and nine). They both went out of their way to report how much they love their co-workers and administration. The two participants do plan together and share lessons, but it was apparent during the NOS unit that they do take liberties. At no time during this nine-week project did I see identical or even similar lessons. I have had previous opportunities to visit their classrooms in the previous school year and have usually seen identical activities within their classroom.

It would seem that the NOS unit was open to interpretation, whereas more traditional topics, such as force and motion or energy, were not. While *Participant Nine* did follow the prescribed curriculum map provided by the District, *Participant Six* took his own path. While this might be construed as a creative measure, it was not beneficial for the topics of NOS.

It was not uncommon, and, in fact, more typically the norm, that the *Lesson Essential Question* (LEQ) on the board was not related to the activities of the class. For instance, in one particular visit, the LEQ posted was "Why Do People Interchange the Terms Science and Technology?" The activity the students were doing included the use of laptops to complete a Frayer Diagram for three vocabulary words: experiment, inference, and investigation. Frayer Models are commonly used to teach vocabulary where students provide a definition, factor characteristic, examples and non-examples of the word. However, there was no follow-up to this activity to make connections between these terms. If the LEQ indicated knowing the difference between investigation and experiment, this may have been an appropriate activity, but here too, without a debriefing to make connections, it is only speculation what knowledge students left the classroom with. Unfortunately, this practice – or lack thereof – seemed to be the norm rather than the exception.

On another visit, the LEQ posted was "How Does Scientific Knowledge Differ from Other Bodies of Knowledge?" Again, a seemingly-unrelated activity accompanied this question. Students spent the class time on a classic activity to determine one's reaction time by dropping and catching a ruler. While this activity could have related to the LEQ, no evidence was apparent this was the case. It was also discovered that this was the second day of this activity and the biggest point the teacher made was "If" and "Then" must be included in their written hypothesis on their lab report.

Based on previous visits to this classroom, I am confident that *Participant Six* is capable of being an effective teacher and believes passionately about providing a great learning environment for his students. When questioned about what the ideal science classroom should look like and the students' role within that classroom, he provided the following response:

> *"It needs to be engaging. It needs to be both interesting and relevant. Students can tell I care about their learning. The student has to be engaged. Students have to be responsible and become an active participant. In my particular Kagan training, I've seen better ways of doing that. I have become more of a facilitator and I check for understanding. Personally one of my strategies that I use is the think-pair-share to explain to them what this means and then they correct each other. We've also traded group to group so they all share their answers."*

It is clear that this participant has the capacity and training to be an effective teacher of all content, not just NOS. Unfortunately, he consistently missed opportunities for greater effectiveness and infusion of NOS, because he focused primarily on the Scientific Method. While his score on the *SUSSI* was higher than others, and within one standard deviation of the mean, perhaps he had not yet reached the threshold to have an adequate understanding of NOS. When asked about what themes are most important, the only thing he mentioned was about the scientific method.

> *Nature of science is a necessity right at the beginning. We have to get them to realize that science is a process. Every single lab we do we go through the major steps of the nature of science, scientific process, all that stuff.*

Besides the scientific process, which I assume he understood to mean the scientific method, in later responses to questions, he also included statements about the teaching of observation and inferences. Furthermore, he mentioned the difference between observation and inferences as indicated on the District's curriculum maps, but I could find no evidence this topic was covered in any meaningful way during classroom instruction.

It was clear that the focus of this nine-week unit was the Scientific Method. He also included instruction about variables and how to write a hypothesis. It seemed the focus on the scientific method and variables was more about preparation for a science fair project than the broader scope of NOS. In contrast, the teacher with whom he co-planned did cover the material more appropriately. This teacher also felt he has the freedom to teach what and how he wants with no constraints from administration, District or the State.

My interpretation of *Participant Six* was that he is a good teacher who cares deeply for his students, yet demands action from his them. It was clear he placed much emphasis on the scientific method. He was outspoken about how much he enjoyed the collegiality of co-planning and felt no constraints from it. He also felt quite free to teach the way he wants.

Participant Seven.

Participant Seven was one of two participants possessing a PhD (Curriculum and Instruction). She, too, had credentials from a major university. Not surprisingly, both her *EBS* (148) and *SUSSI* (153) score were high. She now teaches at a new STEM Academy having just transferred from a nearby high school where I first met her. Her philosophy of teaching, as one might expect, was much different from *Participant Two* who held a PhD in the Biological Sciences.

Participants seven's score on the *EBS* (143) was only two points away from the closest person having a true science background and slightly above the mean. Her *SUSSI* score (153) was fourth to highest of the participants in *Phase Two*, but second highest for those with notable science backgrounds.

If there were ever a true constructivist among the participants, it would be *Participant Seven*. The STEM Academy where she teaches serves a poor population. Before the school took on the brand of STEM Academy, it was known to be a challenging school to work in. Despite these challenges, *Participant Seven* teaches her class in true constructivist fashion. "I am a facilitator. I just give them the tools that they need to learn," she recounted during an interview. "Teaching is like that, you have got to do it individually as much as you can."

This being her first year teaching at the Academy, she was not there to plan the first unit of the year. Moreover, it should be noted, the unit did not follow the District's curriculum maps. Despite this major difference from other participants, I decided to include her in Phase Two anyway to see if and how she wove in aspects of NOS. As she explained, the unit focus was on aqueducts.

> *"The ending concept is how aqueducts and dams are both detrimental to society and also an advantage to society. That's a huge question."*

From the broader discussion about the STEM project, she made it evident that she felt that science and the technology derive from and are interconnected with society. Though the relationship between technology, science, and society are separate from the construct of NOS, it nevertheless shows how this teacher connects scientific knowledge to relevant societal issues.

During this unit and all future units, she offered a unique approach to her teaching. "I'm going to try to run my classroom as if this is their job," she explained during one of the interviews. It was fascinating to watch as student took on the role of an engineer investigating both modern and historical uses, designs, and potentials problems of aqueducts. There was no lecture, only a few minutes of directions at the beginning of class. The students worked all period with their teams, with each student having an assigned role. The teacher circulated and helped as needed, usually answering students' questions with another question in an effort to help guide their thoughts. Her skill was masterful as she roamed the class, never having to raise her voice to focus students.

When asked about constraints to her teaching she offered the following:

> *I have to go with the curriculum established by the District, but there's lots of freedom. We do co-plan. Like aqueducts, [this] would not have been my choice of topics. That was chosen before I got here, but it is okay. I can work with it. Personally, I feel like I have a lot freedom because I have proven myself.*

In terms of NOS, even though the unit did not fall within the District's curriculum, she made sure that NOS was embedded. For example, students were expected to think critically about how science can affect society and vice versa. "The nature of science is the foundation of scientific thinking. It is how society works into these different ideas," she explained during the interviews. She clearly had an understanding of NOS. When asked if there were other ways to teach NOS and what specific themes she thought were most important, she offered the following:

> *We could teach NOS by looking at Jane Goodall's work with the chimps... The students could pull apart parts of her method where Jane Goodall's methods follow only parts of the "scientific method" but still work, even though her methods were not "correct." The students realize the scientific method was not set in stone. In terms of what themes are most important, I think they are all important. The key is to determine which are more important in each setting. Not all equally important all the time.*

My assessment of her classroom was that it was a dynamic venue where she provided learning opportunities to all students regardless of ability and learning style on a moment-by-moment basis. She was not afraid to allow students to explore; in fact, she seemed to revel in it. The planning of her lessons included her taking the content structure and then fitting it into a broader and more social/cultural context (e.g., Jane Goodall reference). Her focus was on scientific thinking and was far beyond the typical scientific method. She also felt few constraints with co-planning, state or district curriculum mandates.

Participant Eight.

Participant Eight had an *EBS* score that was equal to one other participant and tied her for third highest score (150). To differentiate the two participants, despite having similar scores, *Participant Eight* held the highest *SUSSI* score (154) of all *Phase Two* participants. *Participant Eight* holds a biology degree and has worked for many years as a scientist before starting her teaching career. *Participant Eight* teaches at one of the District's magnet schools that are known for high standards.

During every observation, this participant had her students working together. Her classroom is arranged like most others in our district, in quads. While the arrangement may be commonplace, it is rare that it is utilized to its maximum collaborative potential. Interviews of this participant revealed a constructivist mindset. To questions regarding what the best science classroom looks like in terms of the teacher and students, her response confirmed the observations.

> *The perfect classroom has smooth transitions between topics, smooth transitions in answering the questions and keeping the interests of everyone. The students should be engaged at whatever level they can be engaged at. In the perfect model classroom, students are giving me feedback and working with each other to help each other understand. The end goal of instruction is that students learn how to learn; eventually they can teach themselves and the instructor is a facilitator.*

From the interviews and observational data, it was clear *Participant Eight* understood where she was going in terms of classroom practice. She readily admitted that sixth graders were not used to this much freedom and had been accustomed to much more structure and what she referred to as "spoon feeding." She acknowledged that, at the beginning of the year, she had held the role of teacher, but, by the end of the year, this role had transformed into one of facilitator, as the students become more comfortable with *their* new role as learners. As she explained,

At the beginning of the school year I teach differently than at the end. I sort of feel the students out the first nine weeks. Then I adjust my teaching style. I want my role as a teacher to be a facilitator. By the end of the year with my sixth-graders I am that facilitator: it takes a while for them to transition.

In terms of NOS, she conveyed a firm belief in its importance and was one of the few who could carry on that conversation beyond the scientific method. When asked about how she taught different concepts of NOS, she included the following description.

"I bring in the moving of the continents (people thought the Earth was flat), the reversal of the poles (evidence in the sea floor that it has happened before), the Global Warming/Climate Change debate (evidence that the Earth has experienced multiple warming and cooling periods), the Universe –Big Bang-no big bang-expansion; multiple dimensions (new evidence constantly discovered through the study of space with bigger and better technology-telescopes). How scientists are constantly trying to explain the world around them-hence theories and laws. I explain that Newton's Law's work on Earth and they are Laws which cannot be disproven or proven; but that we also have never left Earth so we do not know if those laws work elsewhere."

Within the *SUSSI* survey, where it asked about theories and laws, she wrote:

Laws are subject to natural phenomena that govern our existing conditions where we live. Laws do not change-at least in our Earth-what goes up; must come down.

Theories change over time-for example the theory of Geocentric Solar System vs Heliocentric Solar system. The base of observed knowledge had to grow for that theory to change.

While it is obvious she has some knowledge of NOS, there are still gaps in her knowledge.

Participant Eight had one of the most intriguing *SUSSI* surveys. Having worked as a biologist, she held an understanding that science was a slow meticulous process. She also had high scores within the category regarding collaboration and peer review, hence the emphasis in her classroom.

While it is evident she had a good understanding of NOS and made an attempt to teach NOS, the only thing missing was the activities-based approach to make her instruction explicit-reflective. She readily admitted, when asked about specific activities used to teach these concepts that she did not know what I was talking about. This was unfortunate, as these activities are included on a resource site that provides suggested activities for every topic, including NOS. All science teachers within the School District have access to and are encouraged to utilize this site. Clearly her admission represents a failure of the district to educate teachers about the resources available to them. These NOS resources had become available the past school year.

In this case, institutional barriers to instruction were present to some degree, with new programs being instituted at her school, but *Participant Eight* had chosen to ignore them. “In my classroom, I do what I need to do with my kids,” she replied with confidence.

Overall, *Participant Eight* had good student rapport, with respect being a recursive practice, as she helped them become young investigators. She gave clear directions, and students were able to mostly follow those directions. If students needed more explanation, she provided it in a respectful manner. She favored teaching students to love science along with its investigative properties. She was averse to teaching the facts needed to pass the next test. Although she had constraints with new curriculum mandates that could affect her practice, she chose to ignore what did not contribute to her envisioned classroom environment. She seemed to favor the teaching of inquiry more than strictly concentrating on experiments. This diversity with regard to the methods of science added to students' understandings of this important distinction. She also favored making sure students were able to see the very best of science practices, thus helping, through emphasis on ethical behavior and the peer review (collaboration) process, students make connections with real-life applications of science. In my four visits to her classroom, I observed her doing most of the talking only once. In that situation, she was covering school procedures and rules, not science. In every other visit she was the facilitator, and her students were either doing labs or research for projects. She recently sent me an email to inform me that she was one of two teachers at her school scoring at the top of the District's new evaluation system. As the evaluation focused on constructivist practices, I was not surprised.

Participant Nine.

Participant Nine teaches at the same school as *Participant Six*. Despite co-planning, which both participants noted as valuable, the difference in class practices during the NOS unit is dramatic. Similar to *Participant Eight*, *Participant Nine's* EBS score was 150, just on the verge of the one standard deviation mark. Her *SUSSI* score was 141, at the average of the group. Like *Participant Eight*, in her classroom she was clearly using practices associated with constructivism. She was also the first person that I witnessed doing an assignment that explicitly and reflectively addressed a specific NOS concept. However, in contrast to *Participant One* who used it explicitly, the reflection portion fell short, perhaps due to her limited NOS knowledge.

It was obvious from interviews and confirmed by observations that she viewed her role as a facilitator. Field notes illustrated how she was a master at asking students questions in response to their questions, thereby forcing students to come to their own understanding rather than her giving “The Answer.”

Having students teach other students was another component of her teaching philosophy. I witnessed more than once how she had students explain concepts they had figured out to other students who had not. In her soft voice, she asked an obviously shy student to help out a neighbor. The feeling of student empowerment was obvious on the face of the student as *Participant Nine* later confirmed the transfer of knowledge had happened and thanked the students for helping.

> *Instruction must meet the individual learner at his/her style; the student must “own” the learning. Encouragement from the teacher promotes the ownership. “Give respect to get respect” works both ways. Let the kids know they are important and that their future is important to you. Make sure they know that their future is affected by academics. They tend to “buy in.” They will try to meet you at least halfway.*

Clearly, she had embraced constructivism in a general sense and in terms of NOS: here too I witnessed and heard encouraging things.

> *I've been doing “What is Science” the CONPTT; the pseudoscience activity. I also do the Slime Lab where I focus on observation and inference. For the tentativeness of science, they are accustomed to my asking them “Why” and “How are we supposed to know that!?”*

Participant Nine was one of few teachers who could immediately list some of the NOS topics and had answers about how they were explicitly addressed.

In terms of any institutional restriction, *Participant Nine*, just as *Participant Six*, stated how much she liked the administration. “The Principal is awesome. He is really fantastic. As long as I stay within the safety guidelines I have never heard him say, ‘yes’ or ‘no’ to anything,” she told me. Other constraints seem minimal and were usually viewed as positives.

> *We have been assigned PLC’s. This means collaborating and planning together. We agree to follow the curriculum map. We each maintain responsibility for our students. I do everything in my power to do what is expected of me. I also recognize that there are times when I (think I) know my students and myself better than my superiors do. So, I do what I CAN to meet expectations of admin while doing what I feel best for kids.*

Other restrictions to teaching she felt were the burdens of paperwork and endless testing by the District, which affected the time she had with her students.

Participant Nine was very in tune with her students. She tried hard and seemed to be very successful at anticipating their learning needs. She allowed them to explore rather than giving them the answer. She moderated the time constraints as much as possible. Her NOS instruction focused on making good observations, the steps in the scientific method, and knowing what is and is not science. She believed she had few (if any) teaching constraints from administration. Most constraints come in the form of missed opportunities because of mandatory testing or through the burden of paperwork that kept her from planning, preparing labs, or communicating with parents. From every observation and interview prompt, she clearly demonstrated all the qualities of a constructivist teacher.

Participant Ten.

Participant Ten was one of two rather unique participants. *Participant Ten* came from an elementary background and proclaimed to feel inferior because of a lack of science background. *Participant Ten*'s *EBS* score was 151, placing her as second highest out of the eleven *Phase Two* participants. Her score also placed her over one standard deviation from the mean. It is obvious from the survey score, as well as the interview and observations, that she placed great value on student's developing their own knowledge. While her *SUSSI* score of 140 placed her just slightly below the mean. Interviews and casual discussions confirmed a shortfall in NOS understandings, but what happened in her classroom made up for the shortcomings with regard to NOS knowledge.

