EFFECT OF AUTHENTIC RESEARCH EXPERIENCES ON NATURE OF SCIENCE BELIEFS

A Thesis by

Jason Wade Morphew

Bachelor of Science, University of Nebraska, 2001

Submitted to the Department of Counseling, Educational and School Psychology
and the faculty of the Graduate School of
Wichita State University
in partial fulfillment of
the requirements for the degree of
Master of Education

December 2012

EFFECT OF AUTHENTIC RESEARCH EXPERIENCES ON NATURE OF SCIENCE BELIEFS

The following faculty members have examined the final copy of this thesis for form and content, and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Education with a major in Educational Psychology.

____
Marlene Schommer-Aikins, Committee Chair

____
Susan Unruh, Committee Member

____
Daniel Bergman, Committee Member

DEDICATION

To my wife, Dr. Susan Cooper-Morphew, for her support, understanding, and most importantly for her patience.

ACKNOWLEDGMENTS

This paper would not be possible without the guidance, support, and hard work of a number of people. I would like to thank my committee chair, Dr. Schommer-Aikins, for her guidance throughout this amazing experience. You have been an invaluable teacher, mentor, and counselor. You have kept me sane and encouraged me to go above and beyond the limits I had imposed on myself. I thank you from the bottom of my heart for the time, insights, and direction that you have given me.

I would also like to thank my committee member, Dr. Unruh, for her wisdom, support, and knowledge. You have both encouraged me and guided me through the research and teaching process. I thank you for all of your support and knowledge.

I would also like to thank my committee member, Dr. Bergman, for his mentoring and insights over the past two years. You have encouraged me along my journey and given me the opportunities to connect to the College of Education environment. You have helped me to follow my passion.

Finally, I would like to thank my wife, Dr. Susan Cooper-Morphew, for her support, understanding, and most importantly for her gentle pushes when I became frustrated and overwhelmed.

ABSTRACT

The purpose of this study was to examine the relationship between authentic research experiences and the nature of science (NOS) beliefs of graduate students. Fifty graduate students employed as assistants at a large Midwestern University completed the Views on Science and Education Questionnaire developed by Chen (2006), a survey of their research experiences, and demographic information. Measures were taken to assess the graduate students NOS beliefs, the number of research experiences, the types of activities engaged in during the research experiences, and the epistemic demand of the graduate students' research activities. Descriptive statistics were presented and discussed. The results were analyzed using a Pearson correlation to determine the relationship between number of research hours and NOS beliefs, as well as the number of types of research experiences and NOS beliefs. The results were also analyzed using a multivariate step wise regression, with the epistemic demand of the research experience as one of the predictor variables and NOS beliefs as the criterion variables, to determine whether the nature of the research experience affects the relationship between research experiences and NOS beliefs. Implications of the findings and limitations of the research were discussed.

TABLE OF CONTENTS

Chapter		Page
I.	INTRODUCTION	1
	Rationale	1
	Purpose	4
	Overview	4
	Research Problem	5
II.	LITERATURE REVIEW	6
	Nature of Science Beliefs	6
	Empirical and Tentative Knowledge	7
	Subjectivity	8
	Creativity	8
	Observations and Inferences	8
	Laws and Theories	9
	Scientific Method	10
	Sociocultural Context	11
	Aligned and Unaligned Epistemological Beliefs	12
	Nature of Science Belief Change	16
	Explicit and Reflective Interventions	18
	Authentic Research Experiences	22
III.	METHODS	29
	Participants	29
	Instruments	29
	Nature of science measure	29
	Research experience measure	34
	Demographics	36
	Procedures	36
	Data Analysis	37
IV.	RESULTS	38
	Descriptive Statistics and Psychometric Properties	38
	Hypothesis Testing	40

TABLE OF CONTENTS (continued)

Chapter		Page
V.	DISCUSSION	47
	Study Summary	47
	Findings and Implications	49
	Limitations	53
	Future Research	54
REFERENCES		56
APPENDICES		64
	Views on Science and Education Questionnaire	65
	Research Experience Questionnaire	74
	Demographics Questionnaire	78
	Consent Form	80

LIST OF TABLES

Table		Page
1.	NOS Dimension and Item Number Assessed by VOSE	34
2.	Descriptive Statistics and Psychometric Properties	81
3.	NOS Dimension, Reliability, and Item Number Assessed by VOSE	82
4.	Descriptive Statistics for NOS and NOS Subscales	83
5.	Descriptive Statistics for Number of Different Types of Research Activities	84
6.	Summary of Intercorrelation for NOS Score and NOS Subscores as a Function of Science Classes Taken and Number of Research Projects	85
7.	Means and Standard Deviations for NOS Beliefs by First Language and Belief in Self as Scientist	86
8.	Summary of Intercorrelation for NOS Score and NOS Subscores as a Function of Number of Different Research Activities in Each Area	87
9.	Summary of Intercorrelation for NOS Score and NOS Subscores as a Function of Number of Research Activities at High, Medium, and Low Epistemic Demand	88
10.	Predictors of Overall NOS Score and NOS Subscores	89

LIST OF FIGURES

Figure		Page
1.	Interaction of First Language and Belief in Oneself as a Scientist on NOS Score	43

CHAPTER 1

INTRODUCTION

Rationale

Educational reform in the United States has recently focused on increasing standards and accountability. While these goals are easy to implement and measure, the beliefs that teachers and students possess are important factors in education. Beliefs are ideas that are not dependent on reason or evidence for their formation (Bhattacharyya, Volk, & Lumpe, 2009). As such they are very resistant to change. Beliefs have also been found to be a stronger predictor of behavior than knowledge (Pajares, 1992). An individual's Nature of Science (NOS) beliefs are extremely relevant in today's society. NOS beliefs were the second most frequently published topic in science education research from 1990 to 2007 behind only conceptual change (Chang, Chang, & Tseng, 2010). However there is no consensus on how to align an individual's (non-scientist) NOS with those of practicing scientists (Ab-El-Khalick, Bell, & Lederman, 1998).

A number of issues currently being debated will dramatically affect people's lives now and in the future. Global warming, vaccinations, evolution, stem-cell research, genetically modified food, and sustainable energy production are just a few of the issues that the average person must grapple with, even though he or she does not possess specialized knowledge about each topic. As a result, the individual's NOS beliefs will affect his or her position on these issues and the course of policy decisions.

Although there is not a consensus over the exact components of the Nature of Science, there are certain beliefs that most experts agree upon (Ab-El-Khalick, et al. 1998; Karakas, 2011). Seven beliefs have been proposed to fit into this category of general acceptance (Akerson, Morrison, & McDuffie 2006; Lederman, 1999): First, scientific knowledge is both empirically based and tentative. Second, science is subjective even though it strives to be objective. Third, science involves imagination and creativity. Fourth, although a relationship exists between observations and inferences, they are qualitatively different. Fifth, the relationship between theories and laws is not hierarchical. Sixth, there is not a single scientific method. Seventh, scientific exploration is carried out in a social and cultural context.

National science standards emphasize the teaching of aligned Nature of Science beliefs (American Association for the Advancement of Science 1993; National Academy of Sciences, 1996). While inquiry, high stakes testing and appropriate pedagogy are all emerging features of many science education methods courses, NOS beliefs are generally not taught in science classes as the instructors are more concerned with covering the content, developing problem solving skills, developing an organizational plan for their courses, and dealing with classroom management (Karakas, 2009; Lederman, 1995). In fact Kalman (2009) argues that it may be necessary to change the way that science is presented from a method of solving problems grouped by type and discipline, to a model that emphasizes the interconnection of concepts.

Bencze and Bowen, (2009) found that pre-service teachers generally intended to teach their students in the manner in which they had been taught. However since NOS is not covered in many science courses, and those who do teach NOS may not hold adequate NOS beliefs, these pre-service teachers cannot be expected to teach about NOS effectively. In addition, Yager (1997) asserts that not enough teachers at the primary and secondary levels have practiced science. Gallagher (1991) further contends that this limited experience constrains the ability of the teachers to plan and implement lessons to help their students to develop an appropriate image of science. Furthermore those who eventually develop adequate NOS beliefs through explicit reflective interventions may not develop the ability to effectively transmit those beliefs to their students (Lederman, 1992; Lederman, 1995).

The extent to which a teacher's NOS beliefs directly affect his or her classroom behavior is unclear. Bencze, Bowen, and Alsop (2006) found that the teachers' tendency to use student focused, open-ended instructional methods corresponded to their NOS beliefs. Bhattacharyya, Volk, and Lumpe (2009) also found that elementary teachers' beliefs influenced their effectiveness in implementing inquiry. In contrast Lederman (1999) found that changing teachers' NOS beliefs, did not result in a difference of teaching method. This could be that a preference for instructional method is not connected to NOS beliefs, that instructional change took place over a longer time frame than the studies allowed for, or that there are a number of mitigating factors which determine instructional practices.

With the importance of holding adequate NOS beliefs on current policy decisions, and the emphasis placed on teaching NOS, it is surprising that the majority of teachers, students, and members of society possess inadequate NOS beliefs (Akerson & Hanuscin, 2007; Akerson, Morrison, & McDuffie, 2006; Karakas 2009; Lederman 1999; Schwartz, Lederman, & Crawford, 2004; Smith & Scharmann, 2008; Tairab, 2001). While many attempts have been made to study both explicit and implicit interventions aimed at aligning the NOS beliefs of different populations few studies have looked at the natural development of NOS beliefs in graduate students involved in different domains and experiences to determine the factors that may be considered critical to aligning NOS beliefs. This is a critical piece in understanding the development of NOS beliefs since many individuals engaged in graduate programs tend to learn about their domain through research apprenticeships (Sadler, Burgin, McKinney, & Ponjuan, 2010).

Purpose

The purpose of this study is to examine the relationship between the amount and type of authentic research experiences possessed by graduate students and the NOS beliefs expressed by these students. Furthermore, the alignment of their beliefs with those of practicing scientists and educational reform documents will be explored. This relationship may demonstrate specific research experiences which lead to NOS belief change in one or more of the seven areas mentioned above. This would allow pre-service education programs to more effectively address NOS education.

Overview

This study involves an investigation of the research and theory into nature of science beliefs, specifically focusing on methods used to align students' existing beliefs with those of practicing scientists. Chapter two is presented in two parts. The first part of chapter two discusses nature of science beliefs. The dimensions of nature of science beliefs will be presented and the general positions held by the majority of practicing scientists will be presented. The second part of chapter two discusses the effect of a variety of techniques for aligning students' nature of science beliefs with those of practicing scientists. The primary aim for this study is to analyze the relationship between authentic research experiences and an individual's nature of science beliefs.

Chapter three presents the methodology that is used in the study and the procedure for collecting and analyzing the data. In addition, the instruments for measuring nature of science beliefs and research experiences are discussed. Chapter four contains the results from the study. Chapter five contains a discussion of the results, implications of the findings, and suggestions for future research.

Research Problem

This study proposes to investigate the following hypotheses about the relationship between nature of science beliefs and research experiences:

a) Graduate students with more hours of research experience will tend to have NOS beliefs more aligned with those of practicing scientists.

b) Graduate students with more types of research experiences will tend to have NOS beliefs more aligned with those of practicing scientists.

c) The nature of the graduate students' research experiences will affect this relationship. Specifically, those students who are involved with designing experiments and analyzing data with respect to theories will tend to have NOS beliefs more aligned with those of practicing scientists.

CHAPTER 2

LITERATURE REVIEW

The term “Nature of science (NOS) beliefs” generally refers to the values and assumptions held by scientists, the effect that those values and beliefs have on the construction of scientific theories and knowledge, and the epistemology of science (Lederman, 1992). Descriptions and characterizations of these epistemological positions remain general due to the wide variety and complexity of scientific knowledge and disciplines. In addition, the current conceptions of NOS are “tentative and dynamic” (Lederman, Ab-El-Khalik, Bell, & Schwartz, 2002, p.499). The tentativeness of NOS beliefs are intended to reflect the tentativeness of scientific knowledge and the position that no one NOS belief system is able to reflect all scientific epistemologies or domains in every context. Although there is not a consensus over the exact components of NOS, there are certain beliefs where a general agreement is found across domains and cultures (Ab-El-Khalick, et al. 1998).

Nature of Science Beliefs

Seven aspects of NOS have been proposed to fit into this category of general acceptance (Akerson, Morrison, & McDuffie 2006; Lederman, 1999; Karakas, 2009; McComas, Clough, & Almarzroa, 1998). First, scientific knowledge is both empirically based and tentative. Second, science is subjective even though it strives to be objective. Third, science involves imagination and creativity. Fourth, although a relationship exists between observations and inferences, they are qualitatively different. Fifth, the relationship between theories and laws is not hierarchical. Sixth, there is not a single scientific method. Seventh, scientific exploration is carried out in a social and cultural context. To better highlight the seven beliefs that will be analyzed in this study, and to highlight the "aligned" and "unaligned" perspectives an in depth look at each belief is necessary.