I first met this participant last year when she participated in a pilot for a *Bring Your Own Device* initiative. During an observation, I was in awe as I watched her students interact and work independently using their own electronic devices. Those who did not have their own devices used supplied laptops. Student engagement was 100%, whether doing the formative assessment via texting or continuing work on their projects. Even more profound than the classroom interaction was the students' achievement. At the end of the year, she administered a released State exam. Her sixth grade students, without having had seventh grade Life Science or eighth grade Earth Science, scored twice the school average. Science shortcomings or not, few could argue with her success in the classroom.

In *Participant Ten*'s classroom, there were no lectures or long-winded PowerPoints. It was the students who did the work, guided by a masterful facilitator.

"A lot of people think that the successful classroom is completely silent. I don't agree. I like to do a lot of hands-on and activities that require them to get up and move around. Students become more independent of their own learning and you become more of the moderator so to speak not moderator…. what's the word I'm looking for? Facilitator."

It is obvious she had a lot of CRISS trainings (that she had reported in casual conversations before and after classes) to the point that those strategies were second nature. CRISS is an acronym for (**CR**eating **I**ndependence through **S**tudent-owned **S**trategies) aimed at helping teaching students how to learn. Within every lesson I have ever observed, including some that extend to a previous year, there were always multiple activities used that engage the students in collaborative talk or writing exercises to challenge students to think about their thinking.

During the interviews, I felt bad for asking questions about the importance she placed on NOS, what it should look like in the classroom, and how they were included in her lessons. After a few no responses, she came back with the following, "When you say 'nature of science,' what are you talking about?" Clearly the term and its deeper connotations were not familiar despite being the unit topic for the nine weeks. From the interview, it seemed unlikely that NOS would be present within her instruction, but that was not the case. Though she lacked knowledge about NOS in a formal sense, she had one of the most impressive activities of all the participants that involved NOS.

As I began the day's observation, I quickly noticed a whiteboard displaying past, present and future activities. One particular activity was an instructional model that resembles SSI in that it requires students to use argumentation skills. Developed by the Florida Department of Education, Just Read, Florida! office, this strategy is called the Comprehensive Instructional

Sequence; students analyze complex text and then summarize and make inference from the text. Teachers could choose any text they wanted, from articles on the Internet to their textbook. The text she had chosen was one that I had provided to teachers about how science can be both rigid and flexible. The article covered the methods of science from hypothesis to theories and laws.

During another observation she was using an article about music piracy. The students analyzed the provided data, researched more data and drew conclusions based on their findings. As the conversation was wrapping up, she was able to draw the students to the realization that there was not a conclusive answer to the posed problem. She made the point that, this, too happens in science. When I questioned her about this after class, it was apparent that this train of thinking came from her broader epistemological beliefs and not knowledge of NOS, as she seemed again confused about NOS. It was interesting that it seemed to be more her understanding of how general knowledge was constructed that encouraged the classroom discussion and not her awareness that this is often how science knowledge is constructed with its often tentative nature.

In terms of constraints, she claimed there were no immediate constraints on her teaching. “I've always had the flexibility to be creative in my lessons, except when I was in a structured program like reading,” she replied. *Participant Ten* went on to include that it was only resources that dictate her classroom practice. If she had more science equipment, she claimed she would do more hands-on science.

While knowledge of NOS concepts may be lacking, *Participant Ten* was able to include some of these concepts, either by choosing resources that were offered to her or by her personal epistemological beliefs. In terms of what should be expected in a classroom in terms of constructivist practices, she would have a model classroom. One can only speculate what her classroom would like if she had some training in NOS.

Participant Eleven.

Participant Eleven is perhaps the most interesting case of all the total 28 participants, both in survey responses and classroom actions. Far and away, he held top honors with the highest EBS score (162) for *Phase Two* participants, ten points higher than *Participant Ten*. While one might question this high score as an aberration, from interviews and observations it was well deserved. On the flip side, his knowledge of NOS and perhaps science itself made for an interesting dynamic in the classroom. His score on the *SUSSI* survey (130) indicated his understanding of NOS was not on par with his personal epistemological beliefs. Some categories within the SUSSI survey were extremely low, especially the area pertaining to the methods of science.

From the first interview, it was clear that his *EBS* score was a true representation of his beliefs about knowledge and knowledge construction. He truly believed that students need to create their own knowledge. When asked what the classroom of the best science teacher would look like, he did not hesitate with the following answer.

> *No tables, no desks, no chairs. I would imagine all the students were there wearing lab coats, they were wearing goggles and they were all doing. They were listening to the teacher for direction, but they were all teaching themselves.*

From the survey, as well as the observations, he held true to his beliefs. During my first observation his class was in the computer lab researching ideas for their science fair projects. The students had clear parameters for their research.

They were charged with finding a topic, locating information relating to their topic that may help them carry out their experiment, drafting a hypothesis statement, including all information into a presentation, and saving it onto the school server. The students worked independently and seemed to do a fine job. The teacher circulated, looking over shoulders, making sure everyone was doing okay. I left that day feeling pretty good about the instruction. My second visit I found the students again in the computer lab finishing up the assignment. By the pace of the progress of the students, I became concerned that these students had been in the computer lab many times in between my visits and doing little more than working on a science fair project. It was more typical that science fair projects were started in school, but the bulk of the work was done at home or after school. With my curiosity piqued, the third visit proved the most interesting.

Nearly seven weeks after the first visit, students were still working on science fair projects, but this surprise went beyond timelines. The students received their instructions, which came in the form of a puppet show the teacher performed. Using a puppet with a Scottish accent, he explained the parts of the science fair board. The students were mesmerized, as was I. He was certainly not the typical science teacher. As I further probed his background through casual conversations, I found out he was a theatre major. This detail might explain what came next.

The puppet lecturette explained not just how the board was to be laid out, but also the proper technique for painting the board. At this point I could hardly believe what I was hearing and seeing. Paint brushes were handed out, and painting smocks adorned. The students spent this and the next class period painting the background of their board. As this school had just received a D by the State, it was hard to believe valuable class time was taken up with painting techniques, not to mention, I had not seen or found evidence of NOS instruction, outside the scientific method and variables. It was now clear why he was unable to respond to any question about NOS in a coherent fashion. When asked about how much freedom he has to teach the way he wants, he replied:

> *I think it's almost encouraged because I'm at an art school and I'm in sixth grade so I'm not I'm not really tested on the FCAT. We are given as much freedom as we want so long as that it's a positive learning environment and they are improving their test scores. BUT…the word of the school is, if I don't get these test scores up, I'll lose my job.*

From the EBS scores and interviews, it was clear that *Participant Eleven* embraced the notion of constructivism. I found students working in groups and independently on projects, but unfortunately those projects were not involving the topics associated with NOS. Unfortunately, the truth behind the *SUSSI* score was revealed. I was able to find no evidence of NOS instruction beyond the scientific method and much classroom time was spent on non-science items. It would seem the entire nine week period to cover a host of topics, was limited to the scientific method and how it applies to the science fair project.

The Researcher.

As mentioned earlier, the dual role of researcher and administrator had implications to affect the observations and interviews. In all but two cases, the researcher had known the participants for at least five years and some as much as ten years. In the other two cases, the researcher had a good rapport with the school principal who approached the participant on the researcher's behalf. Throughout the research, great care was taken to separate these two roles as much as possible, but acknowledge that some affects were present, but believe the affects to be minimal to the outcomes of this research.

These relationships between the researcher and participants built over these years by way of interaction and various settings from trainings to many weeks spent together while building the District's curriculum. In many ways, the trust established through the years of working collaboratively on the various District projects or time spent together during trainings afforded the research with honesty between participants and researcher. This same level of honesty may not have been forthcoming without this established trust. The participants seemed at no time constrained about speaking about the day to day struggles of the modern classroom. This trust was continually confirmed as the researcher made sure to mention during any discussion that these words will not be repeated to any direct supervisor.

During the classroom observations, the participants were always eager to know what the researcher thought about their instruction. This eagerness to please may have been present regardless of the role of the observer. The typical response included a statement about this research is looking at overall choices the participants makes during this NOS unit and the relationship to their epistemological beliefs, not was this a good or bad lesson. If teachers were choosing to teach NOS, it was their version of NOS, which provided more observational opportunities.

In almost every case, the teachers had 24 hours' notice before the observations. This served two purposes. First, it gave the teachers advanced warning so that visits were less threatening. Second, and most important, the researcher was able to schedule visits more effectively by making sure science instruction would take place. Many times observations were not possible do to scheduled testing or some other non-science activity (e.g., nurse lessons, assemblies, etc.). Only once was the researcher told not to come on a day when science instruction would take place as the participant (*Participant Five*) felt the activity would not fall into the category the researcher was investigating.

Overall, the researcher's role as administrator was diminished do to pre-existing relationships with most participants. If there was some affect from the role of administrator, it was not noticeable and held in check with the various reminders of the researcher role to hold information private, especially from their immediate supervisor.

Profile Conclusions.

Overall, interesting trends emerged from this group of participants. From the epistemological beliefs surveys, a strong trend emerged about this relationship. While interesting, the more complex nature of how these beliefs affected practice could have escaped notice without the interviews and observations. Table 10 provides an overview of the research findings about participants' epistemological beliefs, purported constraints to instruction and type of instructional practice (decontextualizes or contextualized). For example, Participant One focused solely on one facet of NOS isolated from other related facets. This lack of contextualization of learning separates the learning of basic knowledge from the bigger picture. In contrast, *Participant Nine* placed her NOS instruction within the context of a large setting where students were looking at a data and trying to determine a solution. NOS instruction was inserted into this context when question were presented to students about the certainty of knowledge given the provided information. *Participant Ten*, was the only teacher who provided both contextualized and decontextualized instruction of NOS. These were the only three candidates that had *a NOS-COP* score above the minimum. Even these three participants were limited in their NOS instruction, so though it was observed, the amount was minimal.

As many teachers ventured into more traditional content during this timeframe or used traditional content as a backdrop for teaching NOS, an additional column has been included to describe the types of instruction noted during this instruction. It is included here to provide a richer understanding of the participants and their practice. The categories used to distinguish types of instruction were positivist 1, positivist 2 and constructivist. Differences between the strictly teacher-centered activities of the positivist 1 category were distinguished from positivist 2 by the use of hands-on activities. Criteria distinguishing positivist 2 from constructivist were more qualitative in nature and rested in whether students were expected to come to their own understandings versus being told information or asked to confirm an authoritative answer. For example, a teacher providing instruction using didactic methods would be classified as positivist 1 with regard to instructional style. A teacher employing hands-on activities was classified as at minimum, positivist 2. For a teacher to be categorized as constructivist required a qualitative difference beyond merely using hands-on activities toward one that required students to be involved in the choices made during inquiry, such as designing the experiment, choosing variables, methods to analyze data, and making their own conclusions based upon collected data.

For the types of NOS instruction and its categorization, a similar theme occurred, but since there were few participants who taught NOS, the categories are less robust in terms of differences. Similar to categories used for practice and skills or more traditional content, NOS was divided into two broad, but quite distinct groups. The positivist group, which consisted of one participant (Participant One), taught NOS in a very teacher centered manner, where she gave "THE" answer after students filled out a worksheet on a NOS topic covering the differences between science and pseudoscience. The only other participants that could be considered to have taught NOS (i.e., Participant Nine & Ten) used a much more student-centered approach where students were discussing answers and challenged to think and explain about the situation being posed in relationship to how science knowledge is constructed.

The table below (Table 10) also includes the SUSSI scores for comparison purposes. Though these scores were not used in the categorization of teachers, it seemed prudent to rank their scores to compare their relative position against the types of practices employed. Though the range of SUSSI scores was relatively small at 29 points, there were statistical differences (S.D. = 10.8) between the participants. Given the potential range of the survey of 160 points as 40 would be considered the lowest possible score, there was an 18% difference in points between the lowest scoring participant and the highest. Given this difference in relative scores as compared to types of NOS practice proved interesting. A more robust explanation and examples of teacher's choices regarding methods of instruction are provided in the section that examines research question 1c.

Research Question 1b - In what ways does the co-occurence between understandings of NOS and personal epistemological beliefs affect the importance teachers place on NOS?

All participants either explicitly stated within interviews (See Table 11) or indicated in some way during casual conversations the importance of NOS instruction. All indicated that, in some manner, NOS can improve the learning of science content. Unfortunately, teachers conflated the practice and skills of science with the knowledge construction component commonly referred to as NOS (Khishfe & Abd-El-Khalik, 2002). It was made clear within the interviews: teachers believed that "some version of NOS" served as a foundation for the learning of science.

Table 10

Overview of Participants

Participant	NOS Knowledge	Instructional Type		Constraints						Practice	
Ranked from Low to High According to EBS Survey	SUSSI Score	Contextualized	Decontextualized	Standards	District	Testing	School Admin	Peers	Length of Class Time	NOS	Traditional Content
One (128)	125		X			X	X	X	X	P	P2
Two (131)	146			X	X	X				NA	P2
Three (131)	137									NA	P1
Four (131)	129								X	NA	P2
Five (131)	134						X	X		NA	P2
Six (143)	142				X	X				NA	P2
Seven (148)	153									NA	C
Eight (150)	154						X			NA	C
Nine (150)	154		X							C	C
Ten (151)	140	X	X			X			X	C	C
Eleven (162)	130									NA	C

P1 = Positivist 1 style instruction with no hands-on component
P2 = Positivist 2 style with some hands-on components, but typically conformational in nature. Students mimic teacher.
C = Constructivist with hands-on components where students have the freedom to manipulate their own variables, analyze data, and develop their own conclusions.
NA = Not applicable as it was either not directly observed or evidence of its instruction was not evident via collected artifacts.

Table 11

Importance of NOS within Instruction

Participants	Importance of NOS
One	I think it is as important [as more traditional content] in the broad sense but perhaps not for **6th graders** whose ability to be insightful is limited.
Four	Nature science has been has been one of my key topics as most major assessments include the scientific method are scientific inquiry questions
Five	They need to know what science is before they can learn anything else. [Teaching NOS] needs to be done. They need to know what science is before they can learn anything else. The con is to get hung up on things like variables.
Nine	I don't feel we can teach them anything in science if they don't understand the basics. If they don't understand how it's done. The nature of science is how it comes together why.

Table 11 provides examples of how participants believe NOS was a foundational requirement for students to enable them to comprehend traditional content. Most participants held a view supporting the importance of NOS; what differed among the participants was their interpretation of NOS. Table 12 provides samples from participant interviews to give clarity about their interpretations of what they believe to be NOS.

Unfortunately, knowledge and importance can be blurred, as teachers were mostly unable to differentiate NOS from the practice and skills needed for science. Table 13 provides evidence about how most participants referred to the practices and skills as foundational components or the scientific method and not the NOS constructs this research was investigating. Neither the importance teachers place on NOS nor their understanding of NOS was enough to cause teachers to consider it integral science content, if the presence within instruction is any proxy.

Classroom observations also supported the conclusion that most teachers emphasized the scientific method rather than NOS as only three of the eleven participants included NOS concepts into their instruction.

Table 12

Teacher Interpretations of NOS

Participants	Comments
One	The nature of science confuses me so I tried to teach all the components that I think that are important. I teach what is in the curriculum maps. I use examples that I feel are relevant to our city, county, state, and country. I try to guide the students to 'see' how scientists think or should think and how they might apply that to our studies and beyond the classroom.
Three	though I always tried to emphasize guys this is really performing one of the steps in the scientific method or scientific inquiry because I emphasize both of the differences between them. It's important that they understand the steps
Four	Nature of science has been has been one of my key topics as most major assessments include the scientific method are scientific inquiry questions. Nature science is applied almost all year.
Participant Five	[Teaching NOS] needs to be done. They need to know what science is before they can learn anything else. The con is to get hung up on things like variables.
Six	I value it quite a bit because everything we do focuses on the process of scientific evaluation.
Seven	the nature of science is the foundation the scientific thinking the scientific method how society works into these different actual ideas
Eight	I don't think they can understand the way that scientists work or the way the scientists arrive at anything without knowing how to do it. I try to promote the type of thinking process that leads to invention and inquiry.
Nine	I don't feel we can teach them anything in science if they don't understand the basics, if they don't understand how it's done. The nature of science is the procedures the pieces or parts of how it comes together and why.
Ten	When you say nature science, what are you talking about?
Eleven	It's part of everything. I would never stop teaching that, it would be every day.