Empirically and Tentatively Based Knowledge

Scientific knowledge claims are often made using observations of the natural world. These observations are influenced by the individual's perceptual abilities and the limits of the instrumentation. Scientific knowledge claims are not limited solely to observable phenomenon. Knowledge claims are also made with respect to phenomena that cannot be directly observed. Scientists must rely on observations to derive knowledge about these unobservable events, however, these observations merely support scientific claims rather than prove them. While both experts and novices indicate that observations are used to make scientific knowledge claims, experts are more likely to indicate that these knowledge claims do not rely solely on observations and that these observations support rather than prove knowledge claims (Lederman, Ab-El-Khalick, Bell, & Schwartz, 2002).

Scientific knowledge claims are reliable, but never absolute or certain. Since observations merely support, as opposed to prove, scientific knowledge claims, these knowledge claims are tentatively held. All scientific knowledge claims, whether facts, theories, or laws, are subject to change. This change can occur due to new observations, more accurate instrumentation, theoretical advancement, or the reinterpretation of observation. While both experts and novices indicate that scientific knowledge claims can change, novices were more likely to indicate that knowledge claims change only when new information is discovered, as opposed to a reinterpretation of the evidence (Lederman, et. al., 2002).

Subjectivity

Scientific knowledge construction does not begin with objective observations. All aspects of the construction of scientific knowledge are influenced by the current state of a discipline. The development of research questions, experimental design, and the interpretation of the results are all driven by the current theoretical perspective of the discipline and the scientist. The types of observations that are made, or not made, are also guided by the prior knowledge, expectations, experiences, and beliefs held by the scientist. The subjectivity involved in science is unavoidable, but necessary for scientific knowledge to progress (Schwartz, Lederman & Crawford, 2004). Experts tend to indicate that subjectivity is unavoidable and results in differences in design and interpretation (Lederman, et. al., 2002; Karakas, 2009).

Creativity

Science knowledge is based on observations of natural phenomena. However, scientific knowledge claims are made to explain why these observations occurred, and are made with respect to unobservable phenomena. Concepts such as atoms and extra-solar planets cannot be directly observed, but are created using logical reasoning to explain observations such as spectral lines and orbital wobble. This requires scientists to use creativity to construct knowledge claims rather than to discover existing knowledge claims (Tsai & Liu, 2005). Experts are more likely to indicate that creativity permeates the scientific process (Lederman, et. al., 2002).

Observations and Inferences

Scientific knowledge claims are constructed through the combination of two main processes; observations and inferences. Observations are the descriptions of events that can be obtained by the senses. An example of an observation is that when zinc is placed into a container of acid, bubbles are formed. A further observation would be that if the gas is collected, it combusts. Inferences are explanations of events that are unavailable to the senses or explanations of the observations. For example, the bubbles that are formed when zinc is placed in an acid are due to a chemical reaction, or a rearrangement of the atoms, in the container. The gas could then be inferred to be hydrogen, since many acids contain hydrogen and hydrogen is a gas that undergoes combustion.

The combination of observations and inferences drives the construction of scientific knowledge. Observations lead to inferences in an attempt to explain how and why the observation occurred. These inferences then influence future questions, experiments, and observations. Experts are more likely to indicate that scientific knowledge is constructed from a combination of observations and inferences (Lederman, et. al., 2002).

Laws and Theories

Observations can lead to the formation of either scientific laws or theories. Scientific laws are descriptive statements about the relationship between two or more phenomena across a variety of settings. In other words, a scientific law is a collection of observations conducted under a variety of conditions. Scientific laws are subject to the same subjectivity as all knowledge claims and therefore cannot be proven and can change due to new observations or reinterpreting existing observations.

Scientific theories are explanations of large sets of related observations based on inferences of unobservable phenomenon. Since theories are based on inferences, as such they cannot be tested directly. Indirect evidence can be used to establish a theory's validity by using the theory to create testable predictions which are then tested against empirical evidence. The testability of scientific theories contributes to them being well substantiated and consistent (Suppe, 1977). Theories can change based on new evidence or new ways of looking at the evidence.

While observations and experimentation can lead to the development of either scientific laws or theories, they are "distinct and functionally different" (Schwartz, Lederman & Crawford, 2004, p. 613). In addition, the relationship is not hierarchical. That is, scientific theories do not become laws, nor do scientific laws possess a higher status. Experts are more likely to hold the position that there is not a hierarchical relationship between theories and laws, that theories and laws can change, and that theories and laws are well substantiated (Lederman, et. al., 2002). However, Karakas (2011) found that practicing scientists who were responsible for teaching introductory science courses to undergraduate students tended to express mixed views of the nature of theories, nature of laws, and the hierarchical nature of their relationship.

Scientific Method

Scientists use many of the same processes regardless of their discipline or research question. Science is characterized by observation, comparison, measurement, hypothesizing, hypothesis testing, and constructing inferences and theories. There is not one method for constructing scientific knowledge claims, no sequence of steps that will guarantee the construction of a valid observation or inference. Experts are more likely to assert that no single scientific method exists, rather that various approaches are needed to address the variety of research questions being asked. (Lederman, et. al., 2002).

Sociocultural Context

Scientific knowledge claims are subjective. As such, the values held by the culture and society in which it is practiced affects the scientific process. This includes the types of questions asked and the observations made, as well as the inferences and conclusions drawn from the observations. The sociocultural influence on the scientific process can be seen through the funding of some projects over others, the peer review process, and the culture of the scientific community itself. Experts are more likely to express the involvement of cultural influences on the scientific process, however both experts and novices tend to minimize the effect that the society or culture as a whole, has on the construction of scientific knowledge (Lederman, et. al., 2002).

These NOS aspects can be considered to be interrelated. For example, if an individual were to believe that scientific knowledge is created by scientists to explain natural phenomenon, as opposed to discovering existing knowledge, then he or she would be more likely to believe that knowledge is subjective and tentative. While some have said that these NOS aspects are interdependent (Schwartz, Lederman, & Crawford, 2004), others have found evidence suggesting that these NOS beliefs are independent, and can be analyzed separately. Tsai and Liu (2005) performed a factor analysis on his Science Epistemological Views (SEV) measure and found that the items loaded on five factors. Further analysis found that there was a low correlation between these factors, indicating that there was a high degree of independence of these factors. Tsai did not include questions about the difference between theories and laws, or the difference between observations and inferences in his analysis.

A similar result was found when looking at general epistemological beliefs. Schommer (1990) performed a factor analysis on an epistemological questionnaire and found that while these general epistemological beliefs are also interrelated, they are composed of a number of independent beliefs that do not necessarily develop at the same rate. Schommer (1990) further assessed a group of students' epistemological beliefs and their comprehensions and confidence in a reading task. She found that different beliefs correlated to different outcomes. For example, a belief in quick learning resulted in reaching oversimplified conclusions, whereas a belief in certain knowledge resulted in reaching absolute conclusions. In other words, holding "naïve" or unaligned beliefs in one dimension would lead to different consequences than holding unaligned beliefs in a separate dimension. These results suggest that NOS beliefs should be analyzed independently. Furthermore, it could be assumed that a variety of methods must be employed to change or align an individual's NOS beliefs.

Aligned and Unaligned Epistemological Beliefs

Understanding the basis for scientific knowledge claims is a goal of many science education organizations (American Association for the Advancement of Science, 1993; National Academy of Sciences, 1996). National science standards stress the importance of having students develop an epistemology of science that is aligned with those epistemological beliefs held by practicing scientists, and emphasize the instruction of Nature of Science (NOS) beliefs (American Association for the Advancement of Science, 1993; National Academy of Sciences, 1996; Ryan & Aikenhead, 1992).

The epistemology that an individual holds has an effect on how he or she interacts with learning and knowledge construction. General epistemological beliefs - beliefs about the nature of knowledge and knowing - predict academic performance, comprehension, subject usefulness, study-strategies, motivation, and self-regulation (Paulsen & Feldman, 2005; Schommer-Aikins, 2004; Schommer-Aikins, Duell, & Hutter, 2005; Schommer-Aikins & Easter, 2008). A longitudinal study of 90 German students before and after their first year in college found that beliefs in the certainty of knowledge were negatively correlated with academic performance. Furthermore, the choice of their field of study in college seemed to be related to their belief in the certainty of knowledge (Trautwein & Ludtke, 2007).

NOS views incorporate the epistemology of science as well as the values and assumptions held by scientists. The importance of holding aligned views of NOS should therefore be similar in scope to that of epistemological views in general. Lederman, Wade, and Bell (1998) suggest that individuals who hold an epistemology of science that is not aligned with that of practicing scientists are less able to form images of science with the context needed to make the knowledge relevant and applicable.

Buffer, Lubben, and Ibrahim (2009) found that the NOS beliefs held by first year physics students correlated with their views on appropriate measurement. That is, those students that held unaligned NOS beliefs tended to view measurement as the act of finding the one "true" value, while those students that held aligned NOS view tended to view measurement as uncertain and providing a range of possible values. This has implications for an individual's actions and reasoning during scientific investigations. If individuals view scientific measurements and observations as a process of finding the “correct” value, they will focus their investigations and studies on procedures and memorization. In contrast, if individuals view measurement and observation as uncertain, they may tend to focus on interpretation and explanations of the data (Buffer, Lubben, & Ibrahim, 2009).

Holding aligned views of NOS also has an effect on the actions, reasoning, comprehension, and communication of science across a wide variety of settings (Ryder & Leach, 1999; Tsai, 1999; 2007). Tsai (1999) assessed middle school students’ NOS beliefs, observed their interactions during a laboratory investigation, and then assessed their views of the laboratory activities through the administration of The Science Laboratory Environment Inventory (SLEI), and interviews. Students that held aligned views of NOS tended to have more verbal interactions concerning the meaning of the events that occurred during the laboratory investigation. These students also tended to focus more on interpreting and explaining the outcomes of the investigations.

Ryder and Leach (1999) studied undergraduates in their final year at the University of Leeds as they performed original investigative projects as part of their graduation requirements. Their results suggest that a student’s ability to conduct an investigation can be constrained by the NOS beliefs held by the student in some situations. Students that held unaligned NOS views tended to struggle, but only in projects that had high epistemic demand. Ryder and Leach (1999) define epistemic demands as “the demands a project makes on a student to draw upon his/her views about the relationship between data and knowledge in order to make progress on a project” (p. 951). For the purposes of this paper, epistemic demand will be operationally defined as the demand an activity or event places on the individual to draw upon or confront his or her personally held epistemological beliefs. In other words, an event that has high epistemic demand will require the individual to reflect on the epistemological beliefs held by the individual a great deal in order to proceed or make sense of the event.

A case study conducted by Tsai (2007) looked at the relationship between teachers' NOS views, their instructional practices, and their students' NOS views. Through interviews, classroom observations, and NOS measurement for instructors and students, it was found that instructors that had aligned NOS views tended to focus on student understanding through group learning and inquiry based laboratory activities. They viewed their role as a teacher as one of being a facilitator and model for the students. Those instructors that held unaligned views tended to focus on the student acquisition of knowledge through lectures and tutorials. They viewed their role as a teacher as being a disseminator of knowledge.

With the importance of holding adequate NOS beliefs on current policy decisions, and the emphasis placed on teaching NOS, it is surprising that the majority of teachers, students, and members of society possess inadequate NOS beliefs (Akerson & Hanuscin, 2007; Akerson, et al., 2006; Karakas 2009; Lederman 1999; Ryder, et. al., 1999; Schwartz, Lederman, & Crawford, 2004; Ryan & Aikenhead, 1992; Smith & Scharmann, 2008; Tairab, 2001). The majority of individuals learn about the epistemological positions, values, and assumptions of science implicitly through the interactions and lessons presented in school. This results in many students being presented NOS beliefs that are unaligned with those of practicing scientists (Furtak & Alonzo, 2009; Karakas, 2009; Roth, et. al., 2006)

Furtak and Alonzo (2009) observed and interviewed 28 third grade teachers from a large school district. They found that the teachers tended to focus on facts, data, and the scientific procedures or methods and did not spend much time or emphasize real-world connections or NOS. An analysis of the Trends in International Mathematics and Science Video Study (TIMSS) conducted by Roth, et. al. (2006) found that while more emphasis was placed on real-life connections, eighth grade classrooms tend to focus on different types of knowledge, but not on discussing how that knowledge was developed. NOS beliefs are generally not taught in college science classes as the instructors were more concerned with covering the content and developing problem solving skills (Karakas, 2009).

These results seem to indicate that there is a disconnect between research and policy and implementation in the classroom. In fact, Kalman (2009) argues that it may be necessary to change the way that science is presented from a method of solving problems grouped by type and discipline, to a model that emphasizes the interconnection of concepts. The beginning of this reform will likely occur during the methods courses of pre-service science teachers and continue through inservices and other training.

Nature of Science Belief Change

Beliefs are ideas that are not dependent on reason or evidence for their formation (Bhattacharyya, Volk, & Lumpe, 2009). As such they are very resistant to change. Kang, Scharmann, and Noh (2004) classified students' responses to an event that did not fit with a previously held belief about that phenomenon. They classified the students' responses into seven categories: Rejecting the validity of the discrepant event, reinterpreting the event to fit their previous belief, excluding the event from consideration in analyzing their belief, feeling uncertain about their belief but not changing, feeling dissatisfied with their current belief but not changing, making small adjustments to their current belief, or completely changing their belief in response to the event.

Two factors which seem to facilitate conceptual change and epistemological change are cognitive conflict and socialization. Kang, Scharmann, and Noh (2004) analyzed the amount of conceptual change that occurred after viewing an event that contradicted their existing misconceptions. They found that the extent of cognitive conflict was related to the interaction of their previously held belief and the new experience. Furthermore, they found that there was a correlation between cognitive conflict and conceptual change. Since the misconceptions held by the students were likely formed independently of complete evidence, these misconceptions may function very similar to beliefs. This suggests cognitive conflict may play a role in belief change as well as in conceptual change.

General epistemological beliefs have been shown to change as students are socialized into their community of practice by their instructors and peers within their college majors (King & Magun-Jackson, 2011; Trautwein & Ludtke, 2007). Trautwein and Ludtke (2007) conducted a longitudinal study of a group of German students, assessing their general epistemological beliefs in their final year of secondary schooling and again two years later when they were enrolled in college. They found that students entering into different college majors differed in their initial epistemological beliefs, suggesting that the students were, at least partially, self-selecting their socialization groups. The differences in epistemological beliefs between majors became larger after the students had been enrolled and had attended college classes. This suggests that the socialization within their community of practice played a role in changing their epistemological beliefs.

King and Magun-Jackson (2011) conducted a cross-sectional study of engineering students at three separate universities. They assessed the epistemological beliefs of underclassmen, upperclassmen, and graduate students. A difference in epistemological beliefs was found between underclassmen and upperclassmen, suggesting that the socialization they experienced within their community of learning may have been the impetus for epistemological change.

NOS belief change also seems to occur in situations where cognitive conflict is created and allowed to be resolved through socialization within a community of practice. Interventions aimed at achieving NOS belief change can be categorized as either implicit or explicit. Students receive a large number of implicit messages within any science instruction (Schwartz, Lederman, & Crawford, 2004). Implicit interventions attempt to influence NOS beliefs by modeling scientific processes without direct instruction or intentionally planning and emphasizing specific NOS learning outcomes. The assumption is that a change in NOS will occur as a natural consequence of the scientific process. An example of an implicit intervention is exposing individuals to either research or inquiry activities without planned instruction or reflection of NOS beliefs.

Explicit and Reflective Interventions

Explicit interventions attempt to influence NOS beliefs by intentionally planning and emphasizing specific NOS learning outcomes. This approach can use a variety of instructional approaches from direct instruction to inquiry activities in an attempt to intentionally develop the learners' NOS beliefs.

Several attempts have been made to change NOS beliefs using explicit interventions. Akerson & Hanuscin (2007) worked with three science educators in a three year professional development program. The educators attended monthly workshops where they learned about NOS, inquiry, and participated in activities designed to engage them in inquiry modeling science experiments. The educators also participated in discussions and presented at the science teachers' association conference. All three educators demonstrated unaligned NOS beliefs at the beginning of the intervention and more aligned views, though still holding some misconceptions, at the end of the intervention.

A similar professional development program was conducted by Posnanski (2009) with 22 science educators in a two year program. In addition to explicit discussions and inquiry activities, Posnanski added discussions about current NOS research literature. A majority of the participants displayed more aligned NOS beliefs in general following the intervention however, these gains were only found in some NOS beliefs, and actually were less aligned in other NOS beliefs. In other words, although the NOS were more aligned in general, the desired belief change only occurred for some beliefs and not others.

Akerson, Cullen, and Hanson (2009) also found that participants displayed more aligned NOS beliefs following a professional development program engaging practicing educators in explicit NOS activities and instruction. The participating educators also formed communities of practice to debrief the activities and create lesson plans to implement NOS activities with their students. The participants' NOS beliefs were affected when they struggled with teaching the NOS concepts in their own classrooms and were able to discuss their struggles within their community of practice.

Abd-El-Khalick and Akerson (2009) engaged students enrolled in a science methods course in NOS discussions, assigned reading about currently accepted NOS beliefs, and engaged students in hands-on activities to encourage examination of their NOS beliefs. Students in general displayed more aligned NOS beliefs following the explicit-reflective intervention. This alignment of NOS beliefs was more pronounced when accompanied with metacognitive training.

McDonald (2010) studied five pre=service teachers enrolled in a science content course. The students engaged in explicit NOS instruction during both inquiry-based sessions and theory-based sessions. In addition, students engaged in argumentation instruction and activities, as well as designing and implementing an inquiry-based laboratory project. Four of the pre-service teachers displayed more aligned NOS beliefs in general following the course. The participants that displayed a change in NOS beliefs also experienced cognitive dissonance during the intervention, though the task which generated the cognitive dissonance was not explored.

Other explicit approaches that have been used to align the NOS beliefs of participants have included using historical examples of scientific advancement (Spiliotopoulou-Papantoniou & Agelopoulos, 2009), explicit and reflective NOS classes (Abd-El-Khalick, 2005), using the example of the scientific response to Severe Acute Respiratory Syndrome pandemic to explicitly teach NOS beliefs (Wong, Kwan, Hodson, & Yung, 2009), and using reflection following inquiry activities to explicitly address NOS beliefs (Quigley, Pongsanon, & Akerson, 2010).

Explicit interventions have demonstrated consistent increases in appropriate NOS beliefs (Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick, 2005; Craven, Hand, & Prain, 2002; Hanuscin, Akerson, & Phillipson-Mower, 2006; Wong, Kwan, Hodson, & Yung, 2009). However these interventions may not have been the catalyst for initiating belief change. Bell, Blair, Crawford, and Lederman (2003) reported that one participant reported experiencing a change in his or her NOS beliefs as a result of the questionnaire and interview, stating that, “after I took the questionnaire I started thinking about the answers more and trying to decide if I was right” (p. 495).

In addition, these gains may not reflect actual changes in beliefs. Akerson, Morrison, & McDuffie (2006) found that a majority of those that demonstrated alignment in NOS beliefs had regressed to their original beliefs within five months of the intervention, although those who developed deeper beliefs demonstrated more persistence in their new beliefs. Posnanski (2009) further suggests that the changes in NOS beliefs as a result of explicit NOS instruction or inquiry activities may be short lived and restricted to only certain aspects of NOS.

This regression in NOS beliefs to more unaligned positions may have occurred since the explicit interventions influence the participants’ perceptions of the correct answers on the instruments rather than their perception of appropriate NOS beliefs. In addition, the participants may be expressing a belief about science as an ideal, or as an abstract concept, on one measure and a belief about science as an actual practice on another. For example, expressing that scientists should strive to make unbiased measurements is different than expressing that the observations used to make advancements in scientific knowledge are completely objective. The former statement reflects a belief about the ideals of science, while the later reflects a belief about science as a practice.

An alternative explanation may be that the explicit interventions contradict the implicit messages about appropriate NOS beliefs from both previous and future experiences. In addition, if the activities an individual engages in are not seen as part of an authentic science context, then the beliefs and views of science may not change or, if changed, may not be stable. In their study of undergraduates in their final year at the University of Leeds, Ryder and Leach (1999) found that NOS belief change occurred as the result of both explicit discussions about NOS and as the result of activities not explicitly planned to address NOS. They conclude that NOS belief change occurs as the result of both explicit and implicit messages during authentic scientific research projects.

The effect that implicit messages have on the development of aligned NOS views is not completely clear. In a review of the literature, Sadler, Burgin, McKinney, and Ponjuan (2010) found that while most studies using implicit methods of changing NOS beliefs while engaging participants in authentic research with practicing scientists demonstrated more aligned NOS, other studies demonstrated limited or no alignment in NOS beliefs.

Authentic Research Experiences

Several studies have found that engagement in authentic research experiences, whether they were part of implicit or explicit interventions, have demonstrated improvements in aligning NOS beliefs among a wide variety of populations. Schwartz, Lederman, and Crawford (2004) explored the change in the NOS beliefs of 13 secondary pre-service science teachers during a science research internship that also included explicit NOS instruction and guided reflection. The participants were engaged in research activities that varied with the research setting for 10 weeks. Most of the participants demonstrated more aligned NOS beliefs following the internship. While the effects of the explicit instruction and implicit research experiences on these participants cannot be separated from each other, the participants were also asked to identify which activities influenced their NOS belief change. The majority of participants indicated that the reflective journals and explicit NOS instruction was most influential on the NOS beliefs. However, it is unclear whether this response was due to the actual effect on NOS beliefs, or that these activities were the most saliently connected the measurement of NOS beliefs.

Studies that used implicit interventions have also demonstrated positive alignment of NOS beliefs. Fazio (2009) engaged four middle and secondary science teachers in an action research project. The participants identified, researched, and clarified their own research ideas, constructed a research plan, implemented the research, and analyzed the results of their projects under the guidance of a practicing researcher. At the end of the study all of the participants demonstrated more aligned NOS views.

Richmond and Kurth (1999) investigated the change in the NOS beliefs of collaboration, tentativeness, and processes of scientific investigations of seven high school students engaged in a seven week research apprenticeship program. Participants were matched with a research mentor to conduct research on a current research project. They conducted general research activities, attended collaborative meetings, reflected on their experiences in a journal, and drafted a research proposal and report of their experiences. The participants views on the tentativeness and lack of a single scientific method were more aligned following the apprenticeship. In addition, many of the participants' interview responses seemed to indicate more aligned NOS beliefs concerning the sociocultural influence on the scientific process, as well as on the empirical nature of scientific knowledge formation.

Charney, et. al. (2007) studied the change in NOS beliefs of 30 high school students that engaged in a four-week apprenticeship with practicing scientists. Participants attended presentations and discussions of the theory underlying their research projects, learned and practiced laboratory techniques, collected data, and designed a presentation of the results and their experiences. The participants demonstrated more aligned NOS beliefs after their research experiences.

Although NOS beliefs were not explicitly studied in some of the naturalistic and descriptive studies that have investigated the general effects of authentic research experiences on participants, interviews with the participants seem to indicate a change in their NOS beliefs. Varelas, House, and Wenzel (2005) explored the experiences of three pre-service teachers during a 10 week science apprenticeship through three interviews spread throughout the internship, and one interview a year later. The participants were paired with a research mentor and were allowed to choose the project that wanted to pursue. During the apprenticeship, the participants developed a question and research plan, collected and analyzed data, attended seminars and workshops, and wrote and presented a report of their research. The NOS beliefs that were reflected through their interviews indicated that their NOS beliefs became more aligned throughout the research process.

Bleicher (1996) conducted a case study of one high school student working as an apprentice in a science laboratory as part of a larger study. The participant spent six weeks working in the laboratory collecting data, discussing results and theory, attending group meetings, keeping a journal, and preparing a presentation. This student demonstrated more aligned NOS beliefs at the conclusion of the six week course

Barab and Hay (2001) engaged 24 middle school students and six middle school science teachers in a two week science camp where they served as apprentices to practicing scientists working on a research project. The participants collected notes on research, participated in data collection and laboratory practices, and engaged in discussions with the scientist with whom they were matched. The participants were then provided time to reflect on their experiences, prepare a presentation, and present their experiences and findings to the group. Even though the research questions and procedures were set ahead of time, and the time spent conducting authentic scientific experiments was short, many of the participants demonstrated more aligned NOS beliefs.

Other studies have found that engagement in authentic research experiences whether they were part of implicit or explicit interventions have not demonstrated improvements in aligning NOS beliefs among the same populations.