For example, *Participant Eleven*, despite having a very low score compared to the other participants on the *SUSSI*, felt it was very important. Unfortunately, he never ventured away from the scientific method at any time within the NOS unit. During every observation spread over the nine weeks, *Participant Eleven*'s students were preparing their science fair projects and focused on the scientific method. In this unique case, his *EBS* score was the highest of the *Phase Two* participants, yet his *SUSSI* score was quite low in comparison. While his practice was almost exclusively student-centered as one might envision from a high score on the *EBS* survey, the SUSSI score and the lack of knowledge about NOS was obvious within his instruction.
In contrast, *Participant One* indicated in the interview that she was confused about NOS topics despite having a bachelor's degree in a semi-related field. Her *SUSSI* scores were similar to *Participant Eleven*, but unlike *Participant Eleven*, she received a low score on the EBS survey. Despite this confusion and a low *EBS* score, she put forth her best effort to teach NOS through some of the ENSI activities as she made every attempt to follow the District's curriculum. From observations and interviews, it was obvious her personal epistemological beliefs were commensurate with her practice. The instructional style was teacher-centered, not student-centered, and not explicit-reflective as would be hoped. From *Participant One's* own words, "I try to teach all the components that I think that are important," illustrates the difference between how she may perceive her role during more traditional content (e.g. light, motion, etc.), "a facilitator-director," and how that is different from when she covers the NOS unit. It is also obvious from this statement (See Table 13) and others in the interview that she does what she is told by the State, District or school administration. While it is clear she holds NOS as an important even though she may not have a good understanding of the construct, at the very least she makes every effort to help her students understand it. Unfortunately, the lack of knowledge

about NOS caused difficulties, so too may her personal epistemological beliefs. The influence of epistemological beliefs, both scientific and personal, will be discussed further later in a discussion of *Research Question 1c*.

Knowledge Versus Importance of NOS.

In other cases, where teachers had the knowledge to teach NOS, there was still no guarantee it would be taught, despite the implied importance by State and District mandates. From previous research, it is well known that adequate understandings of NOS do not necessarily influence practice or the importance placed on NOS (Abd- El-Khalik et al., 1998). In other words, when teachers choose to teach NOS, it is this choice that is important indicator of how they value NOS. It is not a matter of merely holding adequate understandings of NOS. For example, *Participant Two* holds a PhD in the field of genetics. He spent many years practicing his craft at the university level and has an intimate knowledge of NOS as evidenced from the fact that he can recite the NOS features included within the District's Curriculum Maps and is able to give examples from within his field. Despite this knowledge, he chooses not to focus on NOS beyond the scientific method. In this case, I surmise that this participant did not internalize the importance of NOS for students, as it is this internalization that is responsible for it to become translated into action (Bell et al., 2000). While what he understands that NOS played a major role during his prior role as a researcher discovered through the interviews, it may not be what he feels is necessary for his students. From the interviews and observations, there is a distinction between what he has done in the field of science research and his classroom practice. At no time was there discussion of major inquiry activities that he clearly had the capacity to undertake with his students. This interpretation is further supported by his rather disparate scores on the *EBS* and

SUSSI. As one might expect from a PhD in the science field, his SUSSI survey score was relatively high and supported through interviews. In contrast, his *EBS* score was second to lowest. As he notes no other constraints to his instruction, it is unclear what else could be a factor of how he chooses to teach or not teach NOS other than views about knowledge acquisition that are more positivist than constructivist.

Summary.

As expected, a lack of NOS knowledge can be a barrier to NOS instruction, but knowledge does not equal importance with regard to students learning about NOS. In the case of these eleven participants, there were many who struggled with a knowledge of NOS and conflated it with the practice and skills of science. In terms of knowledge of NOS, it was participants 2, 6, 7, 8, & 9 who had some knowledge of NOS as defined by the generally accepted list of seven NOS tenets (Lederman & Abd-El-Khalik, 1998). Whether or not this knowledge existed from previous coursework or from being placed in the Curriculum Maps is uncertain. Unfortunately, of these five who possessed adequate knowledge, it was only reflected in three of the classrooms during my visits. What was hopeful was that *Participant One*, with her low NOS score, tried to explicitly addresses the concepts, but, from what I observed, she was held back by her own lack of understanding.

In summary, there existed some evidence that the types of practice observed and epistemological beliefs. There was also some contrast between those who understood and attempted to teach NOS and those who focused entirely on the scientific method. Given that those participants with deficits in NOS understandings, based on the *SUSSI* and interview data, struggled to teach NOS, there may be some threshold of knowledge necessary to effectively teach NOS. In general, those participants with *SUSSI* scores below 140 and *EBS* Survey scores below 148 did not teach NOS other than the scientific method or taught it in a positivist manner. The results confirm the notion that knowledge of NOS was not enough to instill importance in these participants. Even among teachers with higher SUSSI scores, representing better understanding of NOS, none provided the essential NOS instruction called for by the District's Curriculum Maps. Given this information about knowledge, constraints and epistemological beliefs, those with higher SUSSI scores who did not teach NOS may not have had the Pedagogical Content Knowledge to teach the concept of NOS.

Research Question 1c - In what ways does the co-occurrence between understandings of NOS and personal epistemological beliefs affect the classroom activities during NOS instruction?

As mentioned earlier, epistemological beliefs can provide an understanding of a teacher's practice: they can guide instructional decisions, influence classroom management, and serve as a lens for understanding classroom events (e.g., Jones & Carter, 2007; Pajares, 1992; Richardson, 1996). Research regarding epistemological beliefs has revealed that beliefs do affect teacher practices (e.g., Hashweh, 1996; Tsai, 2002; Kang & Wallace, 2004; Yerrick, Parke, & Nugent, 1997). In fact, epistemological beliefs are believed to play a major role in determining classroom practice (Benson, 1989). Table 14 was created to provide examples of how teachers believe they are teaching NOS through the use of the activities they have chosen. Participants' answers provided in Table 13 were derived from responses to questions regarding the extent to which NOS is taught (e.g., reasons for teaching, pros and cons, how it is valued, factors impacting instruction, etc.). Responses indicate confusion as to what is, and what is not NOS, as they answered questions about their teaching of NOS.

Table 13

Participant Responses About NOS Activities

Participants	Participant Comments	Researcher Comments
One	I always coming back to always reminding them about Predicting. What's our hypothesis? I use a lot of worksheets. For example, *Sunsets and Souls* from the University of Indiana. I do a cartoon about how you proceed through solving a problem using the steps of the scientific method and try to go over the *CONPPT* ideas.	Response illustrates some confusion as to what is and what is not NOS. She references an activity that corresponds to science versus pseudoscience , which is NOS, but then mentions the scientific method, which is not NOS.
Two	Sometimes I do a project or lab work on and give them some latitude design we talked about the method in the scientific method your design an experiment is updated pick three different balls of three different heights you get the information that satisfies the scientific method. …but if you just put the scientific method as the nature of science, I'm not sure totally belongs there. In the beginning we talk about certain scientists.	Response illustrates he has an idea of what is NOS, but when asked what he does to teach it, practice and skills are all that are mentioned.
Three	if looking at the difference between theory and law, I certainly make sure they understand the process of going from the point of the hypothesis to the theory and then to a law. Absolutely, I include the steps of the scientific method into the lab reports they did at the end of the class.	Responses indicate confusion between NOS and the Practice and Skills of Science. Also, the response specific to NOS with regard to hypothesis, theory and law demonstrates an inadequate understanding of at least this NOS tenet.

Table 13

Participant Responses About NOS Activities (Continued)

Participants (Continued)	Participant Comments	Researcher Comments
Four	Last year, when teaching how to build a circuit. The students had to come up with a question that involved those materials. They had to develop their hypothesis with the goal of getting the light-bulb to light. I've done the airplane lab.	Response indicates some confusion of NOS with confusion between hands-on science and the NOS tenets required to be taught within the mandated curriculum.
Five	For the lab part the scientific method, it is explicit. The other types of things are implicit. Honestly, have mostly just talked about that [referring to NOS]. I mostly just touch on it and give examples, (this year, they watched videos of scientists at work gathering data, making observations, etc. and we talked about what they were doing.	Response indicates that no NOS activities have been done.
Six	We have to get them to realize different to realize that science is a process. Every single lab we do we go through the major steps of the nature of science scientific process.	Response indicates confusion between the scientific method and NOS
Eight	The most important thing is that they know those steps because we are going into the science projects, but I also teach it will be teach about laws and theories. Also talk about that religion is a belief system and science is not	Response indicates confusion about the difference between the scientific method and NOS
Nine	I've been doing "What is Science (compared to pseudoscience)."	Response indicated his participant had knowledge of NOS, what was required to be taught, and was teaching it.
Ten	Things definitely changed here with the 45 minutes of class time, especially when you're trying to do hands-on and you're trying to go through the steps [of the scientific method] in a 45 minute class.	Response indicates an emphasis on hands-on as it applies to the practice and skills rather than an NOS specific activity.

Table 13

Participant Responses About NOS Activities (Continued)

Participants (Continued)	Participant Comments	Researcher Comments
Eleven	brought in their own matchbox cars were going to weight the vehicles and then we used different heights of the ramp we use a science verbal or in some textbooks and then we use stopwatch and they were calculating the vehicle speed and of course the ones that the reason they had to weigh them in it was to find out about the force and we talked about the car accident and I think they will perceive that it or how the of the variables one or two different variables that we use the scientific method and how to approach experiment.	This response indicates confusion about the difference between NOS and the scientific method. It also shows how this participant was not following the District's pacing guidelines.

While the original sorting of teachers in Phase I was based on standard deviations from the Epistemological Belief Survey mean score, this was not meant to predict classroom practice, but helps in the comparing and contrasting of participants.

To better describe teacher practice, a table was created (See Table 14) to represent the relative position of participants according to epistemological belief scores and the types of practice they most commonly employed. Keeping with the emergent methodology of this research, commonalities arose between the participants with regard to their classroom practice. The range of classroom practice ranged from no hands-on to the use of very student-centered high levels of inquiry. Within this range were distinct clusters of classroom practices. It was these distinct clusters that were used to develop the categories that classify teacher practice. In all cases, these practices were observed first hand. Artifacts were used only to enhance the understandings gained from direct observation as some activities may span multiple days when the researcher may not have been present.

It is important to convey a caveat about using the epistemological beliefs survey with relation to teacher practice. The epistemological beliefs survey assesses beliefs about the construction of knowledge. It does not predict teacher practice based on these scores. It is used here to look at potential relationships only, not as a predictor and does not suggest it as a predictive tool.

Using data from classroom observation and also classroom artifacts when applicable, types of practice were classified. Two of the teachers performed no hands-on activities of any kind, and the classification of positivist 1 evolved reflecting the teacher's actions of ultimate authority holder. *Participant Three* exemplified this position with his choice of classroom activities. A typical class period involved a lecture from a PPT while students copied notes directly from the PPT. At no time was evidence found or discussed where students engaged in hands-on practices or even a small activity using manipulates. All information was provided to students via the PPT. The other two categories were then reflective of the use of hands-on activities. There again was a dichotomous differentiation as to how these activities were carried out. The positivist 2 classification had students mimic the teacher's actions, following directions in a systematic manner in order to confirm what the students had already been told. *Participant Two* serves as an exemplar for this category. This participant would speak at great length about what scientists do to investigate questions to the point that directions were provided to the students about what they were going to do, even down to what would happen as a result of their action. This emphasis on the teacher providing all the answers left little room for students to construct their own knowledge. The third category, also including hands-on activities, required students to utilize their own creativity in either designing their own activity or analyzing and constructing their own conclusion based on their data. An example of this type of instruction is best examined through an activity Participant Nine had her students do. Instead of having students follow a scripted set of instructions, she had her students develop their own question and hypothesis. They then designed their own experiment to test their hypothesis, collect and analyze their data and construct conclusions based on their findings. Throughout this activity the instructor asked questions rather than providing answers as the students grappled with the task. While this exemplar provides a counter-balance to the other forms of instruction that were observed (Positivist 1 & 2), it still does not include what should, or could, be present in terms of NOS. *Participant Nine*, being one of the three who included any form of explicit NOS instruction. She was the only participant who had NOS-COP scores above the minimum ratings during the research period, as most did not teach what is typically thought of as NOS. The majority of participants only taught what they perceived as NOS, or, in the other two cases where NOS was taught, it was either extremely brief or taught in a manner that most would consider lecture. It is for this reason a greater emphasis was placed on field notes rather than the NOS-COP. It should be noted that instruction for all participants was mostly implicit in terms of NOS tenets and much focus on the scientific method itself. Only *Participant One* and *Participant Nine* explicitly targeted NOS tenets through the use of specific activities. Only *Participant Nine* used those activities in a manner to mirror preferred practices (e.g. explicit-reflective).

It is here another caveat should be placed. The categories in many cases represent more a release of responsibilities from teacher to student more than best practices for teaching what most would consider NOS. The teachers were teaching what they thought was NOS or provided activities they felt would cover the NOS benchmarks. Also, teachers taught numerous lessons and not all lessons were the same. Timing also did not permit seeing all lessons. It is the fact that every classroom was observed multiple times during the research period that provides evidence to at least make tentative claims about practice during the NOS unit.

Table 14

EBS/NOS vs. Practice Type

Participant	**(EBS/SUSSI)**	**Practice**
Participant 1	128/125	Positivist 1
Participant 2	131/146	Positivist 2
Participant 3	131/137	Positivist 1
Participant 4	131/129	Positivist 2
Participant 5	131/134	Positivist 2
Participant 6	143/142	Positivist 2
Participant 7	148/153	Constructivist
Participant 8	150/154	Constructivist
Participant 9	150/141	Constructivist
Participant 10	151/140	Constructivist
Participant 11	162/130	Constructivist

P1 = Positivist style instruction with no hands-on component
P2 = Positivist with some hands-on components, but typically conformational in nature. Students mimic teacher.
C = Constructivist with hands-on components where students have the freedom to manipulate their own variables, analyze data, and develop their own conclusions.

Positivist style instruction.

The distinctions in types of practices were quite evident. Teachers were consistent in their instruction methods as that taught what they felt was NOS. Additionally, teachers' beliefs according to survey scores closely mirrored their choices for instruction methods. Lower scores on the epistemological beliefs surveys, or those with more positivist views, were mostly represented by non-constructivist (or more positivist) approaches to teaching.

For example, *Participants One and Three*, each with lower *EBS* scores were categorized as using a more positivist instructional style. They were observed to lecture more and focus on the facts of science (e.g., definitions, formulas and the scientific method).

Participant Three was more typical of someone with more positivist beliefs and instructional methodologies. *Participant Three* employed a more didactic technique, relying on information transfer. Though he mentioned hands-on activities as the practice his students preferred to learn and the manner from which they learned best, there was no evidence of hands-on activities. If hands-on activities did exist, they apparently were infrequent. In the case of *Participant Three*, his *SUSSI* score (137) was higher than his *EBS* score, yet his activities were similar with regard to style and far more limited in terms of NOS than *Participant One*.

Participant One had the lowest *EBS* score and a low *SUSSI* score. She readily admitted to confusion about NOS. Though NOS activities were completed, the method of instruction was more teacher-centered, with the activity treated as another worksheet with correct answers eventually given by the teacher. Unfortunately, the lack of NOS knowledge seemed to limit her within NOS activities.

Positivist 2 methods.