Bell, Blair, Crawford, and Lederman (2003) studied the effect of an eight week science apprenticeship on the NOS beliefs of 10 high school students. The participants were placed with research mentors to participate in existing projects, or to conduct a spin-off project of their own, then to present the research results at a conference. While mentors were encouraged to engage participants in all aspects of research, most projects required participants to learn a large number of procedures and skills. In addition, the participants reported that lab safety, following prescribed procedures, and carrying out scientist designed experiments by engaging in mundane data collection were a significant part their experiences. The majority of participants did not experience a change in their NOS beliefs as a result of this apprenticeship. However, one of the participants that did demonstrate more aligned NOS beliefs appeared to have engaged in analyzing data, and group discussions of the results in which the participant was highly involved.

Buck (2003) engaged 50 high school teachers in a three week field based research experience as part of research class. Participants were placed in existing research projects based on interest however, the lead scientists established the research questions, data collection procedures, and guidelines for field work. Participants' work seemed to be limited to mostly data collection, although they also wrote a research paper, prepared a poster, and gave a presentation of their results. The author reports that, although no significant change in NOS beliefs were found at the .05 level, the results were significant at the .10 level. This may have been due to the NOS measure lacking power, or due to the very limited research activities afforded to the participants.

Although NOS beliefs were not explicitly studied in some of their ethnographic study of undergraduate research experiences, Hunter, Laursen, and Seymour (2007) interviewed seniors engaged in undergraduate research experiences (N = 76) and again after graduation (N = 55). They also interviewed a comparison group before (N = 62) and after (N =25) graduation. Only three percent of students mentioned an alignment of the "complex epistemological understanding of the open-ended nature of scientific knowledge" (p. 47). This result may have occurred because little alignment of NOS beliefs occurred in these students or, more likely, the NOS beliefs were not explicitly assessed. Open-ended questions are often answered by drawing on an inner context that is not explicitly mentioned (Ryder, et. al., 1999). Further complicating analysis was the reduction in the sample size. There was no mention that the groups at the time of the first interview were similar to the groups at the time of the last interview. In addition, the participants were engaged in predetermined activities which may not have featured high epistemic demand. “In most cases, student researchers were assigned to work on predetermined facets of faculty research projects” that were determined to be “appropriate to the student’s level” (Ryder, et. al., 1999, p.40).

These research experiences may not have been authentic, or at least not viewed as authentic by the participants, and consisted of little more than data collection and analysis. By having research questions already established and giving participants simple tasks to complete, the epistemic demands of the projects were not sufficient to generate NOS belief change. In other words, since the participants did not have to confront any NOS misconceptions that they held, little alignment in NOS beliefs occurred.

The type of research experiences an individual undertakes tends to influence the development of his or her NOS beliefs. Ryder and Leach (1999) found that students whose projects had an epistemological focus or were involved with theory building tended to demonstrate more aligned NOS beliefs after the conclusion of the project. Individuals whose projects dealt with testing experimental techniques or working with different materials while using existing techniques tended to show limited NOS belief change.

The present study looks at the effect of research experiences on graduate students’ NOS beliefs. Sadler, et. al. (2010) assert that “most individuals engaged in advanced level graduate work in the sciences learn through research apprenticeships" (p. 235). Although research has shown that research experiences can change NOS beliefs in certain contexts, little research has focused on the natural development of NOS beliefs in graduate students. In addition, none of the research has looked at how the amount of research affects the individual's NOS belief. Furthermore, no current research has investigated the effects of the types of research experiences conducted by graduate students on the individual's general NOS beliefs, nor on the specific NOS beliefs being examined in this study. Because certain types of research experiences may be more effective at aligning NOS in general, or in aligning specific NOS beliefs, it is important to study the correlations these experiences have on individuals' NOS beliefs.

The research cited above on general epistemological beliefs, NOS beliefs, and authentic research experiences leads to several hypotheses about the relationship between research experiences and NOS beliefs. It was hypothesized that those students that have the most research experiences, as defined by number of hours and number of types of experiences, will tend to have the most aligned beliefs. It is further hypothesized that those students who are involved with designing experiments and analyzing data with respect to theories will tend to have nature of science beliefs more aligned with those of practicing scientists. Because epistemological beliefs tend to vary between academic domains, the academic domain of the graduate student may be a confounding variable. The academic domain of the graduate students will be identified and analyzed in this study.

CHAPTER 3

METHODS

Participants

A total of 50 graduate students participated in this study. All students were employed as either a graduate student assistant (GSA), a graduate research assistant (GRA), or a graduate teaching assistant (GTA) at a large, urban, Midwestern University. Eight of the students were employed as graduate student assistants (GSA), 13 of the students were employed as graduate research assistants (GRA), while the remaining 25 were employed as graduate teaching assistants (GTA). There were 20 males and 30 females in this group. The participants' ages ranged from 21 years of age to 59 years of age with an mean age of 28.6. Thirty-seven of the students were in their twenties, seven in their thirties, while the remaining six were in their forties or fifties. Thirty-four of the graduate assistants were Caucasian, one African-American, one African, 11 Asian or Pacific Islander, two Native American, one Middle Eastern, three Hispanic, and three mixed ethnicity or other ethnicity. Thirty-eight of the participants' first language was English, while 12 of the participants' first language was not English.

Instruments

Nature of Science beliefs. Participants' NOS beliefs were measured using the Views on Science and Education Questionnaire (VOSE) (Chen 2006). This questionnaire is intended to measure the participants' NOS beliefs and their attitudes concerning the importance of teaching NOS beliefs in the seven areas that will be explored in this study: (a) the role of empirical and tentative knowledge, (b) the role of objectivity and subjectivity in science, (c) the role of creativity in science, (d) the nature of observations and inferences, (e) the nature of scientific laws and theories and their relationship to each other, (f) the nature of scientific methods, and (g) the role of sociocultural influences in science. The format of the questionnaire contains 13 main statements. In addition, a passage that describes a conflict between two scientists due to sociocultural factors is given followed by two statements concerning the role of sociocultural factors in science. For each statement there are a series of philosophical positions related to the main statement. The participants rank their level of agreement to each philosophical statement using a five point scale ranging from strongly agree to strongly disagree. This method allows individuals who have NOS beliefs across more than one philosophical position to be accurately measured (Chen, 2006).

1) The VOSE measures an individual's NOS belief about the role of empirical and tentative knowledge in science.

Main statement: When two different theories arise to explain the same phenomenon (e.g., fossils of dinosaurs), will scientists accept the two theories at the same time?

Sample Philosophical Position Statements:

A. Yes, because scientists still cannot objectively tell which one is better; therefore, they will accept both tentatively.

H. No, because there is only one truth, scientists will not accept any theory before distinguishing which is best.

2) The VOSE measures an individual's NOS belief about the role of objectivity and subjectivity in science.

Main statement: When two different theories arise to explain the same phenomenon (e.g., fossils of dinosaurs), will scientists accept the two theories at the same time?

Sample Philosophical Position Statements:

D. No, scientists tend to accept new theories which deviate less from the contemporary core scientific theory.

H. No, scientists use intuition to make judgments.

3) The VOSE measures an individual's NOS belief about the role of creativity in science.

Main statement: When scientists are conducting scientific research, will they use their imagination?

Sample Philosophical Position Statements:

A. Yes, imagination is the main source of innovation.

C. No, imagination is not consistent with the logical principles of science.

4) The VOSE measures an individual's NOS belief about the nature of observations and inferences in science.

Main statement: Scientists' observations are influenced by personal beliefs (e.g., personal experiences, presumptions); therefore, they may not make the same observations for the same experiment.

Sample Philosophical Position Statements:

A. Observations will be different, because different beliefs lead to different expectations influencing the observation.

C. Observations will be the same, because through scientific training scientists can abandon personal values to conduct objective observations.

5) The VOSE measures an individual's NOS belief about the nature of laws and theories in science and their relationship to each other.

In comparison to laws, theories have less evidence to support them.

Sample Philosophical Position Statements:

B. Yes, if a theory stands up to the tests it will eventually become a law therefore, a law has more supporting evidence.

D. No, theories and laws are different types of ideas. They cannot be compared.

6) The VOSE measures an individual's NOS belief about the nature of scientific methods and the existence of a single scientific method in scientific investigations.

Main statement: Most scientists follow the universal scientific method, step-by-step, to do their research (i.e, state a hypothesis, design an experiment, collect data, and draw conclusions).

Sample Philosophical Position Statements:

A. The scientific method ensures valid, clear, logical, and accurate results. Thus, most scientists follow the universal method in research.

D. There is no so-called scientific method. Scientists use any method to obtain results.

7) The VOSE measures an individual's NOS belief about the role of an individual's sociocultural context in science.

Main statement: Scientific investigations are influenced by socio-cultural values (e.g., current trends, values).

Sample Philosophical Position Statements:

A. Yes, socio-cultural values influence the direction and topics of scientific investigations.

D. No, because science requires objectivity, which is contrary to the subjective socio-cultural values.

The majority of the philosophical position statements are expressed such that the respondent expresses his or her beliefs of how science is conducted. However, some of the position statements were intended to measure the individual's belief about how science should ideally work.

Main Statement: From the position of the nature of science, what aspects of A and B's thinking do you agree with?

Sample Philosophical Position Statement:

A. Scientists should have a conscience when doing research

This instrument has been shown to be reliable (test–retest correlation coefficient of .82). Chen (2006) established the validity of the VOSE using multiple sources. First, items were constructed using theoretical literature, interviews, and responses given from other established measures. Second, a panel of science education experts who had published in the field of NOS and were "ranked associate professor or above" (Chen, 2006, p. 809) examined the items to establish content validity. Third, a pilot test was given to 120 college students to eliminate any items that did not establish variation or were answered "uncertain" by more than half of the respondents. Fourth, interviews were conducted with college students to ensure that the participants interpreted the questions as intended. Chen (2006) reported that "more than 90% of the subjects interpreted the items consistently with the researcher" (p. 816). The NOS dimensions assessed by each item and the Cronbach alpha for each dimension are presented in Table 1. A copy of the VOSE can be found in Appendix A.

Table 1
NOS Dimension and Item Number Assessed by VOSE

Dimension	Item[a]
Tentativeness	1A, 4A, 4B, 4C[b], 4D[b]
Empirical evidence	1H[b], 1F
Objectivity and subjectivity	1C, 1D, 1E, 1F, 1G
Use of creativity	3A, 3B, 3C[b], 3D[b], 3E[b]
Nature of observations	8A, 8C[b], 8D[b]
Epistemology of theories	5A[b], 5B[b], 5C, 5D, 5E, 5F
Epistemology of laws	6A[b], 6C, 6D, 6E
Comparison of laws and theories	7A[b], 7B[b], 7C, 7D
Scientific method	9A[b], 9B[b], 9C, 9D, 9E, 9F[b]
Sociocultural influence	2A, 2B, 2C[b], 2D[b]

[a] The number represents the main statement, while the letter represents the philosophical position.
[b] The corresponding items are reverse scored to calculate aligned NOS beliefs.
[c] These items investigate beliefs about how science ought to be conducted.

Research Experiences. Participants also completed a questionnaire to record their research experiences. The measure asked about the amount and type of research experiences each participant had. The first two questions asked the participants to estimate the number of research projects they had been associated with as a research assistant or researcher and the number of hours spent working on these projects. Participants were also asked if they had completed undergraduate research projects, completed, or were working on, a thesis or dissertation, or had conducted any independent research projects.

Participants read descriptions about different aspects of the research process and were given a list of possible tasks that are common to many research projects that range from very low epistemic demand (data entry) to high epistemic demand (designing a new questionnaire to measure a hard-to-measure trait). The participants indicated which activities that they had personally conducted and described the activities that they had been involved with.

The questionnaire was scored two different ways. First, a total score was given for the number of research experiences that the individual had engaged in. Second, these experiences were coded as either having low, medium, or high epistemic demand. In this study, tasks that have a high epistemic demand were defined as activities that require the individual to reflect on and confront his or her personal epistemological beliefs in order to proceed or make sense of the event. Tasks with medium epistemic demand were defined as activities that do not require, but may cause, the individual to reflect on or confront his or her personal epistemological beliefs in order to proceed or make sense of the event. Tasks with low epistemic demand were defined as activities that do not require, and likely will not cause, the individual to reflect on or confront his or her personal epistemological beliefs in order to proceed or make sense of the event. In this study, it was assumed that this epistemic demand may be processed either explicitly or implicitly by the individual.

Examples of tasks that possess high epistemic demand include describing a new theoretical model to explain data, or devising a new procedure to measure something that is difficult to measure. Examples of tasks that possess low epistemic demand include data entry, measurement using existing techniques, or summarizing the results of an experiment. Examples of tasks that possess medium epistemic demands include using existing techniques in a novel manner, participating in experimental design, or analyzing the results of an experiment against an existing theory. A copy of the research experience questionnaire can be found in Appendix B.

Reliability of the research experience measure was established through a pilot study of a group of graduate students to ensure readability and clarity of the questions. In addition, a test-retest correlation coefficient was calculated.

Concurrent validity of the research experience measure was established by conducting two procedures. First, the list of activities was analyzed by a panel of researchers for completeness, to detect any omissions, or correct imprecise wording. Second, a sample of the participants was interviewed to determine the extent to which the questionnaire results accurately reflect the research experiences of the participants.

Demographics. Participants also completed a demographics questionnaire that assessed their field of study, cultural background, age, educational experience, and science background. In addition, participants were asked to rate their level of agreement with three statements about their perception of themselves as a scientist, their research experience as being an authentic science experience, and their major as being a science major on a Likert scale ranging from strongly agree to strongly disagree. A copy of the demographics form can be found in Appendix C.

Procedures

Each participant was asked to electronically sign an informed consent form prior to beginning the study. A copy of the informed consent form can be found in Appendix D. Once the consent form was signed, all 50 participants were given a link to the instruments online. To counterbalance the order of the surveys the participants were randomly divided into two groups using their birth month. Participants born in January, March, May, July, September, or November completed the demographics form, followed by the research experience questionnaire, then the NOS questionnaire. Participants born in February, April, June, August, October, or December completed the demographics form, followed by the NOS questionnaire, then the research experience questionnaire.

Data Analysis

Several analyses were conducted in order to address the hypotheses posed in this study: (a) Graduate students with more hours of research experience will tend to have NOS beliefs more aligned with those of practicing scientists; (b) Graduate students with a larger variety of research experiences will tend to have NOS beliefs more aligned with those of practicing scientists; (c) The epistemic demand of the graduate students' research experiences will affect this relationship. Specifically, those students who are involved with designing experiments and analyzing data with respect to theories will tend to have NOS beliefs more aligned with those of practicing scientists.

First, descriptive statistics of the individuals' scores on the VOSE were analyzed for any trends, and to ensure that the sample is representative of a wide range of NOS beliefs. Second, two Pearson correlations were conducted to test the first two hypotheses. The individuals' scores on the VOSE were correlated with the number of research hours, and the number of research experiences. Follow-up MANOVA and step-wise regressions were conducted to determine the nature of the relationship. Third, zero-order correlations were run to determine the relationship between the nature of the research activities and specific NOS beliefs. A follow-up stepwise multiple regression was then conducted to determine if the epistemic demand of the participants' research experiences could predict their general and specific NOS beliefs.

CHAPTER 4

RESULTS

Three main questions were addressed in this study. First, does the amount of research experience relate to aligned NOS beliefs? Second, does the number of different types of research activities undertaken by the participants relate to their NOS beliefs? Third, does the nature of the participants' research experience, specifically the epistemic demand of their research activities, predict the alignment of their NOS beliefs? Three specific hypotheses were formed to address these questions: (a) Graduate students with more hours of research experience will tend to have NOS beliefs more aligned with those of practicing scientists and educational reform documents, (b) Graduate students with more types of research experiences will tend to have NOS beliefs more aligned with those of practicing scientists and educational reform documents, and (c) The nature of the graduate students' research experiences will affect this relationship. Specifically, those students who are involved with designing experiments and analyzing data with respect to theories will tend to have NOS beliefs more aligned with those of practicing scientists and educational reform documents.

Descriptive Statistics and Psychometric Properties

Descriptive statistics for all ratio and interval level variables were calculated and observed for any exceptionalities. The means, standard deviations, and skewness for all variables conformed to the assumption of normality with the exception of age (skew = 2.24), number of research projects (skew = 2.31,) and number of science classes taken at the graduate level (skew = 2.92). These variables all had a positive skewness, that is they contained a lower bound and a relatively few individuals with high values for these variables. This distribution should not affect the interpretation of the results that follow. Sample sizes, means, standard deviations, and skewness for all variables can be found in Tables 2, 4, and 5 in Appendix E.

Before any statistical tests were performed, a number of scores were calculated. NOS subscale scores were calculated by summing the score to the individual questions as prescribed by Chen (2006). An inter-item reliability analysis was then conducted and items were removed from each subscale to maximize reliability while maintaining sufficient validity. The final NOS subscore calculations are summarized in Table 3 in Appendix F. Inter-item reliability of the subscales on the VOSE ranged from moderate to strong ($\alpha = .63$ to $.86$) with the exception of the empirical subscale ($\alpha = .13$). This subscale consisted of two questions which lowered the reliability of the subscale. Since the use of this subscale led to no significant findings, the low inter-item reliability does not affect the analysis which follows.

Research activities were also coded based on the type of activity (e.g. question formulation, data analysis, etc.) and epistemic demand. The sum of each type of research activity was then calculated by adding the number of different activities that were engaged in by the participant. The epistemic demand of each activity was coded and summed to obtain the number of high epistemic demand activities, medium epistemic demand activities, and low epistemic demand activities that were engaged in by each participant. For the purposes of this paper, epistemic demand will be operationally defined as the demand an activity or event places on the individual to draw upon or confront his or her personally held epistemological beliefs. In other words, an event that has high epistemic demand will require the individual to reflect on the epistemological beliefs held by the individual a great deal in order to proceed or make sense of the event.

Hypothesis Testing

In order to address each hypothesis a variety of analyses were conducted. First, zero-order correlations were run to determine the relationship between number of hours of research experience, number of semesters of research experience, and number of different research projects and the participants' general and specific NOS beliefs. Second, zero-order correlations were run to determine the relationship between the number of different types of activities conducted during the participants' different research projects and the participants' general and specific NOS beliefs. Follow-up MANOVA and step-wise regressions were conducted to determine the nature of the relationship. Third, zero-order correlations were run to determine the relationship between the nature of the research activities and specific NOS beliefs. A follow-up stepwise multiple regression was then conducted to determine if the epistemic demand of the participants' research experiences could predict their general and specific NOS beliefs.

The first hypothesis investigated the relationship between the number of hours of research, the number of research projects worked on, and the number of semesters spent working on research projects with the participants' general and specific NOS beliefs. There were no significant correlations with the overall NOS score, but several significant correlations existed for NOS subscores. The number of research projects an individual engages in correlates positively with tentative NOS ($r = .37$, $p < .05$), and the nature of observations ($r = .35$, $p < .05$). The number of hours per week an individual spends engaged in research correlates positively with tentative NOS ($r = .29$, $p < .05$) and negatively with the nature of theories ($r = -.35$, $p < .05$). The number of semesters spent engaged in research projects correlates positively with tentative NOS ($r = .34$, $p < .05$), and the nature of observations ($r = .31$, $p < .05$).

The second hypothesis investigated the relationship between the number of different types of research activities and specific NOS beliefs. The number of different data collection activities correlates positively with the overall NOS score ($r = .29$, $p < .05$), and several significant correlations also exist for NOS subscores. The number of different question formulation activities an individual engages in correlates positively with tentative NOS ($r = .29$, $p < .05$). The number of different question hypothesis formulation activities an individual engages in correlates positively with the nature of observations ($r = .29$, $p < .05$). The number of different data analysis activities an individual engages in correlates positively with tentative NOS ($r = .32$, $p < .05$), and the nature of observations ($r = .36$, $p < .05$). The number of different data collection activities an individual engages in correlates positively with tentative NOS ($r = .36$, $p < .05$), and the nature of observations ($r = .30$, $p < .05$). The number of different activities an individual engages in with respect to reporting findings correlates negatively with nature of theories ($r = -.29$, $p < .05$). The number of different overall research activities an individual engages in correlates positively with tentative NOS ($r = .31$, $p < .05$), and the nature of observations ($r = .29$, $p < .05$).

Since zero-order correlations imply a relationship between variables, but do not allow for an in depth analysis of the relationships of the first two hypotheses, two additional analyses were conducted. To test the hypothesis that a participants' first language affects his or her NOS beliefs, a four way MANOVA (English X belief in self as scientist X belief in job as science X belief in major as science) was conducted using NOS beliefs as the dependent variables. Wilks's lambda multivariate statistic was not significant for any of the main effects: English ($F(10, 28) = 1.31$, n.s.), belief in self as a scientist ($F(10, 28) = 1.42$, n.s.), belief in job as science ($F(10, 28) = 1.31$, n.s.), or belief in major as science ($F(10, 28) = .50$, n.s.). Wilks's lambda multivariate statistic was significant for the interaction between English and the belief in self as scientist ($F(10, 28) = 2.90$, $p < .05$). Univariate analyses indicated a significant interaction in overall NOS ($F(1, 49) = 10.99$, $p < .01$).

Post-Hoc t-tests indicate that: (a) individuals whose first language was not English, and who see themselves as scientists, have less aligned overall NOS beliefs than individuals whose first language was not English, and who do not see themselves as scientists ($t(10) = -3.05$, $p < .05$); (b) individuals whose first language was not English, and who see themselves as scientists, have less aligned overall NOS beliefs than individuals whose first language was English, and who see themselves as scientists ($t(10) = 3.47$, $p < .01$); (c) there were no differences between individuals whose first language was not English, and who did not see themselves as scientists and individuals whose first language was English, and who do not see themselves as scientists ($t(10) = -.37$, ns). Descriptive statistics for the means and standard deviations for each group can be found in Table 7 in Appendix J.

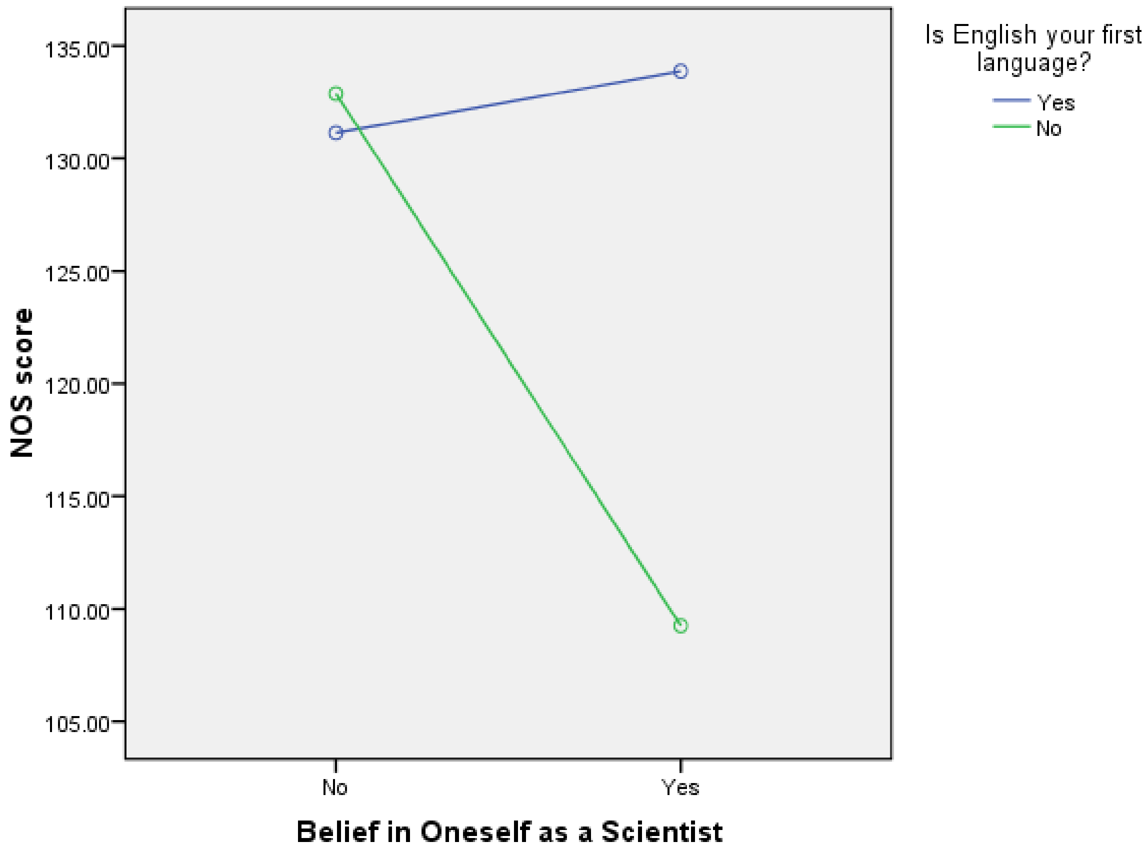

Figure 1: Interaction of First Language and Belief in Oneself as a Scientist on NOS score

In addition, to determine whether the number of science classes taken predicted beliefs about theories, three step-wise regressions were conducted. In a stepwise regression, predictor variables compete for entry with the variable accounting for the most variance entering first. In the next step the variable accounting for the second most variance enters, and so forth. The first regression used the belief that scientific theories are discovered as the criterion variable and number of high school science classes, number of undergraduate science classes, and number of graduate level science classes as the predictor variables. Only the number of high school science classes predicted the belief that scientific theories are discovered ($F(1, 48) = 7.52$, $p < .01$, $R^2 = .14$). The second regression used the belief that scientific theories are invented as the criterion variable and number of high school science classes, number of undergraduate science classes, and number of graduate level science classes as the predictor variables. None of the variables predicted the belief that scientific theories are invented. The third regression used the belief that scientific theories are both discovered and invented as the criterion variable and number of high school science classes, number of undergraduate science classes, and number of graduate level science classes as the predictor variables. Only the number of undergraduate science classes predicted the belief that scientific theories are both discovered and invented ($F(1, 48) = 7.79$, $p < .01$, $R^2 = .14$).