Positivist 2 methods are marked by the use of hands-on activities and are emergent at best with regards to the pedagogical stance between positivist and constructivist. Clearly, hands-on activities do not equate to constructivist practices. Hands-on practices that were observed with a higher level of inquiry level above “cookbook” or conformational lab, where students took on more responsibility were reserved for the constructivist designation. *Participant Four* was another participant with a similar score on the *EBS* as *Participant Two*, *Three*, and *Five* (but lower on the *SUSSI*). She employed hands-on activities in a far greater numbers. Although her activities were limited to the scientific method, they were present. The same case could be made for *Participant Five*.

One group with scores in the mid-range of the *Phase Two* participants (*Two, Four Five, & Six*) was more positivist 2, sometimes using a hands-on activity, but not to its fullest extent. Instead, the participants kept control by having students mimic their actions as opposed to letting students have the freedom to make choices about the investigation. The reason some participants struggled to get past this positivist 2 stage is unclear.

The teacher (*Participant Two*) with a lower epistemological belief gave students a lengthy description of how variables could be manipulated within a limited range of options. Students needed to do little more than mimic the teacher to perform the experiment correctly. In the latter situation, the class was mostly taken up by the lengthy lecture with little time left for the hands-on activity. In this case it was the attempt at applying hands-on activities that differentiates the teacher from a positivist 1 categorization.

Constructivist methods.

To illustrate the difference between positivist 2 and constructivist, *Participant Two* with his lower epistemological beliefs (131/146) can be contrasted with *Participant Nine* who held higher epistemological beliefs (150/141). Like *Participant Two*, *Participant Nine* had students do a nearly identical activity in which they designed their own investigation. *Participant Nine* provided students more freedom to choose variables and write their own procedures (*Participant Nine*). Furthermore, this teacher used questioning techniques rather than giving students answers in an attempt to help guide their progress. *Participant Nine* also emphasized constructing knowledge from the data, collaboration, repetition and replication of data. *Participant Two*, in contrast, focused more on the steps of the scientific method, with the importance of repetition left to chance.

Overall, data may suggest a potential trend of increasing constructivist activities with higher EBS scores. Again, it is not suggested that the Epistemological Beliefs Instrument can or should be used as a predictive tool. This research did have the limitation of not mandating lessons. Given the freedom for teacher's to choose lessons and the fact they all had diverse backgrounds of both science and pedagogy to teach, it is admittedly difficult to make any broad claims about these relationships. Those participants with *EBS* scores closer toward the upper range of epistemological beliefs (*Participants Seven* through *Eleven*) were more student oriented, and they included more hands-on and inquiry activities (See Table 14).

Research has shown that these same epistemological beliefs affect **how** NOS is taught (Gallagher, 1991). This was certainly the case within this group of participants. Those with low scores on the *SUSSI* either did not teach NOS or it was limited to the scientific method. For those who taught NOS, the quality of that instruction as judged by whether it was constructivist, positivist 2 or positivist 1 methodologies, may have been reflective of their EBS scores.

Research Question 1d - What other factors are responsible for influencing the choices teachers make about classroom instruction?

Effects on classroom instruction are multi-faceted in that typically no single thing controls the choices teachers make about teaching NOS. Certainly, teachers themselves need to possess adequate understandings of NOS. Teachers must also feel NOS to be an important part of science instruction. Both these conditions can be thought of as teacher's internal affordances to NOS instruction, but there are also external stimuli that can affect instructional practice. These situational and institutional barriers constraints typically include: pressure to cover content, classroom management skills, constraints imposed by cooperating teachers, beliefs about students, etc. Using observational data, formal interview and casual discussions with teachers during this research, potential trends emerged as to common institutional barriers. Table 15 provides an overview as to what the constraints to instruction were as well as which participants believed they faced these constraints.

Although some teachers mentioned a number of constraints, in most cases, constraints were acknowledged to be minimal by the participants; but a few overall potential trends developed from their responses. To acknowledge that the dual role of research and administrator may could in some cases affect the types of responses given by participants. In this case, there was never a situation in which the researcher felt the participants were holding back. In fact, the opposite case was more often true, that the trust of the prior relationship made participants open to providing honest response. As *Participant Eight* mentioned how the administration may have wanted her to do something, but when the door closed she did what she thought best for the benefit of her students. Overall, limitations from the dual role did not seem to affect the honesty of barriers provided by participants, evidenced by the numerous, but not severe constraints to instruction they felt were present.

These common themes served as the source of the categories presented below (See Table 15). These listed constraints include: State Standards, District mandates such as Curriculum Maps and timelines, testing, school-based administration, peers & duration of class periods. These constraints are discussed in further detail below.

Table 15

Teacher Perceived Constraints

Participant	Standards	District	Testing	School Admin	Peers	Length of Class Time
One			X	X	X	X
Two	X	X	X			
Three						
Four						X
Five				X	X	(X) planning related
Six		X	X			
Seven						
Eight				X		
Nine						
Ten			X			X
Eleven						

State Standards & District Curriculum.

There is an expectation by the District that the State Standards be covered. The District has also aligned the curriculum with the expectation that teachers' pacing should be close to one another. It is felt that concurrent pacing of courses is necessary because of the high mobility of the District's students. It is not uncommon that students are enrolled in several different schools during the school year. There are some schools where special programs such as *Science, Technology, Engineering, Arts and Mathematics* (STEAM), *Science technology, Engineering and Mathematics* (STEM), and *Pre-International Baccalaureate Academies* (Pre-IB) that exist that may preclude the following of the pacing guides, but for the most part, adherence to the guides is the rule.

Only one teacher took exception to the State's Standards (Florida Department of Education, 2008). *Participant Two* felt constrained by the fact he could not pursue a topic even if student interest was there. He was also one of the few teachers who may have had the background knowledge to carry out such a variance from a standard curriculum. All other teachers felt comfortable with teaching the State Standards and using the District's pacing guide.

In contrast, it would seem that *Participant One*, with her extremely low score on the SUSSI, may have been constrained by the District's curriculum in a positive way. *Participant One*, despite her limited NOS knowledge, made every attempt to follow what she felt was a restrictive District curriculum. As a result, she did include pieces of NOS that were likely not to have been included if she was left to her own choices. Even then, the instructional methods employed were not what would be hoped for by the District Administration, and did not include every construct that should be covered. *Participant One* was the exception in that she held a relatively inadequate understanding of NOS but still tried her best to teach the mandated curriculum. Most others who held similar low scores made no attempt to teach NOS beyond the scientific method. Lederman & Niess (1997) note, NOS understandings do not come naturally, nor can they be mandated. Overall, even with NOS having a prominent role in both the State's standards and being clearly defined within the District's curriculum, it had little effect on most teachers' practice, either positive or negative.

Class Time, Planning Time and Testing as a Function of Time.

Time was perceived as the biggest constraint and usually was mentioned in connection with District progress monitoring testing, which takes place three times per year for each core subject. This untimed test can exceed the allotted time for a class, so each core test can cannibalize much classroom time outside of the tested course. Testing was mentioned as a constraint by three participants (1, 2, & 6). The concern was voiced over the lost instruction time. Time was also a factor mentioned by participants in terms of scheduling models. It was noted that not having a block schedule was a limiting factor for providing hands-on opportunities. Time for planning was noted by *Participant Five* as being a limitation to instruction. If concerns about testing and planning are included as a function of time lost to instruction, then the majority (6/11) of teachers see that time lost as problematic (See Table 16 below).

Table 16

Time as a Barrier

Participants	Participant Comments	Researcher Comment
One	Last year it was very restrictive with extended reading passages, Discovery [progress monitoring] testing, behavioral issues. Time is probably the big gap because I do feel pressured to move through the curriculum. The first year I was here we had block schedule and I felt like at least I could get a lab accomplished	Progress monitoring occurs three times per year for math, science, and language arts.
Two	Lack of time for planning & classroom setup. We have [time] pressure[s] because of testing.	
Four	55 minutes, [makes it] so hard to do labs.	
Five	Also, to come up with effective and engaging lessons it takes time and when you don't have enough time.	Refers to a planning time constraint
Six	Discovery [progress monitoring] testing is a little bit of a hindrance	
Ten	…Discovery [progress monitoring testing] testing… with the 45 minutes of class time, especially when you're trying to do hands-on and you're trying to go through the steps in a 45 minute class. I had block scheduling so there's a big difference with 45 minutes and 90 minutes.	

School Administrative and Peer Constraints.

For the most part, the majority of participants felt they had the freedom to teach the way they wanted. While three of the eleven participants voiced explicit concerns about administrative constraints (*Participant One, Two and Five*), only one felt direct barriers (See Table 17). *Participant Two*, while vocal about his concerns, admitted that he felt few constraints from his current administration. *Participant Five,* on the other hand, vocalized her concerns about administrative controls as immediate concerns. *Participant One* voiced a general concern (See Table 17), but her biggest concerns, while related to administrative constraints, are better explained through the co-planning section to follow. Fortunately, most participants felt a great deal of freedom to teach the way they wanted with little interference from school administration.

Perhaps a more interesting finding is the mention of barriers to instruction based upon peer interaction through the co-planning process (see Table 18 below). As mentioned earlier, co-planning is a practice promoted by the District but implemented by the school administration. For most of the participants, there were short replies to questions about co-planning, such as “We have a great team,” or “we work well together.” In these responses, gathered during interviews, it was clear that most enjoyed sharing the workload, collaborating with peers and having a general sense of camaraderie with their peers. Though most had positive remarks about co-planning, four participants voiced concerns about co-planning. These concerns were related to both their peers and the administrational mandate to co-plan.

Table 17

Administrative Constraints

Participants	Comments
One	It's a high expectation for us to do very similar things. They [The School Administration] want to see consistency. I think it comes from the District administration, which comes from the State.
Two	Number one comes from State & District. People telling me how to teach and what to teach and I don't have the freedom to take the ideas and run with them. Fortunately, I don't have that kind of administration (that tells me what to do).
Three	I feel like we have a lot of freedom to choose. We are not dictated to at all. They want us to stick with the curriculum map absolutely as far as the concepts. As far as the activities, we choose. I feel like I have as much freedom as I want.
Four	The biggest constraints are parental, not institutional (just getting parent's permission to do things).
Five	I would have given you a different answer last year, but at this point in time, I'd say 50% [freedom]. … I agree that there needs to be standards created to make sure that all students are exposed to evidence-based, productive teaching practices. However, some of these practices are put out [by administration] to everyone regardless of subject matter and it's a struggle to make it fit.
Six	The curriculum map determines how and what I do.
Seven	Personally I feel like I have a lot [of freedom] because I have proven myself. I have to go with the curriculum established by the district but there's lots of freedom
Eight	Sigh!... I would say that I have some freedom to instruct the way that I want to since we have started the NYP process, it's a lot more possibilities, but it's also way more structured. They want the right verbiage, they don't want just the activity they want it written saying a certain thing. There not in my classroom every day you know.
Eleven	*When asked about academic freedom*…I think it's almost encouraged because I'm at an art school and I'm in sixth grade, so I'm not I'm not really tested on the FCAT.

Table 18

Co-Planning w/Peers

Participants	Comments
One	I have freedoms, but within a guideline that do not allow for much divergence.
Five	We have group lesson planning and can be a really great thing, but if the other people you're working with disagree with you on teaching strategies or even they don't know the difference between theory and law, anything like that, you have to either make concessions or do things the way they want. So, co-planning. …It can be good when all individuals are open-minded to the ideas of others and willing to do their fair share of the work (One creates a worksheet, the other types up the lesson plan into the template, etc.) They should also be willing to learn if they lack background knowledge. … Some people aren't as willing to learn and take it as a personal insult if they make an error and it's brought to their attention.
Eight	Not really mandatory. We pretty much have a pretty good team now. Of course, there are the hogs and there are logs.
Eleven	I think it's more engaging to do a lab, but someone else may not feel the same way and want students to write the definitions to the words, so having a co-plan person makes it more realistic. … They can be the left-brain figure.

Participant Five felt that being forced to do the same lesson as another teacher took away her freedom. She emphasized that she did not mind the co-planning process as it could help develop better lessons, but struggled to come to a meeting of the minds with the person she was "forced" to plan with. She felt it was unfair to her and her students to have to plan with an uncompromising and unknowledgeable peer. Fortunately, few others had this same situation. *Participant Eight* mentioned how a new program was constraining, but only if she chose to follow it. In this case, it seemed more a matter with administration, though she did mention how some of her peers were more favorable to work with than others. *Participant Eleven* mentioned how planning with the ESE inclusion teaching kept him from straying too far from the path.

Certainly this was a constraint for him. *Participant One* did have some constraints within her co-planning groups given her interviews responses.

Summary of Barriers.

While constraints other than NOS knowledge appeared with regularity, few participants voiced concerns of this having a major impact on their practice. It was Participants One, Two, and Five who voiced concerns more than others. It should also be noted that those with lower EBS scores (i.e., *Participants One, Two and Five*) voiced their concerns with greater frequency and had more constraints individually than participants having higher *EBS* scores. However, few if any of these constraints could account for the lack of NOS instruction.

Question One Summary

Research question 1a provided evidence of a strong correlation between personal epistemological beliefs and understandings of NOS, which has been suggested by others (Akerson et al, 2008) but never quantitatively supported. While relationships existed, care must be taken to assume which belief predicted the other. For instance, one participant had an extremely high *EBS* score (162) and a low *SUSSI* score (130). Others with disparate scores with the reverse situation, a high *SUSSI* score and a low *EBS* score, were more moderate in the difference. In fact, they were never more than half the most extreme difference. This could mean that increases in knowledge about NOS have an effect on personal epistemological beliefs more so than the reverse, which would make sense. Why would personal epistemological beliefs lead to knowledge about how scientific knowledge is constructed? On the other hand, one participant who admittedly lacked NOS knowledge but had a high *EBS* score, was able to bring in a construction of scientific knowledge into an activity. It would make sense that a higher *EBS* score would aid in the learning and internalization of NOS. This notion supports other work that states how epistemological beliefs are linked to NOS retention (Akerson, et al. 2006) and are related to teachers' NOS views (Akerson et al.,2008).

As expected, participants' lack of NOS knowledge was a major constraint. For many of these participants, it was their biggest barrier to teaching NOS. In terms of knowledge of NOS, it was Participants 2, 6, 7, 8, & 9 who had observable knowledge of NOS, at least as defined by the generally accepted list of NOS tenets (Lederman & Abd-El-Khalik, 1998) drawn from the *SUSSI* survey, interviews, casual conversations or observations of practice. Unfortunately, the remaining participants struggled to define these concepts, though there were exciting moments, as when *Participant Ten* unexpectedly included NOS within a lesson.

The general trend was participants with SUSSI scores of 142 and under did not teach NOS beyond the scientific method. While constraints with NOS knowledge existed, according to the teachers, they were not the only constraints.

In terms of other constraints to teaching, an interesting pattern emerged among the participants. In general, participants with higher *EBS* and *SUSSI* scores noted fewer constraints to their teaching. One possibility may have been because these teachers with epistemological beliefs more toward a constructivist view were regarded by their administration as good educators since their practice matches the new teacher evaluation protocol. They may also have had better coping mechanisms to deal with the constraints, such as ignoring them. As a result of this perception of freedom, those with higher EBS and *SUSSI* scores felt empowered to engage in whatever type of classroom practice they chose. While administrative constraints were limited to three teachers (1, 5, & 8), time was mentioned as a constraint the same amount and mostly limited to those with lower belief scores. When testing became part of the mentioned time constraint, time was mentioned twice as often as administrative concerns.

Most teachers felt additional time was needed to adequately cover the existing standards they are expected to teach in a school year (Kendall & Marzano, 2000). It is of little surprise that participants mentioned time (to include time lost to testing requirements) as a major constraint. If testing were included along with time constraints, then six of the eleven participants directly or indirectly described time as a constraint to their practice.

Overall, even those who commented about constraints admitted to not having large constraints other than time that had any appreciable effect on their practice. *Participant One* perhaps had the most rigid working conditions, followed by *Participant Five*. There were mentions of restrictions from State Standards and District curriculum, but only by one participant (*Participant Two*). Fortunately, for this research, one common constraint to instruction of NOS was removed. The District curriculum, unlike other studies (Lederman & Abd-El-Khalik, 2000) served as a positive factor, as it provided ample time for the instruction of NOS. NOS was not an *additional component* within the general curriculum: it *was* the curriculum.