The third hypothesis investigated the role that the nature of the research activities plays in the development of NOS beliefs. Pearson zero-order correlations indicate that the number of low epistemic demand activities do not correlate with any NOS beliefs. The number of medium epistemic demand activities correlates positively with Tentative NOS ($r = .28$, $p < .05$) and Nature of observations ($r = .28$, $p < .05$). The number of high epistemic demand activities positively correlates with Tentative NOS ($r = .41$, $p < .01$), Nature of observations ($r = .41$, $p < .01$), Sociocultural influences ($r = .34$, $p < .05$), and overall NOS score ($r = .28$, $p < .05$).

Since the relationship seemed to be increasing in strength, a stepwise multiple regression was conducted with NOS score as the criterion variable and number of high epistemic demand activities, number of medium epistemic demand activities, number of low epistemic demand activities, belief in self as a scientist, belief in job as doing science, belief in major as science, age, total number of different research activities, number of research projects, hours per week, and semesters spent doing research as the predictor variables. The number of research experiences that possess high epistemic demand ($F(1,46) = 5.55$, $p < .05$, $R^2 = .11$, b-weight = 1.10), and the perception of the individual that his or her research was authentic science ($F(1,46) = 4.92$, $p < .05$, $R^2 = .09$, b-weight = 3.74) were both significant predictors of overall NOS score.

Two variables predicted Tentative NOS beliefs. The greater the number of research experiences that possess high epistemic demand ($F(1,46) = 11.68$, $p < .01$, $R^2 = .20$, b-weight = .42), and the greater the perception of the individual that his or her research was authentic science ($F(1,46) = 4.96$, $p < .05$, $R^2 = .08$, b-weight = .94), the more aligned their tentative NOS beliefs.

One variable predicted nature of observation beliefs. The greater the number of research experiences that possess high epistemic demand ($F(1,46) = 11.63$, $p < .01$, $R^2 = .20$, b-weight = .25), the more aligned his or her beliefs about the nature of science.

Two variables predicted beliefs about the nature of theories. The greater the perception of the individual that his or her personal research experiences were authentic science, the more aligned his or her beliefs about the nature of theories ($F(1,46) = 11.02$, $p < .01$, $R^2 = .19$, b-weight = 1.20). Conversely, The more hours of research per week an individual worked ($F(1,46) = 5.68$, $p < .05$, $R^2 = .09$, b-weight = -.10), the less aligned his or her beliefs about the nature of theories. A one-way ANOVA found that the interaction between English as a first language and the belief in self as a scientist was significant for the nature of theories ($F(3,46) = 3.32$, $p < .05$), and beliefs about the sociocultural influences on the scientific process ($F(3, 46) = 2.74$, $p < .05$). Follow-up t-tests indicated that those whose first language was English and who saw themselves as scientists had more aligned beliefs about the nature of theories than those whose first language was not English and who saw themselves as a scientist ($t(25) = 2.39$, $p < .05$).

One variable predicted nature of scientific laws. The greater the perception of the individuals that their major was a science major ($F(1,46) = 5.20$, $p < .05$, $R^2 = .10$, b-weight = .77), the more aligned their beliefs about the nature of scientific laws.

Two variables predicted beliefs about sociocultural influences on the scientific process. The greater the number of research experiences that possess high epistemic demand ($F(1,46) = 6.96$, $p < .01$, $R^2 = .13$, b-weight = .80), the more aligned their beliefs about the sociocultural influences on the scientific process. Conversely, the greater the number of research experiences that possess medium epistemic demand ($F(1,46) = 7.44$, $p < .01$, $R^2 = .12$, b-weight = -.30), the less aligned their beliefs about the sociocultural influences on the scientific process. A follow-up independent samples t-test found that those whose first language was English were more aligned in their beliefs about the sociocultural influences on the scientific process than those whose first language was not English ($t(48) = 2.88$, $p < .01$).

CHAPTER 5

DISCUSSION

Summary of the Study

This study was designed to examine the effect of authentic research experiences on the NOS beliefs of graduate students. Belief formation and change are complex phenomena which are affected by many factors, both implicit and explicit. Ryder, Leach, & Driver (1999) assert that all students have been exposed to a wide range of explicit and implicit beliefs about the nature of science throughout their lifetimes. Many of these beliefs that individuals are exposed to are views that are not aligned with those of practicing scientists and educational reform documents (Akerson & Hanuscin, 2007; Akerson, et al., 2006; Karakas 2009; Lederman 1999; Schwartz, Lederman, & Crawford, 2004; Smith & Scharmann, 2008; Tairab, 2001).

Several psychometric factors have been found to influence an individual's NOS beliefs. Akerson and Buzzelli (2007) assessed pre-service elementary teachers on their NOS beliefs, cognitive development levels, and cultural values. They found that all of the pre-service teachers in their study held unaligned NOS views, but that they expressed their views in ways that were aligned with their view of the world.

Abd-El-Khalick and Akerson (2004) found that three factors mediate the change in NOS beliefs: processing orientation, perceived usefulness, and global worldview. First, the processing orientation of the participant affects the extent to which NOS beliefs are accepted. Those individuals with deep processing orientations will display more appropriate NOS beliefs. This suggests that cognition plays a role in belief formation.

Second, the individual's perception of the importance and usefulness of acquiring aligned NOS beliefs will determine his or her motivation for learning appropriate NOS beliefs. NOS beliefs will be more firmly developed if an individual believes that holding the appropriate beliefs are important and useful.

Third, the global worldview that an individual possesses will affect the amount to which the individual incorporates appropriate NOS beliefs. Ab-El-Khalick and Akerson (2004) found that those who held a dualistic worldview and perceived a conflict between science and their beliefs tended to evaluate NOS ideas from an absolute perspective. For example, since a theory cannot be "proven" to be true, it is not credible. Therefore all alternative explanations must be equal.

In addition to these factors, the formation of the individuals' initial beliefs may determine the extent to which a belief can be amended. Those individuals that form their initial NOS beliefs with an affective component, or based on an affective response, may be more resistant to a change in their beliefs as compared to those who formed their initial NOS beliefs based on more cognitive components (Brunning, Schraw, Norby, & Ronning, 2004).

Authentic research experiences provide an effective method to change existing NOS beliefs as long as they engage the student in a variety of research experiences, have a high epistemic demand, provide socialization into the culture of science, and engage the participant in theory construction and testing rather than simple data collection. These types of research experiences give the students a concrete framework in which to hold the theoretical ideas and beliefs that make up aligned NOS beliefs (Blanchard, Southerland, and Granger, 2009).

Three hypotheses were tested in this study to try to describe the factors that influence the development of NOS beliefs in graduate students. First, it was hypothesized that graduate students with more hours of research experience will tend to have NOS beliefs more aligned with those of practicing scientists and educational reform documents. Second, it was hypothesized that graduate students with more types of research experiences will tend to have NOS beliefs more aligned with those of practicing scientists and educational reform documents. Finally, it was hypothesized that those graduate students whose research experiences were characterized by high levels of epistemic demand will tend to have NOS beliefs more aligned with those of practicing scientists and educational reform documents.

Zero-order correlations were run for each hypothesis. A follow up MANOVA and step-wise multiple regression were then conducted to explore the factors that mediate the relationship between amount of research and NOS beliefs. A follow up step-wise multiple regression was conducted to determine the effect that the epistemic demand of an individual's research activities has on his or her NOS beliefs.

Findings and Their Implications

The first hypothesis that graduate students with more hours of research experience will tend to have NOS beliefs more aligned with those of practicing scientists and educational reform documents was partially supported by the results of this study. The number of different research projects and the number of semesters of having research experiences, positively correlated to aligned NOS beliefs in two dimensions, tentative NOS and the nature of observations. In other words, graduate students who worked on more research projects or spent more semesters engaged in research also tended to believe that scientific knowledge is tentative and is subject to change either through new discoveries or new ways of thinking. These students also tended to believe that observations can differ between scientists based on the scientist's personal beliefs.

The number of hours an individual was engaged in research activities per week positively correlated to aligned NOS beliefs in one dimension, tentative NOS, but was negatively correlated in another dimension, the nature of theories. Graduate students who spent more hours per week engaged in research activities tended to believe that scientific knowledge is tentative and is subject to change either through new discoveries or new ways of thinking. These students also tended to believe that theories are discovered through direct observation rather than invented through inferences.

The second hypothesis that graduate students with more types of research experiences will tend to have NOS beliefs more aligned with those of practicing scientists and educational reform documents was also partially supported. The number of different research activities positively correlates with aligned NOS beliefs in two dimensions, tentative NOS and the nature of observations. In other words, graduate students who engaged in more research activities tended to believe that scientific knowledge is tentative and is subject to change either through new discoveries or new ways of thinking. These students also tended to believe that observations can differ between scientists based on the scientists' personal beliefs.

Exploring the relationship between the types of research activities and NOS beliefs, further significant positive correlations were found between aligned tentative NOS and number of question formulation activities, number of data collection activities, and number of data analysis activities. In addition, significant positive correlations were found between aligned nature of observation beliefs and number of hypothesis formulation activities, number of data collection activities, and number of data analysis activities. However, a moderate negative correlation was found between aligned nature of theories belief and number of reporting findings activities.

In order to explore the nature of the relationship between research activities and NOS beliefs, three possible confounding variables were explored. A follow-up MANOVA indicated that neither first language, nor belief in oneself as a scientist, was related to the individual's overall NOS belief. However, an interaction between these two variables produced a significant finding. Those individuals whose first language was not English and who saw themselves as scientists had less aligned NOS beliefs than individuals whose first language was English and who saw themselves as scientists and individuals whose first language was not English and who did not see themselves as scientists. This suggests that there may be implicit communication of inappropriate NOS beliefs in the laboratory setting when the first language of the primary investigator and their assistants differs. Another possibility is that the assistants' culture had given them beliefs that are different than those being advocated for by American educational reform documents.

The other possible confounding variable explored was the number of science classes completed. Three step-wise multivariate regressions were conducted to determine the predictors of an individual's nature of theories beliefs. The number of high school classes predicted a belief that theories were discovered through direct observations. The number of undergraduate science classes predicted the belief that sometimes theories are discovered and sometimes invented. Both of these observations tend to fit with the observations that secondary science instructors tend to have unaligned nature of science views (Akerson & Hanuscin, 2007; Akerson, Morrison, & McDuffie, 2006; Karakas, 2009; Lederman 1999; Schwartz, 2004, Smith & Scharmann, 2008; Tairab, 2001).

Bencze and Bowen, (2009) found that pre-service teachers generally intended to teach their students in the manner in which they had been taught. However, since NOS is not covered in many science courses, and those who do teach about the nature of science may not hold adequate NOS beliefs, these pre-service teachers cannot be expected to teach about NOS effectively. This is especially true if they have inadequate NOS beliefs themselves.

This suggests that students receive implicit messages about the NOS beliefs that scientists tend to hold in their science classes through activities, textbooks, and lectures that influence their perceptions about the nature of science. These messages may lead to more unaligned NOS beliefs in some areas, especially considering that NOS beliefs are generally not taught in science classes as the instructors were more concerned with covering the content, developing problem solving skills, developing an organizational plan for their courses, and dealing with classroom management (Karakas, 2009; Lederman, 1995).

The third hypothesis, that the nature of the graduate students' research experiences will affect this relationship, also was supported by the results of this study. The correlations between number of research activities and NOS beliefs tended to demonstrate more alignment in NOS beliefs as the level of epistemic demand of the activity increased. This suggests that the nature of an individual's research activities will influence his or her NOS beliefs.

The number of high epistemic demand activities predicted aligned overall NOS beliefs, tentative NOS beliefs, nature of observation beliefs, and sociocultural influence beliefs. The belief that an individual's job involved doing science predicted aligned overall NOS beliefs, tentative NOS beliefs, and nature of theory beliefs. The belief that an individual's major is a scientific field predicted aligned nature of scientific laws beliefs. On the other hand, the number of hours spent working on research activities per week predicted unaligned nature of theory beliefs, while the number of medium epistemic demand activities predicted unaligned sociocultural influence beliefs.

An individual's NOS science beliefs are influenced by both implicit and explicit messages about the values and assumptions held by scientists, the effect that those values and beliefs have on the construction of scientific theories and knowledge, and the epistemology of scientific knowledge (Ryder & Leach, 1999). The findings of this study support the hypothesis that authentic research experiences are related to aligned nature of science beliefs. However, the nature of those experiences determine the strength of that relationship.

Limitations of the Study

There are limitations to this study. The sample consisted entirely of graduate students employed at the University as an assistant. The results may not be generalizable to the population as a whole. A graduate student's worldview, processing orientation, and belief about the importance of holding aligned NOS beliefs may differ significantly from that of individuals not in graduate school or than those not employed by the University.

Another limitation is the small sample size. The study would benefit from a sample size of greater than 50 participants. In addition, if it were possible to ensure a representative sample of all majors and research areas, the result would be more generalizable. For example, the extent to which the questionnaires accurately measure beliefs is not certain. There is concern that questionnaires with fixed responses do not accurately reflect the beliefs held by the participants (Lederman, Ab-El-Khalick, Bell, & Schwartz, 2002). However open-ended questions are often answered by drawing on an inner context that is not explicitly mentioned (Ryder, et. al., 1999).

Finally, the nature of this research was descriptive and quantitative. More insight into the causal relationship between the variables would be gained from an experimental method. A naturalistic methodology would also be helpful to explore and more accurately code the epistemic demand of the research activities.

Future Research

The importance of all individuals holding adequate beliefs about the Nature of Science is greater today than in years past. As the pace of scientific discovery quickens, the need for the people driving policy decisions to hold adequate NOS beliefs becomes increasingly more important. This is especially true for the future educators that will construct the implicit and explicit messages about appropriate NOS beliefs. Future research is needed to address the complex and diverse area of NOS belief formation.

Descriptive research is needed to further refine the relationship between amount and type of research and NOS beliefs. In addition, research should explore how specific authentic research experiences affect the NOS beliefs of pre-service teachers, and their teaching practices. The extent to which a teacher's NOS beliefs directly affect his or her classroom behavior is unclear. Bencze, et al., (2006) found that the teachers' tendency to use student focused, open-ended instructional methods corresponded to their NOS beliefs. Bhattacharyya, Volk, & Lumpe (2009) also found that elementary teachers' beliefs influenced their effectiveness in implementing inquiry. In contrast, Lederman (1999) found that changing teachers' NOS beliefs did not result in a difference of teaching method. This could be that a preference for instructional method is not connected to NOS beliefs, that instructional change took place over a longer time frame than the studies allowed for, or that there are a number of mitigating factors which determine instructional practices. In addition, beliefs are found to be a more reliable predictor of behavior in well-structured contexts (Liu, 2010).

Changing the beliefs of pre-service teachers through explicit instruction and using reflection is one of the methods put forth for aligning science teachers' beliefs (Ab-El-Khalik, 2005; Ab-El-Khalik & Akerson 2004; Lederman, 2004). However, these newly formed beliefs become challenged when these individuals begin teaching through various sources (Tillema, 2000). As such, future research should investigate whether research experience facilitates or hinders the individuals' ability to maintain their aligned beliefs in the face of these challenges.

Another area for future research would be to explore the effect that the nature of an individual's major or research domain has on his or her NOS beliefs. Biglan (1973) characterized different academic areas across three dimensions and the nature of these dimensions could affect both the explicit and implicit messages communicated about science and the research process.

REFERENCES

REFERENCES

Abd-El-Khalick, F. (2005). Developing deeper understandings of nature of science: The impact of a philosophy of science course on preservice science teachers' views and instructional planning. *International Journal of Science Education*, *27*(1), 15-42. doi: 10.1080/0950060410001673810

Abd-El-Khalick, F., & Akerson, V. L. (2004). Learning as conceptual change: Factors mediating the development of preservice elementary teachers' views of nature of science. *Science Education*, *88*(5). 785-810. doi: 10.1002/sce.10143

Abd-El-Khalick, F., & Akerson, V. L. (2009). The influence of metacognitive training on preservice elementary teachers’ conceptions of nature of science. *International Journal of Science Education*, *16*(1), 2161-2184. doi: 10.1080/09500690802563324

Abd- El- Khalick F., Bell R. L., & Lederman N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education*, *82*, 417–437.

Akerson, V. L., & Buzzelli, C. A. (2007). Relationships of preservice early childhood teachers’ cultural values, ethical and cognitive developmental levels, and views of nature of science. *Journal of Elementary Science Education*, *19*(1), 15-24.

Akerson, V. L., Cullen, T. A., & Hanson, D. L. (2009). Fostering a community of practice through a professional development program to improve elementary teachers’ views of nature of science and teaching practice. *Journal of Research in Science Teaching*, *46*(10), 1090-1113. doi: 10.1002/tea.20303

Akerson, V. L., Morrison, J. A., & McDuffie, A. R. (2006). One course is not enough: Preservice elementary teachers' retention of improved views of nature of science. *Journal of Research in Science Teaching*, *43*(2), 194-213. doi: 10.1002/tea.20099

Akerson, V. L., & Hanuscin, D. L. (2007). Teaching nature of science through inquiry: Results of a 3-year professional development program. *Journal of Research in Science Teaching*, *44*(5), 653-680. doi: 10.1002/tea.20159

American Association for the Advancement of Science (1993). Benchmarks for science literacy. New York: Oxford University Press.

Barab, S. A., & Hay, K. E. (2001). Doing science at the elbow of experts: Issues related to the science apprenticeship camp. *Journal of Research in Science Teaching*, *38*(1), 70-102.

Bell, R. L., Blair, L. M., Crawford, B. A., & Lederman, N. G. (2003). Just do it? Impact of a science apprenticeship program on high school students’ understandings of the nature of science and scientific inquiry. *Journal of Research in Science Teaching*, *40*(5), 487-509. doi: 10.1002/tea.1086

Bencze, L. J., Bowen, M. G., & Alsop, S. (2006). Teachers' tendencies to promote student-led science projects: Associations with their views about science. *Science Education*, *90*(3), 400-419. doi: 10.1002/sce.20124

Bencze, L. J., & Bowen, M. G. (2009). Student-teachers' dialectically developed motivation for promoting student-led science projects. *International Journal of Science and Mathematics Education*, *7*(1), 133-159.

Bhattacharyya, S., Volk, T., & Lumpe, A. (2009). The influence of an extensive inquiry-based field experience on pre-service elementary student teachers' science teaching beliefs. *Journal of Science Teacher Education*, *20*(3), 199-218. doi: 10.1007/s10972-009-9129-8

Biglan, A. (1973). The characteristics of subject matter in different academic areas. *Journal of Applied Psychology*, *57*(3), 195-203.

Blanchard, M. R., Southerland, S. A., & Granger, E. M. (2009). No silver bullet for inquiry: Making sense of teacher change following an inquiry-based research experience for teachers. *Science Education*, *93*(2), 322-360. doi: 10.1002/sce.20298

Bleicher, R. E. (1996). High school students learning science in university research laboratories. *Journal of Research in Science Teaching*, *33*(10), 1115-1133.

Brunning,R. H., Schraw, G. J., Norby, M. M., & Ronning, R. R. (2004). *Cognitive Psychology and Instruction* (4th ed.) Upper Saddle River, New Jersey: Pearson Prentice Hall.

Buck, P. E. (2003). Authentic research experiences for nevada high school teachers and students. *Journal of Geoscience Education*, *51*(1), 48-53.

Buffer, A., Lubben, F., & Ibrahim, B. (2009). The relationship between students' views of the nature of science and their views of the nature of scientific measurement. *International Journal of Science Education*, *31*(9), 1137-1156. doi: 10.1080/09500690802189807

Chang, Y. H, Chang, C. Y., & Tseng, Y. H. (2010). Trends in science education research: An automatic content analysis. *Journal of Science Education and Technology*, *19*(4), 315-331. doi: 10.1007/s10956-009-9202-2

Charney, J., Hmelo-Silver, C. E., Sofer, W., Neigeborn, L., Coletta, S., & Nemeroff, M. (2007). Cognitive apprenticeship in science through immersion in laboratory practices. *International Journal of Science Education*, *29*(2), 195-213. doi: 10.1080/09500690600560985

Chen, S. (2006). Development of an instrument to assess views on nature of science and attitudes toward teaching science. *Science Education*, *90*(5), 803-819. doi: 10.1002/sce.20147

Craven, J. A., Hand, B., & Prain, V. (2002). Assessing explicit and tacit conceptions of the nature of science among preservice elementary teachers. *International Journal of Science Education*, *24*(8), 785-802.

Fazio, X. (2009). Development of a community of science teachers: Participation in a collaborative action research project. *School Science and Mathematics*, *109*(2), 95-107.

Furtak, E. M., & Alonzo, A. C. (2009). The role of content in inquiry-based elementary science lessons: An analysis of teacher beliefs and enactment. *Research in Science Education*, *40*(3), 425-449. doi: 10.1007/s11165-009-9128-y

Gallagher, J. J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. *Science Education*, *75*(1), 121-133

Hanuscin, D. L., Akerson, V. L., & Phillipson-Mower, T. (2006). Integrating nature of science instruction into a physical science content course for preservice elementary teachers: NOS views of teaching assistants. *Science Education*, *90*(5), 912-935. doi: 10.1002/sce.20149

Hunter, A., Laursen, S. L., & Seymour, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education*, *91*(1), 36-74. doi: 10.1002/sce.20173

Kalman, C. (2009). The need to emphasize epistemology in teaching and research. *Science & Education*, *18*(3-4), 1-23. doi: 10.1007/s11191-007-9135-1

Kang, S., Scharmann, L. C., & Noh, T. (2004). Reexamining the role of cognitive conflict in science concept learning. *Research in Science Education*, *34*(1), 71-96.

Karakas, M. (2009). Cases of science professors' use of nature of science. *Journal of Science Education and Technology*, *18*(2), 101-119. doi: 10.1007/s10956-008-9136-0

Karakas, M. (2011). Science instructors' views of science and nature of science. *The Qualitative Report*, *16*(4), 1124-1159.

King, B. A., & Magun-Jackson, S. (2011, July). Differences in engineering students' beliefs about knowledge across educational levels. Paper presented at ASQ Advancing the STEM agenda in education, the workplace, and society, University of Wisconsin-Stout.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, 29(4), 331-359.

Lederman, N. G. (1995, January). Teachers' conceptions of the nature of science: Factors that mediate translation into classroom practice. Paper presented at the annual meeting of the Association for the Education of Teachers in Science, Charleston, West Virginia.

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching*, *36*(8), 916-29.

Lederman, N. G. (2004). Revising instruction to teach nature of science. *The Science Teacher*, *71*(9), 36-39.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. (2002). Views of nature of science questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*(6), 497-527.

Lederman, N. G., Wade, P. D., & Bell, R. L. (1998). Assessing the nature of science: What is the nature of our assessments? *Science and Education*, *7*(6), 595-615.

Liu, P. H. (2010). Are beliefs believable? An investigation of college students' epistemological beliefs and behavior in mathematics. *Journal of Mathematical Behavior*, *29*(2), 86-98. doi: 10.1016/j.mathb.2010.05.001

McComas, W. F., Clough, M. P., & Almazroa, H. (1998). The nature of science in science education: An introduction. *Science and Education*, *7*(6), 511-532.

McDonald, C. (2010). The influence of explicit nature of science and argumentation instruction on preservice primary teachers' views of nature of science. *Journal of Research in Science Teaching*, *47*(9), 1137-1164. doi: 10.1002/tea.20377

National Academy of Sciences, National Committee on Science Education Standards and Assessment, National Research Council (1996) *National Science Education Standards* (ISBN No. 0-309-05326-9). Retrieved from http://www.nap.edu/catalog/4962.html

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. Re*view of Educational Research, 62*(3), 307-332.

Paulsen, M. B., & Feldman, K. A. (2005). The conditional and interaction effects of epistemological beliefs on the self-regulated learning of college students. *Research in Higher Education*, *46*(7), 731-767. doi: 10.1007/s11162-004-6224-8

Posnanski, T. J. (2009). Developing understanding of the nature of science within a professional development program for inservice elementary teachers: Project nature of elementary science teaching. *Journal of Science Teacher Education*, *21*(5), 589-621. doi: 10.1007/s10972-009-9145-8

Quigley, C., Pongsanon, K., & Akerson, V. L. (2010). If we teach them, they can learn: Young students' views of nature of science aspects to early elementary students during an informal science education program. *Journal of Science Teacher Education*, *21*(7), 887-907. doi: 10.1007/s10972-009-9164-5

Richmond, G., & Kurth, L. A. (1999). Moving from outside to inside: High school students' use of apprenticeships as vehicles for entering the culture and practice of science. *Journal of Research in Science Teaching*, *36*(6), 677-697.