Question Two - In what ways do classroom practices differ between NOS instruction and instruction of scientific practices and skills?

To answer this question, I looked specifically at the instructional practices for NOS and related aspects of the skills and practices of science such as measuring, graphing, & lab safety. Within the first nine weeks of this research, teachers were required to cover content involving what the science education community understands as NOS. During the same unit, they were also required to provide instruction in the processes and skills necessary to conduct science

Table 19 provides an overview of teacher instruction during the nine week NOS unit. Included within the unit were not just NOS constructs, but items that involve the practice and skills of science (measuring, graphing, lab safety, etc.). To mirror the previous section qualitative categories, methods of instruction were categorized as positivist 1, positivist 2, and constructivist.

Using data from classroom observation and classroom artifacts when applicable, types of practice were again classified just as they were for the previous section involving NOS instruction. The positivist 1 category acknowledged that no hands-on activity or inquiry of any type occurred. In these cases, only didactic instruction was employed, sometimes inter-mixed with student worksheets for gathering information and "facts" from the PPt. In this case, the worksheet was used more as a graphic organizer to keep track of important notes and not as a way to help conceptualize components of the instruction. For example, one teacher (*Participant Three*) performed no hands-on activities of any kind. His classification of Positivist 1 is reflective of someone who positions himself as the ultimate authority holder. The other two categories (positivist 2 and constructivist) made use of hands-on activities. There again was a distinct differentiation as to how these activities were carried out. The Positivist 2 classification had students mimic the teacher's actions and activities were always confirmational in nature. The constructivist category had students move beyond confirmation science. In this category students utilized their own creativity either to design their own activity or to analyze and construct their own conclusion based on their data. Table 19 also indicates the frequency of occurrence for inquiry in order to provide a sense of the classroom environment (Low, Medium, & High). Categories were defined, with Low being described as hands-on activities either never or quite rarely present in the classroom. Medium was defined as hands-on activities being witnessed or hands-on artifacts found more than twice during the nine weeks up to small portions of days. High was defined as doing hands-on inquiry type activities during the majority of class periods, with the exception of days devoted to testing. Furthermore, a category for the quality of NOS instruction has been included to provide a comparison to the instruction of practice and skills. Most (8) participants did not address NOS beyond the scientific method. The remaining participants only addressed the desired tenets of NOS infrequently. The following section provides a description of how these components (quality and quantity of instruction between these two constructs of NOS and practice and skills) are intertwined with epistemological views.

Table 19

Instructional methods during practice and skills activities

Participant	(EBS/SUSSI)	NOS Practice	Practice and Skills (Freq. of Inquiry)	Practice and Skills (Quality of Inquiry)
Participant 1	128/125	Positivist	(L)	(Positivist 1)
Participant 2	131/146	NA	(M)	(Positivist 2)
Participant 3	131/137	NA	(L)	(Positivist 1)
Participant 4	131/129	NA	(H)	(Positivist 2)
Participant 5	131/134	NA	(M)	(Positivist 2)
Participant 6	143/142	NA	(M)	(Positivist 2)
Participant 7	148/153	NA	(H)	(Constructivist)
Participant 8	150/154	NA	(H)	(Constructivist)
Participant 9	150/141	Constructivist	(H)	(Constructivist)
Participant 10	151/140	Constructivist	(H)	(Constructivist)
Participant 11	162/130	NA	(L)	(Constructivist)

Research Question 2a - In what ways are these differences reflective of understandings of NOS?

Using evidence gained from the *SUSSI* survey to provide understandings of NOS, classroom artifacts and observations to provide evidence of practice, a characterization of was developed for each teacher with regard to their instructional practice. Perhaps not surprising, a general trend of instructional practice was evident, given the apparent correlation between *EBS* and *SUSSI* scores previously discussed in question 1a, within most classrooms. As understandings of NOS increased using evidence from the *SUSSI*, so did the quality and frequency of activities that would be cited as practices associated with constructivism, evidenced from observation, casual discussion noted in researcher's journal, and artifacts. Those participants with higher *SUSSI* scores were usually more apt to employ inquiry as a methodology. Their classrooms were also more student-centered. This orientation may have had nothing to do with NOS understanding, but more to do with quality of teacher preparation, which included NOS in its curriculum. There was also a general trend of increasing quality of those inquiry activities with increases in NOS knowledge. So too, the number and quality of hands-on experiences and other types of inquiry, such as collaborative research, were employed at a far greater frequency by teachers with increased *SUSSI* scores.

As expected, the barrier of knowledge of NOS appeared to exert a large influence on instruction. With the exception of *Participant One*, who employed activities to directly target NOS understanding, it was (with the exception of *Participant One*), the other two participants who mention NOS beyond the scientific method within their classrooms had higher SUSSI scores. It should be noted that only *Participants One, Eight* and *Nine* provided explicit instruction, where the outcome of instruction was planned rather than hoped for as an artifact from the lesson. This intentional focus on outcome is known to be critical for the understanding of NOS (Abd-El-Khalik & Lederman 2000a; Akerson et al., 2000; Akindehin 1988; Bell et al., 2000; Clough 1997, 1998, 2004; Khishfe & Abd-El-Khalik 2002; Lederman 1992; McComas 2000). Whether explicit or implicit, it was only those two participants with higher SUSSI scores who mentioned NOS in an appropriate manner. One might surmise this was the effect of limited knowledge of NOS, more so than importance, but there were some outliers to this line of thought. *Participant One* struggled with the concept of NOS, yet attempted to incorporate it into her lessons because she felt it had value. *Participant Two,* with a PhD in a science field, years of lab experience, and a satisfactory SUSSI score did not include aspects of NOS into his instruction beyond the scientific method, perhaps indicating that he did not hold NOS as important as other aspects of science. Perhaps his situation raises a question about whether the importance was reserved for those who use science and not students who perhaps, in his view, only needed to learn about science. It is here that the visions of scientific literacy may be related to the importance factor for NOS. The explanation may be related to how one views science for students. Is it viewed as something students do or need to know some facts about (Vision I) or is it something students will apply in their daily lives (Vision II)? Unfortunately, data do not exist to answer this question, but the link to Robert's (2007) visions of scientific literacy does pose an interesting question.

Another possibility exists for the reason NOS instruction was absent for those with lower SUSSI scores and mostly limited to those with higher scores. With increased NOS knowledge, one might have expected a rapid increase in the teaching of NOS. Clearly, knowledge of NOS was not enough for it to be emphasized to the same degree as the skills and practice. A limiting factor may have been training of pedagogical methods aimed at teaching NOS.

One could assume that teachers with a background in science courses have had some experience carrying out experiments and the skills that accompany the practice of science. The likelihood that these teachers learned about the pedagogy of teaching NOS through their science coursework is slim (Abd-El-Khalick & BouJaoude, 1997; Carey & Strauss, 1968; Duschl, 1990; Kimball, 1967-1968; King, 1991; Lederman, 1992; Pomeroy, 1993).

In contrast, NOS scores may have played a smaller role in terms of the practice and skills of science. With the exception of *Participant Three*, every teacher employed some type of hands-on or student-centered activity for the teaching of the practices and skills of science. At the lower extremes of *SUSSI* scores, there were small attempts at hands-on activities or other inquiry based student-centered activities. Even *Participant One*, with her low scores on the *SUSSI*, had her students complete an activity that required students to use the tools of science in order to learn about lab safety.

While hands-on or other student-centered activities focused on the practice and skill of science were limited for those participants having lower *SUSSI* scores, compared to the lack of NOS instruction it was a distinct difference. With increasing *SUSSI* scores, the amount and quality of student-centered activities focused on the practices and skills portion of the curriculum increased. For those in the lower realm, these student-centered activities were focused on research projects more than hands-on inquiry. For example, *Participant Five* had students complete a research project about scientists. *Participant Eleven* had his students research ideas for science fair projects. As the levels of understandings of NOS increased, so too did the number of hands-on activities focused on lab investigations. Looking at the backgrounds of these of participants, it is perhaps not unexpected. A good example is *Participant Eight* who has worked in a lab as a biologist. She had students perform no less than four elaborate lab investigations focused on helping students become familiar with the methods and practice of science. Many of these investigations spanned multiple days. Other teachers who had strong science backgrounds from their coursework also had students actively engaged in hands-on science (e.g., *Participant Seven* and *Nine*). There was some evidence to suggest a relationship between SUSSI scores, amounts of previous science coursework, and amounts of laboratory investigations. Unfortunately, I was not able to obtain lesson plans from every participant, which would have provided a much better quantitative measure. Even without exact numbers, the large difference in terms of types of practice and numbers of hands-on activities between teachers made the distinction obvious. I was able to use teacher observations (4 to 5 for each teacher) and artifacts (such as posted work and informal discussion) to reliably assess these differences. Many also responded to a later question asking for this information, which does provide more clarity and supported previous estimations based on other data.

Participant Two, who held a large amount of knowledge about NOS as evidenced on the SUSSI as well as interviews and casual conversation throughout the research period, perhaps due to his research background, focused entirely on the scientific method. He did make use of hands-on activities such as designing and carrying out experiments, but these were far from the higher level of inquiry that was hoped for. As mentioned previously, students needed only to mimic what he had just explained to accomplish their assigned tasks and he was always ready to provide the answer to students who asked. This method stands in contrast to *Participant Nine*, who answered questions with more questions as she guided students' understandings. Although he was ranked as positivist 2 in terms of methods employed, his activities were not at high quality as the lack the minds-on components called for in reforms (NRC, 1996). In the case of *Participant Two*, it would seem that the greater NOS understanding had little to do with the quality of hands-on activities. It also had little relationship with the types of activities chosen for NOS instruction. The hands-on activities were focused on the teaching of the scientific method or practice and skills and not NOS.

Research Question 2b - In what ways are these differences reflective of personal epistemological beliefs?

Again, it was *Participant Eleven* who proved most interesting. Although he is clearly a constructivist, given his student-centered approach to practice and extremely high *EBS* score, his NOS activities were limited to the scientific method and all computer-based research on science fair projects. At no time did I witness, or find evidence for, any hands-on inquiry. It is here, with his personal epistemological beliefs score at the upper extreme of the group and his SUSSI score near the lowest, that his teaching would make an interesting case study on its own. *Participant Eleven*'s practice may have been driven by his epistemological beliefs, given his *SUSSI* score was so low. There seemed to be no connection between how science knowledge was constructed and how other knowledge is constructed. This can perhaps be explained by a lack of science knowledge, including coursework. While student-centered activities increased with rising EBS scores, it is not surprising that hands-on activities were much more present in those participants with science backgrounds.

For example, *Participant Eight*, having worked in a lab as an environmental biologist, engaged students in many quality hands-on activities and on research focused activities. *Participant Eight* conducted six quality student-centered activities over the nine weeks, some lasting for more than one day. Of the six, four were directed toward student learning of the practice and skills of science. Two were inclusive of NOS. In one such activity, students investigated the relationship of theories, laws and models. Upon completion of the research, students completed a Venn diagram comparing and contrasting theories and laws. In the same activity, they also completed another Venn diagram about the difference between experiments and investigations. While the term “model” was used in her lesson plan, no such reference could be found in the activity. Like other participants in the study, she also had students design their own activity. Other activities included the finding of volumes, masses, densities, etc.

While a general theme developed based on *EBS* scores and *SUSSI* scores in terms of the limitations of just a high *EBS* score, one episode illustrates how co-mingled these two constructs are and may provide additional information about how best to teach NOS. *Participant Ten* constantly engaged her students in what would be considered student-centered activities. What was never observed in her classroom was any type of science inquiry that one would expect to see in a sixth grade science classroom. Instead, her lessons focused more on how to use science than doing science through individual and group research. There were many opportunities for students to discuss ideas and think about solutions to broad issues related to science and society. In these instances, her classroom was definitely student-centered, but there was little in the way of typical hands-on science activities. Not as extreme as *Participant Eleven* – although the dichotomy of practices was striking – was *Participant Eleven*, when her practices were compared to those of *Participant Eight*. Her epistemological beliefs score would certainly suggest a constructivist-minded teacher. She admitted during the interviews and other casual discussions to a lack of general science and NOS knowledge. What made her unique was her classroom approach, and how she was able to weave in NOS despite her lack of knowledge. I can only surmise that she was able to translate her strong epistemological beliefs into a scientific epistemological belief.

Question 2 Summary

Given the evidence for a correlation of the relationship between understandings of NOS and personal epistemological beliefs discussed to answer research question 1a, it is perhaps of little surprise that similar themes were evident between the quantity & quality of student-centered activities and participants' personal epistemological beliefs within the two domains (practice & skills and NOS). With the exception of *Participant One*, those with lower *EBS* scores either did not teach NOS, or instruction during this unit was aimed at learning the steps of the scientific method rather than the knowledge construction components associated with NOS. Furthermore, only 3 of the eleven participants taught NOS explicitly to include *Participant One*. With only one exception (*Participant Three*), those who did not teach NOS beyond the scientific method still provided students with hands-on opportunities to explore the practice of science. The *SUSSI* survey was not valuable in predicting who explicitly taught NOS beyond the scientific method, but may be helpful for predicting the quantity and quality of inquiry activities, and the broader shift from research-based activities (e.g. finding science fair projects or biographical information) to laboratory experiences.

While clearly, research has provided evidence that epistemological beliefs are a profound driver of classroom practice (Tsai, 2004); in this research they did not appear to be sufficient to provide an impetus for teachers to include hands-on science. Perhaps the most prevalent theme in this research was the potential relationship in terms of the *EBS* score was the qualitative change of teacher practice reflected in the use of higher levels of inquiry within their hands-on components. It is this emphasis about how to use science, not just do science. Though evidence does not support such as claim at this point, the linkage between personal epistemological beliefs, understandings of NOS, may prove an interesting quest to investigate relationship between these two constructs (NOS and personal epistemological beliefs) and visions of scientific literacy proposed by Roberts (2007).

Chapter Five

Introduction

While the previous chapter was a presentation and analysis of data, this chapter relates the findings with the research base in this area. This chapter begins with a recapitulation of key results, followed by conclusions, implications, limitations, and considerations for further research. In the study summary, a brief review of the study, including the research questions and methods employed, will be revisited.

Discussion of Findings

The study itself was separated into two phases. *Phase One* was intended to accomplish two goals. First, it served as a sorting mechanism to choose participants that would later serve in *Phase Two*. Second, *Phase One* was used to investigate the correlation between the two epistemological beliefs. Though relationships between these two beliefs had been suggested previously (Abd-El-Khalik, 2003), scant research exists to confirm this notion. In 2010, Yang and Tsai put forth the notion that this connection between understandings of NOS and personal epistemological beliefs deserves further research, but currently suffers a lack of research as much of the current research focuses on domain specific contexts.

To be able to answer RQ1, potential relationships were investigated in terms of two types of epistemological beliefs (NOS and personal epistemological beliefs). Results from scores on both the EBS and the SUSSI survey showed a strong correlation using the Pearson r Correlational Coefficient ($r = 0.62$). More significantly, by removing one extremely disparate score, the correlation increased dramatically (r = .80). This one participant affected the correlational score because of the extreme nature of his score (ranging 32 points between the two beliefs constructs: twice that of the next highest ranging score). He held one of the highest epistemological beliefs scores, but one of the very lowest NOS scores. So while a strong correlation may be more typical, a few dissimilar scores within the participant group suggest the two epistemological beliefs are not the same and are not recursive with respect to their support of one another.

A higher NOS score does not guarantee higher personal epistemological beliefs scores. The previous statement may seem obvious, in that knowledge of science would seem to be more of a prerequisite to a higher score on a NOS survey than personal epistemological beliefs. In contrast, a personal epistemological belief score does serve as a fair predictor of better understandings of NOS, but is no guarantee. The reasoning for this statement is found in the nature of these observed relationships. The differences between high *EBS* and low *SUSSI* scores were more dramatic than the differences between higher *SUSSI* scores than *EBS* scores.

While *RQ1a* could be answered strictly from quantitative data, the remaining questions required additional evidence to help explain how beliefs affect practice. The *EBS* score can give us a relative approximation to a participant's beliefs about knowledge and knowledge construction, but the non-domain specificity suggested by this research does leave a margin of error. According to Bell and Linn, (2002), individuals can hold independent beliefs that are sometimes in conflict with one another. They may also represent themselves differently across domains. Furthermore, the *SUSSI* survey spans a large domain; a participant may have an adequate understanding of one domain and not another. For instance, a participant might understand how theories change based on new evidence, but not understand that scientific laws can change for the same reason.

Multiple data sources are required to answer the following questions. Through the use of a constant comparative method (Merriam, 1998), the remaining research questions were to be answered using the appropriate data sources to triangulate the best possible understanding. Every attempt was made to develop a rich description of the topic in order to provide answers towards the research questions.

Phase Two was designed to more deeply probe teachers' epistemological beliefs through interviews, examination of artifacts, and observations of classroom practice. Research has suggested these relationships of epistemological beliefs are extremely important due to the impact they have on choices teachers make in their classrooms (Feucht, 2008; Feucht & Bendixen, 2010; Patrick & Pintrich, 2001; Schraw & Olafson, 2002; Tsai, 2002). To further help in answering the final questions, teacher profiles were developed using multiple data sources. Also, consideration of the many variables beyond epistemological beliefs that are known to affect a teacher's practice required the probing of these additional factors to help isolate them from the epistemological beliefs. From the list of typical constraints, it became necessary to include additional questions to help answer the overarching question: *In what ways do teachers' epistemological beliefs affect practice in the science classroom during NOS instruction?* With evidence suggesting a strong relationship between NOS and personal epistemological beliefs among these participants, it was then necessary to answer the tougher questions about why evidence was not more prevalent in classroom practice. As suggested by previous research (Abd-El-Khalik et al., 1998; Bell et al., 2000; Lederman, 1992) knowledge alone does not always translate into practice. Teachers must possess not only adequate knowledge and pedagogy to teach it, but also they must believe NOS to be important (Abd-El-Khlaik & Akerson, 2004). It was this dynamic of knowledge, pedagogy, and importance that were revealed within this research. While there are other constraints, for the most part, only one participant had a social/institutional constraint that may have directly affected her instruction. All other participants were able to overcome real or perceived constraints during the teaching of NOS. That is not to say they taught NOS with integrity, only that decisions about teaching were not due to a constraint other than knowledge, pedagogy or importance.

Beliefs and their influence on importance about NOS.

Clearly, teachers cannot teach what they themselves do not understand. Furthermore, even when teachers have an understanding of NOS, it may not emerge in practice for a variety of reasons (Abd-El-Khalik et al., 1998; Bell et al., 2000; Lederman, 1992). Of the eleven teacher/participants in this study, some clearly had neither adequate knowledge of NOS nor necessary pedagogy to teach NOS. Even when they did have knowledge of NOS, it did not always emerge in practice to a degree required by the school district.

All teachers who participated in this study remarked on the importance of NOS. In many of those cases, the importance was centered on what they knew to be NOS, rather than what is mostly agreed upon by the science education community to be NOS. Knowledge of NOS, as was expected from the onset, was limited (Abd-El-Khalik & BouJaoude 1997; Behnke 1950; Carey & Stauss 1970; Duschl, 1990; Lederman, 1992, 2007; Pomeroy 1993). Although few participants had representations of explicit-reflective NOS instruction, most teachers emphasized NOS to the best of their abilities. Clearly, knowledge impacted importance of different aspects of NOS as defined by the *Lederman Seven* (Lederman & Abd-El-Khalik, 1998), but it was not the only constraint.

Beliefs and their implications to practice.

Data suggest a definite contrast between those who understood and attempted to teach NOS and those who focused entirely on the scientific method. For most participants, there is a potential for a threshold of perception of NOS knowledge appeared to be necessary for them to effectively teach NOS. It was participants with higher scores on the SUSSI survey or who displayed proficient understandings of NOS within the interviews that more effectively implemented NOS instruction. A rich history of research supports the fact that NOS may not translate into practice (Abd-El-Khalik et al., 1998; Bell et al., 2000; Lederman, 1992) thus fortifying the notion that there are sometimes other factors beyond mere knowledge of NOS that constrain importance. In contrast, it also became evident, though perhaps not typical, that it is possible to include aspects of NOS within instruction without the threshold NOS knowledge being met if certain criteria are in place in terms of epistemological beliefs.

These variations in whether or not a teacher chooses to teach NOS in relationship to certain epistemological beliefs being in place may suggest some restrictive or catalyzing, affecting the importance teachers place on NOS. While this situation applied to only a few participants whose scores were not in concert (referring the relationship of the personal epistemological beliefs and understandings of NOS), this difference may be associated with some of the reluctance or struggle to emphasize NOS. While these cases represent only a fraction of the individuals in the study, they do represent an interesting scenario.

Personal epistemological beliefs may buffer or catalyze the importance placed on NOS as judged by their inclusion within instruction.

In summary, all participants viewed NOS as important and foundational for the learning of science. What differentiated these participants were their epistemological beliefs and how these beliefs affected NOS instruction. While, clearly, the importance the District placed on NOS was quite explicit within its description on the Curriculum Maps, even with this stated importance, many teachers taught NOS only to the limits of their understanding. Anything beyond those understandings may be assumed was not as important as the scientific method and in many cases, not even important enough to mention.

As understandings of NOS increased, so too did the number of topics within NOS that were placed into practice. In some ways, this may be viewed as increased knowledge of NOS, but the results were not that clear. Some instances suggest importance goes beyond knowledge about the construct and into the realm of epistemological beliefs. There was a definite relationship between the quantity and quality of NOS instruction. As the *SUSSI* scores increased so too did the amounts of NOS topics introduced, as well as the quality of the instruction. Those participants with higher *SUSSI* scores used didactic measures less often and were more apt to embed NOS into a lesson. Whether or not these intentions were planned is questionable; nevertheless, they did occur.

Perhaps the most interesting evidence came in the form of how personal epistemological beliefs might help support or restrict NOS importance. It was observed in several cases where personal epistemological beliefs seemed to play a role, especially in the quality of NOS instruction, whether favorable or unfavorable. For one participant with a fairly sophisticated NOS understanding and a low personal epistemological beliefs score, the instruction of NOS never advanced beyond the scientific method, hands-on was limited to following directions, and there was a liberal use of didactic instruction. In essence, the lower epistemological beliefs score seemed to keep him from teaching in a manner closer to that of a constructivist, even though his background in science should have suggested the opposite.

Without a doubt, knowledge was a limiting factor for instruction. Those who lacked more advanced knowledge were in most cases unable to include effective NOS instruction and were restricted to the scientific method. Personal epistemological beliefs played a larger than expected role in governing the types or quality of instruction with regards to NOS instruction. It may have been necessary to have adequate NOS knowledge to teach NOS, but those participants with the greater personal epistemological beliefs were best able to present it in a more constructivist manner.

Epistemological Beliefs and Other Constraints to Practice.

While constraints are mentioned in the literature (Lederman & Abd-El-Khalik , 2000) as impediments to instruction of NOS, for the most part, these were minimal within this participant group. The participants themselves listed few constraints overall, and I observed few true constraints to practice during this investigation and no classroom environmental factors that should restrict NOS teaching (e.g., classroom management, time constraints, etc.).

The more typical curricular constraints normally associated with the teaching of NOS were irrelevant here, as the District's curriculum required the teaching of NOS. NOS was not something that took away from the time required to teach the more traditional content (e.g., force, gravity, energy, etc.) as the unit was specially built to ensure NOS was covered effectively and given the time it deserves. Because of this purposeful NOS unit, there was not the pressure to cover other content as noted by Abd-El-Khalik (1998) as a constraint. Lederman et al. (2000) discussed the problem that teachers face to find resources from which to teach NOS concepts. This problem, too, should not have been a problem, as many activities were available to teachers via a teacher resource site created the previous year. With that said, to this day, teachers still utilize this site and these resources to a lesser extent than one would expect given the necessity to teach NOS. A few teachers did have knowledge of the University of Indiana site that provides NOS activities, but they were not the majority. Therefore, not having adequate resources must be considered as one possible constraint. On the other hand, they were made aware of the District resource site on many occasions, yet they chose not to utilize those resources for NOS or any other topic within the first nine weeks, so the problem may run deeper than access. Choosing not to retrieve activities may be related to either the teacher's *knowledge of* or *importance placed on* NOS. Given the correlation observed between knowledge of NOS and inclusion within practice, it may be a matter that they chose to teach they already knew, which, in most cases, was the scientific method to the exclusion of the other topics of NOS. It also partially explains the overall lack of quality and quantity of NOS instruction.

In general, participants with epistemological beliefs more like that of a constructivist noted fewer constraints than their more positivist peers. As constructivist practices are believed by many administrators to be associated with best practice, this belief may be related to teacher constraints. As noted previously, teachers' classroom practices were generally reflective of their beliefs. It would seem possible that this "good teaching" as viewed by an administrator results in fewer constraints for teachers. In contrast, teachers not employing what are considered best practices may find themselves in a more structured environment by way of administrative mandates in the hopes their teaching practice may improve. Given the new evaluation inventory now in place within the District that favors the constructivist teacher style; this opportunity for freedom will hopefully become more prevalent. Another possibility is that epistemological beliefs are somehow correlated to coping mechanisms, at least in terms of being capable of ignoring constraints.

Even so, few noted administrative constraints as a problem that would affect their classroom practice. The only constraint that was not limited to those with lower epistemological belief scores was time. While time was mentioned in terms of scheduling models, it was also at the root a problem of testing to address accountability mandates causing additional instructional time lost. With the inclusion of testing as a loss of time, time in general was noted as a factor more often than any other constraint. It comes as little surprise that most teachers feel additional time is needed to adequately cover the existing standards (Kendall and Marzano, 2000).

With respect to the previous listing of constraints voiced or observed by teachers, these constraints were not severe and were usually prefaced as such by the participants. Perhaps the largest potential constraint could have been the District curriculum. Unlike other studies where lack of time and pressure to cover content were problematic (Lederman & Abd-El-Khalik, 2000), it was not so here. The District curriculum in this case supported the teaching of NOS, but even with this important support, teachers were inconsistent in their implementation of NOS. NOS instruction was typically non-existent beyond the scientific method or extremely limited. What came to be an interesting bit of evidence was that personal epistemological beliefs that led to constructivist practices were typically associated with good NOS practice.

Overall, even those who commented about constraints did not have large constraints other than time. Fortunately for this research, one common constraint to instruction of NOS was removed. The District curriculum, unlike that noted in other studies (Lederman & Abd-El-Khalik, 2000), served as a positive, since it provided ample time for the instruction of NOS. Notably, NOS was not something additional to the general curriculum: it was the curriculum. As expected, knowledge of NOS was a major constraint, but certainly not the only factor minimizing NOS instruction. With few other social or institutional constraints, it would seem logical to conclude that indeed epistemological beliefs played a major role in predicting the amount, type, and quality of NOS instruction. The amounts of NOS instruction would seem to be more linked to NOS knowledge with personal epistemological beliefs boosting the quality observed within the instruction. It is important to note and there was no evidence to suggest that personal epistemological beliefs can predict the quality of NOS instruction without some knowledge of NOS.

NOS/Practice and Skills.

Within the nine-week unit were portions where a focus on the skills and practices of science were expected. In some ways, the relationship observed between personal epistemological beliefs, understandings of NOS, and classroom instruction was similar to what was observed during the NOS portions of instruction, there were differences. These differences occurred perhaps because these two beliefs contributed to and detracted from classroom practices. Furthermore, these beliefs may also affect practice as judged by quantity and quality of activities and may even contribute to the scope and purpose of the science instruction.

As perhaps expected, a lack of NOS knowledge as determined by the *SUSSI* survey, interviews, and observation may have been, in general, related to the amounts of NOS activities observed in the classroom. In fact, an interesting phenomenon resulted in Those participants with *SUSSI* survey scores above 147 were able to include NOS to a far greater degree of effectiveness than those with lower scores, but explicit-reflective practice was limited to two participants. With increases in understandings of NOS, a trend in instructional practices emerged demonstrating a shift from mostly positivist approaches to more constructivist practices (e.g., inquiry, collaborative research, etc.). Unfortunately, even though the amounts of NOS instruction and the quality of that instruction improved, it was rare to find explicit-reflective instructions approaches within the participants' practice. As this type of instruction is critical for students to effectively learn about NOS (Abd-El-Khalik & Lederman 2000a; Akerson et al., 2000; Akindehin 1988; ell et al., 2000; Clough 1997, 1998, 2004; Khishfe & Abd-El-Khalik 2002; Lederman 1992; McComas 2000), there was a definite need to look more closely at professional development in an effort to remediate this lack of best practices. Even those teachers holding NOS views more like a constructivist included NOS only to a limited basis. For most, it was extremely unlikely they have learned about the pedagogy necessary to teach NOS from any of their science coursework (Abd-El-Khalick & BouJaoude, 1997; Carey & Strauss, 1968; Duschl, 1990; Kimball, 1967-1968; King, 1991; Lederman, 1992; Pomeroy, 1993).

On the other hand, for the practice and skills portion, those same beliefs about science were less predictive for the number and quality of hands-on activities normally associated with the development of these skills.

Almost every participant employed hands-on activities as part of their instruction that were related to the practice/ skills of science. This instructional practice was in sharp contrast to the almost non-existent activities for NOS within this same group with the lower SUSSI survey scores. Similar to the possible relationship between epistemological beliefs and NOS instruction, higher scores can be associated with increased frequency and quality. One potential reason for this increased frequency and quality was that many of the participants with higher NOS scores had done some type of science research or had been connected with higher education in terms of science education, and in all cases, participants had more science coursework. While coursework has been shown to be a poor indicator for NOS instruction, in this case, it suggests support for more hands-on or student-centered learning opportunities for students in the teaching of the practices and skills of science.

Personal Epistemological Beliefs/NOS/ Practice and Skills.

It perhaps comes as little surprise, given the correlation between epistemological beliefs, that personal epistemological beliefs may have visible relationships with the two constructs of *NOS* and *practice & skills*. In general, participants with lower *EBS* scores did not teach NOS or it was limited to the scientific method. Participants with higher *EBS* scores were able to teacher NOS more effectively, but to the greatest extent when the two epistemological beliefs were in tandem. Increased *EBS* scores also were often associated with to student-centered activities. Furthermore, participants with higher *EBS* scores employed more activities associated with constructivism. Most intriguing was that participants with higher *EBS* scores appeared to have a different vision of scientific literacy.

This emergent trend may suggest that personal epistemological beliefs affected not just the instruction, but also may be related to a teacher's broader vision of scientific literacy.

Conclusions

Given the struggle for science educators to incorporate NOS into the classroom practice, this research does support previous research in the field and also extends that research. *Phase One* confirmed a correlation between personal epistemological beliefs and understandings of NOS as suggested by Abd-El-Khalik (2003). *Phase Two* further delineated how these beliefs interacted with other known constraints to instruction mentioned by Lederman and Abd-El-Khalik (2000).

Fortunately, and different from other studies, by easing curricular restraints with the pressure to cover content removed, a better focus could be placed on teacher beliefs and how they affect practice. As it turned out, it was not so much the understandings of NOS that revealed surprises, but rather the co-occurrence of the personal epistemological beliefs that may provide interesting extensions from this work. The following points summarize the main findings of this study.

First, there was a moderately high correlation between understandings of NOS and personal epistemological beliefs suggesting NOS understandings predict broader epistemological beliefs. I do not suggest that personal epistemological beliefs affect understandings of NOS. Second, understandings in NOS in general affected the amount and quality of NOS instruction. With increases in NOS scores, the number and quality (e.g., *confirmation* vs. *open inquiry* &

beyond/not beyond the scientific method) of NOS was increased. Third, there was limited use of explicit-reflective instruction for NOS and few instances of accessible activities for its instruction being used, suggesting problems with awareness of materials and the importance of this type of instruction. Fourth, the lack of knowledge of NOS, whether high or low, appeared to place NOS instruction at a disadvantage to the practice and skills content. All participants, with only one exception, included hands-on practices, but the majority (8/11) of the participants were unable to include NOS instruction beyond the scientific method. Fifth, with increases in understandings of NOS, increases in the numbers and quality of instruction to include hands-on activities were observed. Sixth, to a certain degree, understandings of NOS predicted constructivist practices, but not as powerfully as personal epistemological beliefs with regard to predicting types of classroom practices associated with constructivism. In only a few instances, this divergence of beliefs and practice was observed, but this insight may provide opportunities to better remediate teacher practice. If a teacher does not have adequate beliefs about the broader scope of knowledge (i.e., personal epistemological beliefs), this research suggests the teacher will have difficulty emphasizing the importance of NOS beyond the scientific method. In contrast, those teachers with minimal understandings of NOS, but having personal epistemological beliefs closer to a constructivist, may be in a better position to learn about and place more importance on the teaching of NOS. In final, those with higher personal epistemological beliefs seem to gravitate towards what Roberts (2007) has defined as Vision II of scientific literacy, while those with lower scores on the *EBS* seem relegated to his Vision I description. With only limited data to suggest this link, it is difficult to say where or why this relationship may exist. For now, it may just represent potential fertile ground for future research.

In contrast to tandem beliefs, (i.e., closely matched scores of personal epistemological beliefs & understandings of NOS) disparate epistemological scores were quite interesting. Table 20 provides observations to compare varying relationships between personal epistemological beliefs and understandings of NOS. Again, these disparate beliefs and the potential effect of personal epistemological beliefs might suggest relationships to visions of scientific literacy.

Table 20

Potential Effects of Disparate Beliefs

Tandem increases of EBS and SUSSI scores	With increases in epistemological beliefs, so too increased the quantity and quality of instruction for both NOS and the Practice & Skills of science
Higher EBS as compared to SUSSI scores	Increased use of student-centered activities (e.g., individual research, student to student discussions, etc.), but limited NOS instruction.
Higher SUSSI compared to EBS scores	Increased amounts of hands-on learning targeted at the practice of science, but to a much lesser degree NOS instruction (limited to the scientific method)

By moving beyond knowledge of NOS to include personal epistemological beliefs yet exclude curricular constraints, this research has extended the boundaries of the more typical quest to enhance NOS instruction in the classroom. This extension now suggests personal epistemological beliefs may play a more powerful role in determining how NOS is learned and taught. It also has further ramifications in terms of predicting the vision of scientific literacy taught the classroom.

Implications

Even with this new data, it is still unknown how much NOS knowledge and pedagogical skills are necessary to teach NOS in a manner reflective of the goals of the scientific community. As this research study demonstrated, even if constraints are removed and known best practices are supported and encouraged, NOS is still mostly neglected in favor of the practice and skills of science or relegated to inclusion with the scientific method. Clearly, some level of NOS knowledge combined with the support to teach NOS was not enough to overcome the current schism between theory and practice. Given that NOS plays a major role in scientific literacy, it is vital to find ways to overcome known boundaries and help focus instruction.

Given the importance that some people in the science education community feel is essential to making science relevant for decisions about socio-scientific issues, the importance of the effect of personal epistemological belief on NOS instruction should not be overlooked. Perhaps the most important point is that further research is needed to better understand the complex relationship between these beliefs (personal epistemological beliefs and understandings of NOS) and student outcomes (Hofer & Pintrich, 2002; Pajares, 1992; Schraw & Olafson, 2002). In other words, what is it we want students to be able to do? Is that outcome more aligned with Vision I (Roberts, 2007) of scientific literacy where the focus is on the facts of science and learning how to do science? Or is it on making sure students are able to use science in a practical way within their own lives, via Vision II (Roberts, 2007) or even Vision III to include the moral and ethical aspects of science as a societal endeavor (Zeidler & Keefer, 2003; Zeidler et al., 2005; Zeidler & Sadler, 2008)? As many in the science education community hope to move at minimum toward Robert's Vision II (2007) of scientific literacy, personal epistemological beliefs may play a large role in this transition.

Additional reasons to consider personal epistemological beliefs also exist with relation to Vision II of scientific literacy in terms of how we expect students to learn. It would make sense that if the goal is to produce students capable of using science effectively in their own lives, they must first be able to practice those skills. There is a growing body of research that suggests that personal epistemologies play a crucial role in promoting the types of learning associated with Vision II (Feucht & Bendixen, 2010). Environments that do not foster critical thinking can be counter-productive to students (Chandler, et al., 2002; Feucht, 2008; Walton, 2000). Jonassen, Marra and Palmer (2004) claim students can have their learning impeded in a non-constructivist learning environment. In those situations, unfortunately, it is the teacher's subconscious epistemological beliefs that can have a major negative effect on student achievement (Calderhead, 1996). Furthermore, this lack of exposure to constructivist practices adversely affects the students' own developing epistemic beliefs (Bendixen & Rule, 2004) thereby making them less able to think critically and more reliant on authority for knowledge (Feucht & Bendixen, 2010). It is for these reasons, personal epistemological beliefs must become a focus of the educational community, not just for the teaching of NOS, but for the future of Vision II for both the teacher and the student.

Also, even though these personal epistemological beliefs and understandings of NOS do have a high correlation, they are often distinct. Given that those participants with more positivist beliefs as measured by personal epistemological beliefs seem to be more prone to treat knowledge as transferrable as discrete units (Hagege et al., 2007), what does that mean for the teaching of NOS? Are these personal epistemological beliefs related to the importance factor often cited as a constraint to the teaching of NOS beyond the scientific method?

To improve the overall stock of science teachers, a greater importance must be placed on developing and shaping their personal epistemological beliefs. Given that epistemological beliefs are a more predictive factor in determining the types of instructional practices than either content knowledge or instructional strategies (Jones & Carter, 2007; Pajares, 1992; Richardson, 1996), personal epistemological beliefs must become a focus. Fenstermacher and Richardson (2000) suggest good teaching within many pedagogical paradigms is synonymous with constructivist teaching. Unfortunately, it is not a matter of teaching teachers better techniques: the problem is far more complex. Cohen (1990) and, more recently, Tsai (2006), suggest the root of the problem is not the ability to learn better teaching techniques: rather, the problem is teachers' deep-rooted transmission beliefs. To summarize, as long as teachers have beliefs that are not associated with constructivism, they will struggle to teach science well, and especially NOS, with its philosophical roots in the construction of scientific knowledge. It is not to say a positivist style of teaching is ineffective, only that instructional method must be aligned to instructional goals (Kuhn, 2007).

To help the stock of current sixth grade teachers, there are several things that may need to occur if NOS instruction is to improve. As evidence by this research, time to teach NOS and even explicit concepts being included within curriculum maps is not enough to overcome barriers. Beyond professional development to increase understandings of NOS, which is needed in many cases, teachers need help to learn specific pedagogies to teach concepts of NOS in an effective manner. They also need professional development, or some type of focused response, to inspire personal epistemological growth. Teachers need to understand that students need to be constructing their own understand and not just be capable of parroting the teachers knowledge.

Limitations

One limitation that became apparent was the immense geographical size of the district. Even though much time was allotted to carry out this research, the size of the district became a limiting factor. Combined with the more typical restrictions of school start times, varying lunch schedules, and differing teacher schedules, it became difficult to visit multiple schools in one day. Because of this limitation, schools visits were usually limited to one or two schools per day. Given that restriction, I was not able to observe every teacher as they incorporated the same exact topics from the district's curriculum timeline. But again, as many of the teachers were not teaching the topics included on the curriculum maps, it may not have been a significant factor. In a perfect world, I would have limited my research to those participants working in nearby schools and included more teachers within the schools to provided adequate, more highly comparable participation.

Another limitation would be the ability to transfer these findings, either to different grades, different geographic regions, or even demographics. Given the District's range, having both urban and rural, it might not be possible to transfer these generalizations to other areas, whether they are all rural or strictly urban. The largest city in the District has also been recently ranked as one of the poorest in the Nation (Brookings Institute, 2010). Of the 170+ schools, 90 are Title I. Of the 18 middle schools within the District, 15 are Title I. Therefore, the transferability of the findings from this study to a more affluent area may be problematic.

Another limitation was the assumption teachers would closely follow and use the ample information about NOS on the District's Curriculum Maps. Such was not the case and much time was wasted by the researcher observing classroom where NOS topics should have been taught, but instead were by-passed by the teachers in favor of other content that was sometimes unrelated to the State's standards (Florida Department of Education, 2008). It was the limitation of not mandating lessons or at least seeing similar lessons that made drawing anything more than tentative conclusions difficult to make regarding broad claims about relationships between pedagogy and epistemological beliefs. Also, the fact that participants all had diverse backgrounds of both science, the nature of science, and pedagogy to teach NOS, placed limitations on making claims.

The non-compliance issue of not following the prescribed curriculum, that should have benefitted NOS instruction, did little to support the transferability of this research. The knowledge gained from this investigation may be limited to other Districts with similar curricular non-compliance issues.

Perhaps the biggest limitation of the study was the self-selecting process, because it might not have garnered a true representative sample of the district. It is difficult to speculate if I was able to include those with epistemological beliefs lower than what was observed. It was unfortunate that the two participants that held more sophisticated epistemological beliefs were not included in Phase Two because of position changes and administrator reservations about the invasiveness of the research.

Suggestions for Future Research

Within this research project, important constraints that typically affect NOS instruction (e.g., not enough time to include NOS) were minimized with its inclusion into the prescribed curriculum to provide a focus on epistemological beliefs. Given the interesting relationship that developed between personal epistemological beliefs and understandings of NOS and their effect on instruction, what are the next steps? Further isolating restraints to instruction is recommended, such as choosing participants with firm knowledge of NOS and traditional science content knowledge, having all participants participate in professional development to inform about appropriate pedagogy, and providing better scripted curriculum to include specific activities. Also, examining epistemological beliefs as coping mechanisms may prove fruitful.

The interviews moreover revealed that those participants with higher personal epistemological beliefs voiced fewer concerns about constraints to their instruction.

A final thought concerns future direction to look more closely at NOS as a vehicle to improve decision-making through socioscientific issues (SSI). Those participants with more constructivist beliefs related to their personal epistemological beliefs seemed to embrace a more progressive view of scientific literacy. Because they may have felt students needed to learn how to use science in a relevant manner, it would seem prudent to look more closely at this relationship between personal epistemological beliefs and visions of scientific literacy.

Overall, this research provides an additional examination of the problems associated with students' general lack of NOS knowledge. Much of the typical constraints to teaching NOS, such as teacher knowledge, pedagogy, and institutional constraints of various kinds, and the importance factor still present a large barrier that is not very well understood. This research furthermore provides the science education community with an indication of how the relationship between understandings of NOS and personal epistemological beliefs may play a role in the importance teachers place on NOS.

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Appendix A

Epistemological Belief Survey

Please indicate how strongly you agree or disagree with each of the statements listed below. Please circle the number that best corresponds to the strength of your belief.

1.You can believe most things you read.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

2. The only thing that is certain is uncertainty itself.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

3. If something can be learned, it will be learned immediately.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

4. I like information to be presented in a straightforward fashion; I don’t like having to read between the lines.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

5. It is difficult to learn from a textbook unless you start at the beginning and master one section at a time.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

6. Forming your own ideas is more important than learning what the textbooks say.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

7. Almost all the information you can understand from a textbook you will get during the first reading.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

8. A really good way to understand a textbook is to reorganize the information according to your own personal scheme.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

9. If scientists try hard enough, they can find the answer to almost every question.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

10. You should evaluate the accuracy of information in textbooks if you are familiar with the topic.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

11. You will just get confused if you try to integrate new ideas in a textbook with knowledge you already have about a topic.

strongly disagree	disagree	unsure	agree	strongly agree

12. When I study, I look for specific facts.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

13. If professors would stick more to the facts and do less theorizing, one could get more out of college.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

14. Being a good student generally involves memorizing a lot of facts.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

15. Wisdom is not knowing the answers, but knowing how to find the answers.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

16. Working on a difficult problem for an extended period of time only pays off for really smart students.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

17. Some people are born good learners; others are just stuck with a limited ability.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

18. Usually, if you are ever going to understand something, it will make sense to you the first time.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

19. Successful students understand things quickly.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

20. Today's facts may be tomorrow's fiction.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

21. I really appreciate instructors who organize their lectures carefully and then stick to their plan.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

22. The most important part of scientific work is original thinking.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

23. Even advice from experts should be questioned.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

24. If I can't understand something quickly, it usually means I will never understand it.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

25. I try my best to combine information across chapters or even across classes.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

26. I don't like movies that don't have a clear-cut ending.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

27. Scientists can ultimately get to the truth.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

28. It's a waste of time to work on problems that have no possibility of coming out with a clear-cut answer.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

29. Understanding main ideas is easy for good students.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

30. It is annoying to listen to lecturers who cannot seem to make their mind up as to what they really believe.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

31. A good teacher's job is to keep students from wandering from the right track.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

32. A sentence has little meaning unless you know the situation in which it was spoken.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

33. The best thing about science courses is that most problems have only one right answer.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

34. Most words have one clear meaning.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

35. The really smart students don't have to work hard to do well in school.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

36. When I learn, I prefer to make things, as simple as possible.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

37. I find it refreshing to think about issues that experts can't agree on.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

38. The information we learn in school is certain and unchanging.

strongly disagree	disagree	unsure	agree	strongly agree
1	2	3	4	5

Appendix B

District's Curriculum

Please use the link below to view district curriculum.

http://publish.learningfocused.com/6352747

Appendix C

Student Understanding of Science and Scientific Inquiry

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. Ensure to provide detailed written responses where directed. If you need more room to complete your written responses, please place the number of the particular item at the end of the instrument and continue writing.

SD = Strongly Disagree
D = Disagree More Than Agree
U = Uncertain or Not Sure
A = Agree More Than Disagree
SA = Strongly Agree

1. Scientific Observations

A.	Scientists' observations of the same event may be different because the scientists' prior knowledge may affect their observations.	SD	D	U	A	SA
B.	Scientists' observations of the same event will be the same because scientists are unbiased.	SD	D	U	A	SA
C.	Scientists' observations of the same event will be the same because observations are facts.	SD	D	U	A	SA
D.	Scientists may make different interpretations based on the same observations.	SD	D	U	A	SA

With examples, explain why you think scientists' observations and interpretations are the same **OR** different.

Where do you recall acquiring the **examples** and **ideas** regarding this question?

2. Scientific Theories

A.	Scientific theories are subject to on-going testing and revision.	SD	D	U	A	SA
B.	Scientific theories may be completely replaced by new theories in light of new evidence.	SD	D	U	A	SA
C.	Scientific theories may be changed because scientists reinterpret existing observations.	SD	D	U	A	SA
D.	Scientific theories based on accurate experimentation will not be changed.	SD	D	U	A	SA
<u>With examples,</u> explain why you think scientific theories change OR do not change over time. Where do you recall acquiring the **<u>examples</u>** and **<u>ideas</u>** regarding this question?						

3. Scientific Laws Compared to Theories

A.	Scientific theories exist in the natural world and are uncovered through scientific investigations.	SD	D	U	A	SA
B.	Unlike theories, scientific laws are not subject to change.	SD	D	U	A	SA
C.	Scientific laws are theories that have been proven.	SD	D	U	A	SA
D.	Scientific theories explain scientific laws.	SD	D	U	A	SA
<u>With examples</u>, explain what scientific theories and laws are and how they are different. Where do you recall acquiring the **<u>examples</u>** and **<u>ideas</u>** regarding this question?						

4. Social and Cultural Influences on Science

A.	Scientific research is not influenced by society and culture because scientists are trained to conduct pure, unbiased studies.	SD	D	U	A	SA
B.	Cultural values and expectations influence <u>what</u> science is conducted and accepted.	SD	D	U	A	SA
C.	Cultural values and expectations influence <u>how</u> science is conducted and accepted.	SD	D	U	A	SA
D.	All cultures conduct scientific research the same way because science is universal and independent of society and culture.	SD	D	U	A	SA
<u>With examples</u>, explain how society and culture affect OR do not affect scientific research. Where do you recall acquiring the **<u>examples</u>** and **<u>ideas</u>** regarding this question?						

5. Imagination and Creativity in Scientific investigations.

A.	Scientists use their imagination and creativity when they collect data.	SD	D	U	A	SA
B.	Scientists use their imagination and creativity when they analyze and interpret data.	SD	D	U	A	SA
C.	Scientists do **not** use their imagination and creativity because these conflict with their logical reasoning.	SD	D	U	A	SA
D.	Scientists do **not** use their imagination and creativity because these can interfere with the need to be unbiased.	SD	D	U	A	SA

With examples, explain why scientists use OR do not use imagination and creativity.

Where do you recall acquiring the **examples** and **ideas** regarding this question?

6. Methodology of Scientific Investigations

A.	Considering what scientists actually do, there really is no such thing as the scientific method.	SD	D	U	A	SA
B.	Scientists follow the same step-by-step scientific method.	SD	D	U	A	SA
C.	When scientists use the scientific method correctly, their results are true and accurate.	SD	D	U	A	SA
D.	Experiments are the only way scientists develop valid scientific knowledge when they investigate the natural world.	SD	D	U	A	SA

With examples, explain whether scientists follow a single, universal scientific method OR use a variety of methods.

Where do you recall acquiring the **examples** and **ideas** regarding this question?

7. Social Interaction among Scientific Researchers

A.	Scientists usually work collaboratively with other scientists when conducting research.	SD	D	U	A	SA
B.	Scientists usually work with other scientists, but only to share results.	SD	D	U	A	SA
C.	Scientists usually work alone when conducting research.	SD	D	U	A	SA
D.	Scientific knowledge usually emerges from discussions and social interactions among scientists.	SD	D	U	A	SA

With examples, explain to what degree scientists work with other scientists when doing research.

Where do you recall acquiring the **examples** and **ideas** regarding this question?

8. Science and Religion

A.	Science and religion are usually in conflict with one another.	SD	D	U	A	SA
B.	Supernatural explanations are not useful for helping scientists understand the natural world.	SD	D	U	A	SA
C.	Science ideas that have religious implications usually set scientists who do believe in supernatural beings against those who do not believe in supernatural beings.	SD	D	U	A	SA
D.	Scientists who will not use supernatural explanations when doing science can still believe in a supernatural being.	SD	D	U	A	SA

With examples, explain why supernatural explanations should OR should not be used in credible scientific ideas.

Where do you recall acquiring the **examples** and **ideas** regarding this question?

9. Development and Acceptance of Science Ideas

A.	Credible scientific ideas are <u>usually</u> generated in a matter of days, weeks or months.	SD	D	U	A	SA
B.	Scientific ideas <u>usually</u> come to be accepted by the scientific community in a matter of days, weeks or months.	SD	D	U	A	SA
C.	Credible scientific ideas are <u>usually</u> generated over a period of years to decades.	SD	D	U	A	SA
D.	Scientific ideas <u>usually</u> come to be accepted by the scientific community over a period of years to decades.	SD	D	U	A	SA

With examples, explain how much time is usually required for credible scientific ideas to be generated, and then accepted by the scientific community.

Where do you recall acquiring the **examples** and **ideas** regarding this question?

10. Discovery and Invention

In responding to the four items below, assume that a gold miner "discovers" gold while an author "invents" a story.

A.	Scientific theories (for example, atomic theory, plate-tectonic theory, gene theory) are discovered.	SD	D	U	A	SA
B.	Scientific laws (for example, laws of planetary motion, gas laws, gravitational law, law of pendulum motion) are discovered.	SD	D	U	A	SA
C.	Scientific theories (for example, atomic theory, plate-tectonic theory, gene theory) are invented.	SD	D	U	A	SA
D.	Scientific laws (for example, laws of planetary motion, gas laws, gravitational law, law of pendulum motion) are invented.	SD	D	U	A	SA

With examples, explain whether scientific laws and theories are invented OR discovered.

Where do you recall acquiring the **examples** and **ideas** regarding this question?

For items which you needed additional space to write, in the remaining space below and on the back, please place the item number and continue your written response.

Appendix D

Nature of Science Classroom Observation and Artifact Protocol

Herman, B. C., Olson, J. K. & Clough, M. P.   2011 NARST International Conference in Orlando, FL   April 6, 2011

APPENIDX A. NATURE OF SCIENCE CLASSROOM OBSERVATION AND ARTIFACT PROTOCOL (NOS-COP)

Key indicators	Not At All — To a Great Extent	*D/K	†N/A
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

*Don't Know
†Not Applicable

NOS Implementation Synthesis Rating:

1	2	3	4	5
Not at all reflective of best practices in science education				Extremely reflective of best practices in science education

APPENIDX A. NOS-COP CONTINUED

Coding scheme for determining the extent that the instructor and/or artifacts actually *did* accurately, explicitly, and reflectively address the NOS.

Score	Observations	Artifacts
3	Attention is limited in explicitness, reflectivity, and/or depth. 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." (Peter)	Attention is limited in explicitness, reflectivity, depth, and/or consistency. 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?" (Sharon, A4)
1	Non-existent	Non-existent
6. Students' attention was explicitly and reflectively drawn to the NOS in the context of science content being taught.		
5	Attention drawn explicitly, reflectively and deeply. Exemplar: In relation to glacially carved valleys: "Why should we not use supernatural ideas such as Paul Bunyan to explain the natural world?" (Luke)	Attention drawn consistently, explicitly, reflectively and deeply. 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?" (Luke, A1)
3	Attention is limited in explicitness, reflectivity, and/or depth. 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 (Maddy)	Attention is limited in explicitness, reflectivity, depth, and/or consistency. 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 (Carey, A4)
1	Non-existent	Non-existent

APPENIDX A. NOS-COP CONTINUED

Coding scheme for determining the extent that the instructor and/or artifacts actually *did* accurately, explicitly, and reflectively address the NOS.

Score	Observations	Artifacts
7. Students' attention was explicitly and reflectively drawn to NOS ideas implicit in inquiry activities.		
5	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?" (Luke)	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?" (Matthew, A11)
3	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?" (Matthew,)	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 (Mary, A4).
1	Non-existent	Non-existent
8. NOS ideas were explicitly and reflectively scaffolded back and forth along the decontextualized to highly contextualized NOS instructional continuum		
5	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)	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." (Isaac, A4)

APPENIDX A. NOS-COP CONTINUED

Coding scheme for determining the extent that the instructor and/or artifacts actually *did* accurately, explicitly, and reflectively address the NOS.		
Score	**Observations**	**Artifacts**
3	Scaffolds may be superficial or incomplete (e.g. decontextualixed to moderately contextualized). Exemplar: Asking: "Why did we need to make models of the tube in relation to making models of the moon, sun, and earth?" with no reference to real scientists. (Andrew)	Scaffolds may be superficial, inconsistent or incomplete (e.g.. decontextualixed to moderately contextualized). In inquiry based activity with density asking: "How does this lab compare to how real science works? How is this lab like the tube activity?" and never linking the experience to real scientists. (Andrew, A6)
1	Non-existent	Non-existent
9. Students were required to reflect on explicitly identified NOS ideas in the lesson.		
5	Reflections required were 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?" (Andrew)	Reflections required were 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." (John, A2)
3	Reflections 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?" (Mark)	Reflections required may lack consistency, depth and or explicitness. Asking: "Why do scientists use scientific notation?" on a test (Mary, A2).
1	Non-existent	Non-existent

Appendix E

Semi-Structured Interview Questions

1. Variables targeted: View on learning, general teaching 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?*
- *Why do you think this approach is important?*
- Describe a classroom situation where you believed as though your students were really learning?
- What do you think your responsibilities are as a teacher?
- In your view, what does the most successful science teacher like? Why?

2. Variables targeted: General and NOS teaching and understanding of NOS teaching, motivation to teach the NOS (value or compliance), teaching constraints.

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 feel are most important and why?*
- *To what extent do you explicitly or not explicitly draw your student' attention to NOS ideas.*

3. Variables targeted: Teaching constraints (i.e. classroom management, institutional constraints).

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?*
- *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?*
- *What external factors impact your instructional practices both in general content or NOS?*

Additional questions (Post Interview Only) about teacher's scientific epistemological beliefs will be based on their written responses to the following to provide further clarification if necessary:

FROM SUSSI

1. **With examples**, explain why you think scientists' observations and interpretations are the same **OR** different. Where do you recall acquiring the **examples** and **ideas** regarding this question?
2. **With examples,** explain why you think scientific theories change OR do not change over time.Where do you recall acquiring the **examples** and **ideas** regarding this question?
3. **With examples**, explain what scientific theories and laws are and how they are different. Where do you recall acquiring the **examples** and **ideas** regarding this question?
4. **With examples**, explain how society and culture affect OR do not affect scientific research. Where do you recall acquiring the **examples** and **ideas** regarding this question?
5. **With examples**, explain why scientists use OR do not use imagination and creativity. Where do you recall acquiring the **examples** and **ideas** regarding this question?
6. **With examples**, explain whether scientists follow a single, universal scientific method OR use a variety of methods. Where do you recall acquiring the **examples** and **ideas** regarding this question?
7. **With examples**, explain to what degree scientists work with other scientists when doing research. Where do you recall acquiring the **examples** and **ideas** regarding this question?
8. **With examples**, explain why supernatural explanations should OR should not be used in credible scientific ideas. Where do you recall acquiring the **examples** and **ideas** regarding this question?
9. **With examples,** explain how much time is usually required for credible scientific ideas to be generated, and then accepted by the scientific community. Where do you recall acquiring the **examples** and **ideas** regarding this question?
10. **With examples,** explain whether scientific laws and theories are invented OR discovered. Where do you recall acquiring the **examples** and **ideas** regarding this question?

Appendix F

Participant Profiles

Of the 18 traditional middle schools where participants for Phase I of this research were drawn, 15 were Title I. Of the 11 participants selected for Phase II, 10 schools were represented, of which, 8 schools were Title I. The table below illustrates the participants with regard to the schools Title I status and years teaching.

Participant	EBS/SUSSI Score	Title I (Y/N)	Years Teaching (avg. 13.7 yrs.)	Sex M/F
One	128/125	Y	5	F
Two	131/146	Y	18	M
Three	131/137	Y	14	M
Four	131/129	N	3	F
Five	131/134	Y	12	F
Six	143/142	Y	17	M
Seven	148/153	Y	24	F
Eight	150/154	N	9	F
Nine	150/154	Y	25	F
Ten	151/140	Y	17	F
Eleven	162/130	Y	7	M

Appendix G

Informed Consent to Participate in Research
Information to Consider Before Taking Part in this Research Study

IRB Study # Pro00008042

You are being asked to take part in a research study. Research studies include only people who choose to take part. This document is called an informed consent form. Please read this information carefully and take your time making your decision.

We are asking you to take part in a research study called:

The Effect of Teachers' Epistemological Beliefs on Practice

The person who is in charge of this research study is Milton Huling**.** This person is called the Principal Investigator. He is being guided in this research by Dr. Dana Zeidler.

The research will be conducted at various schools within Polk County.

Purpose of the study

The purpose of this study is to gain a better understanding of the relationship between teacher's philosophy about knowledge and its effects on classroom practice. By gaining this understanding, improvements can be made within preservice science methods courses, as well as improve professional development opportunities for active teachers.

This research is being conducted by a doctoral student as part of a dissertation process.

Study Procedures

You are being asked to take part in this study because you are a sixth grade teacher. If you take part in this study, you will be asked to complete an online questionnaire/survey (**Phase One**) taking less than one hour. A selected number of initial participants will be contacted about participating in Phase Two of this research.

Participants being contacted about **Phase Two** of this research will be provided an additional informed consent document to sign. The following bulleted items describe Phase Two.

- ***Phase Two*** *will consist of three interviews (pre, mid, & post, each approximately one-hour in length) over a nine-week period. These interviews will take place at your convenience. The interviews will either take place face-to-face when possible, or, through the use of technology (Live-Meeting, SKYPE, etc.). Period-long classroom visits will also be conducted throughout the nine-week research period. During these visits, information about practice will be collected, including artifacts of instruction (lesson plans, copies of student assignments). To be clear, no student work will be reviewed as part of this research.*

- *Data collection is expected to start several weeks before the beginning of the school year with the questionnaire/survey. Participants selected for Phase Two will participate in a one-hour long preliminary interview, on, or before, the first week of school. Participants should expect to have period-long classroom visits every two to three weeks, or more if possible. The second interview will be conducted during the fifth or sixth week of school. The final interview will be conducted soon after the first nine weeks of the school year. Participation in this research will involve a total of approximately four hours of additional time beyond a typical school requirement.*

- *The initial questionnaire/survey will be conducted online and taken at a location of the participant's choice (home, school, my office, etc.). The interview location will be a mutually agreeable site selected to provide the participant maximum convenience.*

- *All interviews will be digitally recorded (either by video or audio). The researcher will hold the only copy of the digital information and its transcription. All materials will be kept in a secure location, with only the researcher knowing the identity of the participants. Only the researcher and his research supervisor will have access to this collected data. Any collected information will be kept for five years and disposed of thereafter in a means necessary to safeguard the identity of the participants. Any transcriptions will be shredded and digital information erased.*

Total Number of Participants

Approximately 30 individuals will take part in Phase One this study. Nine teachers of the original 30 will be asked to participate in Phase Two of this research.

Alternatives

You do not have to participate in this research study.

Benefits

We are unsure if you will receive any benefits by taking part in this research study. There will be no financial reward for participation.

Risks or Discomfort

This research is considered to be of minimal risk. That means that the risks associated with this study are the same as what you encounter every day. There are no known additional risks to those who take part in this study.

Compensation

You will receive no payment or other compensation for taking part in this study.

Privacy and Confidentiality

We will keep your study records private and confidential. Certain people may need to see your study records. By law, anyone who looks at your records must keep them completely confidential. The only people who will be allowed to see these records are:

The research team, including the Principal Investigator, study coordinator, research nurses, and all other research staff**.**

Certain government and university people who need to know more about the study. For example, individuals who provide oversight on this study may need to look at your records. This is done to make sure that we are doing the study in the right way. They also need to make sure that we are protecting your rights and your safety.

Any agency of the federal, state, or local government that regulates this research. This includes the Office for Human Research Protection (OHRP).

The USF Institutional Review Board (IRB) and its related staff who have oversight responsibilities for this study, staff in the USF Office of Research and Innovation, USF Division of Research Integrity and Compliance, and other USF offices who oversee this research.

We may publish what we learn from this study. If we do, we will not include your name. We will not publish anything that would let people know who you are.

Voluntary Participation / Withdrawal

You should only take part in this study if you want to volunteer. You should not feel that there is any pressure to take part in the study. You are free to participate in this research or withdraw at any time. There will be no penalty or loss of benefits you are entitled to receive if you stop taking part in this study. Voluntary participation or withdrawal from this study will have no impact on the job status of any participant.

You can get the answers to your questions, concerns, or complaints

If you have any questions, concerns, or complaints about this study, or experience an adverse event or unanticipated problem, call Milton Huling at 863-370-3087.

If you have questions about your rights as a participant in this study, general questions, or have complaints, concerns or issues you want to discuss with someone outside the research, call the USF IRB at (813) 974-5638.

Consent to Take Part in this Research Study

It is up to you to decide whether you want to take part in this study. If you agree to take part, please choose yes, to agree to participate. By choosing the YES option, you are affirming that you have read and understand this document and agree to participate in Phase One of this research.

If you want to take part, please choose the YES option and press submit, if the following statements are true.

I freely give my consent to take part in this study as agreed above, be collected/disclosed in this study. I understand that by choosing YES and completing this electronic survey form I am agreeing to take part in Phase One of this research. Please print this page for future use.