Roth, K. J., Druker, S. L., Garnier, H. E., Lemmens, M., Chen, C., Kawanaka, T. et. al. (2006). Teaching science in five countries: Results from the TIMSS 1999 video study (NCES 2006-011). U.S. Department of Education, National Center for Educational Statistics. Washington, DC: U.S. Government Printing Office.

Ryan, A. G., & Aikenhead, G. S. (1992). Students' preconceptions about the epistemology of science. *Science Education*, *76*(6), 559-580.

Ryder, J., & Leach, J. (1999). University science students' experiences of investigative project work and their images of science. *International Journal of Science Education*, *21*(9), 945-956.

Ryder, J., Leach, J., & Driver, R. (1999). Undergraduate science students' images of science. *Journal of Research in Science Teaching*, *36*(2), 201-219.

Sadler, T. D., Burgin, S., McKinney, L., & Ponjuan, L. (2010). Learning science through research apprenticeships: A critical review of the literature. *Journal of Research in Science Teaching*, *47*(3), 235-256. doi: 10.1002/tea.20326

Sadler, T. D., & McKinney, L. (2010). Scientific research for undergraduate students: A review of the literature. *Research and Teaching*, *39*(5), 43-49.

Schommer, M. (1990). The effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology*, *82*(3), 498-504.

Schommer-Aikins, M. (2004). Examining the epistemological belief system: Introducing the embedded systemic model and coordinated research approach. *Educational Psychologist*, *39*(1), 19-29.

Schommer-Aikins, M., Duell, O. K., & Hutter, R. (2005). Epistemological beliefs, mathematical problem solving, and academic performance of middle school students. Elementary School Journal, *105*(3), 289-304. doi: 0013-5984/2005/10503-0003

Schommer-Aikins, M., & Easter, M. (2008). Epistemological beliefs' contributions to study strategies of Asian Americans and European Americans. *Journal of Educational Psychology*, *100*(4), 920-929. doi: 10.1037/0022-0663.100.4.920

Schwartz, R., Lederman, N. G., & Crawford, B. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education*, *88*(4), 610-645.

Smith, M. U., & Scharmann, L. (2008). A multi-year program developing an explicit reflective pedagogy for teaching pre-service teachers the nature of science by ostention. *Science & Education*, *17*(2-3), 219-248. doi: 10.1007/s11191-006-9009-y

Spiliotopoulou-Papantoniou, V., & Agelopoulos, K. (2009). Enhancement of pre-service teachers' teaching interventions with the aid of historical examples. *Science & Education*, *18*(9), 1153-1175. doi: 10.1007/s11191-008-9176-0

Suppe, F. (1977). *The structure of scientific theories* (2nd ed.) Chicago: University of Illinois Press.

Tairab, H. H. (2001). How do Ppre-service and in-service science teachers view the nature of science and technology? *Research in Science and Technological Education*, *19*(2), 235-50.

Tillema, H. H. (2000). Belief change towards self-directed learning in student teachers: immersion in practice or reflection on action. *Teaching and Teacher Education*, *16*(5-6), 575-591.

Trautwein, U., & Ludtke, O. (2007). Epistemological beliefs, school achievement, and college major: A large-scale impact of certainty beliefs. *Contemporary Educational Psychology*, *32*(3), 348-366. doi: 10.1016/j.cedpsych.2005.11.003

Tsai, C. C. (1999). "Laboratory exercises help me memorize the scientific truths": A study of eighth graders' scientific epistemological views and learning in laboratory activities. *Science Education*, *83*(6), 656-674.

Tsai, C. C. (2007). Teachers' Scientific epistemological views: The coherence with instruction and students' views. *Science Education*, *91*(2), 222-243. doi: 10.1002/sce.20175

Tsai, C. C., & Liu, S. Y. (2005). Developing a multi-dimensional instrument for assessing students' epistemological views towards science. *International Journal of Science Education*, *27*(13), 1621-1638. doi: 10.1080/09500690500206432

Valeras, M., House, R., & Wenzel, S. (2005). Beginning teachers immersed into science: Scientist and science teacher identities. *Science Education*, *89*(3), 492-516. doi: 10.1002/sce.20047

Wong, S. L., Kwan, J., Hodson, D., & Yung, B. H. W. (2009). Turning crisis into opportunity: Nature of science and scientific inquiry as illustrated in the scientific research on severe acute respiratory syndrome. *Science & Education*, *18*(1), 95-118. doi: 10.1007/s11191-007-9123-5

Yager, R. E. (1997). Science education: A science? *Electronic Journal of Science Education*, {On-line serial}, *2*(1). Available: http://unr.edu/homepage/jcannon/ejse/ejsev2n1.html

APPENDICES

APPENDIX A

Views on Science and Education (VOSE) Questionnaire

Instructions to participants:
Each question of this questionnaire starts with a statement about the nature of science or science education. Most statements adopt a certain radical stance. You may strongly agree with it, strongly disagree with it, or have other thoughts about it. Each statement is followed by several responses. **Please read all of the responses first**, then circle your opinion on the right side (SD, D, U, A, SA) of each response according to your knowledge of scientific activities or scientists, or what ought to be taught in science courses. There is no right or wrong answer. Thank you.

SD= Strongly Disagree
D = Somewhat Disagree
U = Uncertain
A = Somewhat Agree
SA = Strongly Agree

1. When two different theories arise to explain the same phenomenon (e.g., fossils of dinosaurs), will scientists accept the two theories at the same time?	
A. Yes, because scientists still cannot objectively tell which one is better; therefore, they will accept both tentatively.	SD D U A SA
B. Yes, because the two theories may provide explanations from different perspectives, there is no right or wrong.	SD D U A SA
C. No, because scientists tend to accept the theory they are more familiar with.	SD D U A SA
D. No, because scientists tend to accept the simpler theories and avoid complex theories.	SD D U A SA
E. No, the academic status of each theory proposer will influence scientists’ acceptance of the theory.	SD D U A SA
F. No, scientists tend to accept new theories which deviate less from the contemporary core scientific theory.	SD D U A SA
G. No, scientists use intuition to make judgments.	SD D U A SA
H. No, because there is only one truth, scientists will not accept any theory before distinguishing which is best.	SD D U A SA

2. Scientific investigations are influenced by socio-cultural values (e.g., current trends, values).	
A. Yes, socio-cultural values influence the direction and topics of scientific investigations.	SD D U A SA
B. Yes, because scientists participating in scientific investigations are influenced by socio-cultural values.	SD D U A SA
C. No, scientists with good training will remain value-free when carrying out research.	SD D U A SA
D. No, because science requires objectivity, which is contrary to the subjective socio-cultural values.	SD D U A SA

3. When scientists are conducting scientific research, will they use their imagination?	
A. Yes, imagination is the main source of innovation.	SD D U A SA
B. Yes, scientists use their imagination more or less in scientific research.	SD D U A SA
C. No, imagination is not consistent with the logical principles of science.	SD D U A SA
D. No, imagination may become a means for a scientist to prove his point at all costs.	SD D U A SA
E. No, imagination lacks reliability.	SD D U A SA

4. If scientific investigations are carried out correctly, could the scientific knowledge gained through the investigations change in the future?	
A. Yes, Scientific knowledge is always tentative and can change when there is a new discovery.	SD D U A SA
B. Yes, Scientific knowledge is always tentative and can change when scientists look at the data from a different perspective.	SD D U A SA
C. No, Scientific knowledge has been proven through experimentation, and is constant	SD D U A SA
D. No, If scientific knowledge changes, then it was not really true or known in the first place.	SD D U A SA

5. Is scientific theory (e.g., natural selection, atomic theory) "discovered" or "invented" by scientists from the natural world?	
A. Discovered, because the idea was there all the time to be uncovered.	SD D U A SA
B. Discovered, because it is based on experimental **facts**.	SD D U A SA
C. Some scientists discover a theory accidentally, but other scientists may invent a theory from their known facts.	SD D U A SA
D. Invented, because a theory is an interpretation of experimental **facts**, and experimental facts are discovered by scientists.	SD D U A SA
E. Invented, because a theory is created or worked out by scientists.	SD D U A SA
F. Invented, because a theory can be disproved.	SD D U A SA

6. Is scientific law (e.g., gravitational law) "discovered" or "invented" by scientists from the natural world?	
A. Discovered, because scientific laws are out there in nature, and scientists just have to find them.	SD D U A SA
B. Discovered, because scientific laws are based on **experimental facts**.	SD D U A SA
C. Some scientists discover a law accidentally, but other scientists may invent a law from their known facts.	SD D U A SA
D. Invented, because scientists invent scientific laws to interpret discovered experimental facts.	SD D U A SA
E. Invented, since there are no absolutes in nature, therefore, the law is invented by scientists.	SD D U A SA

7. In comparison to laws, theories have less evidence to support them.	
A. Yes, theories are not as definite as laws.	SD D U A SA
B. Yes, if a theory stands up to many tests it will eventually become a law, therefore, a law has more supporting evidence.	SD D U A SA
C. Not quite, some theories have more supporting evidence than some laws.	SD D U A SA
D. No, theories and laws are different types of ideas. They cannot be compared.	SD D U A SA

8. Scientists' observations are influenced by personal beliefs (e.g., personal experiences, presumptions); therefore, they may not make the same observations for the same experiment.	
A. Observations will be different, because different beliefs lead to different expectations influencing the observation.	SD D U A SA
B. Observations will be the same, because the scientists trained in the same field hold similar ideas.	SD D U A SA
C. Observations will be the same, because through scientific training scientists can abandon personal values to conduct objective observations.	SD D U A SA
D. Observations will be the same, because observations are exactly what we see and nothing more. Facts are facts. Interpretations may be different from one person to another, but observations should be the same.	SD D U A SA
E. Observations will be the same. Although subjectivity cannot be completely avoided in observation, scientists use different methods to verify the results and improve objectivity.	SD D U A SA

9. Most scientists follow the universal scientific method, step-by-step, to do their research (i.e., state a hypothesis, design an experiment, collect data, and draw conclusions).	
A. The scientific method ensures valid, clear, logical and accurate results. Thus, most scientists follow the universal method in research.	SD D U A SA
B. Most scientists use the scientific method because it is a logical procedure.	SD D U A SA
C. The scientific method is useful in most instances, but it does not ensure results; therefore, scientists invent new methods.	SD D U A SA
D. There is no so-called the scientific method. Scientists use any methods to obtain results.	SD D U A SA
E. There is no fixed scientific method; scientific knowledge could be accidentally discovered.	SD D U A SA
F. No matter how the results are obtained, scientists use the scientific method to verify it.	SD D U A SA

10. Students should learn the procedure of the scientific method.	
A. Yes, so the students have guidelines to work within.	SD D U A SA
B. Yes, because the students are still incapable of coming up with more appropriate methods.	SD D U A SA
C. Yes, they should learn what scientists do.	SD D U A SA
D. Yes, because the scientific method is the best method that scientists have developed so far.	SD D U A SA
E. Yes, it helps the students to learn an objective way of studying science.	SD D U A SA
F. Yes, it could help the students to understand the essence of science.	SD D U A SA
G. No, we should not only teach one scientific method. Students should be given space to think and develop their own methods.	SD D U A SA
H. No, there is no so-called the scientific method.	SD D U A SA
I. No, the teachers and the students should brainstorm different research methods together.	SD D U A SA

11. In science classes, when students are observing the same event, the teacher or professor should expect the students to come up with the same findings.	
A. Yes, the teacher should advise students to carry out objective observations to get identical findings.	SD D U A SA
B. Yes, if the students are careful enough, they should arrive at the same findings.	SD D U A SA
C. Yes, experimental facts will not differ with the person, thus no matter who makes the observation, the result will always be the same.	SD D U A SA
D. No, the observation will be affected by the students' preconceptions.	SD D U A SA
E. No, the teacher should discuss with the students how observation can be affected by preconceptions.	SD D U A SA

12. Students should understand that scientific knowledge may change.	
A. Yes, so they realize the real nature of science.	SD D U A SA
B. Yes, so they realize the reason why science advances.	SD D U A SA
C. No, it will decrease the students' interest in learning science.	SD D U A SA
D. No, it will decrease the students' acceptance of science.	SD D U A SA
E. No, the students only need to learn about the constant fundamentals of scientific knowledge.	SD D U A SA

13. The science courses in school should investigate the definitions of and the relationships between hypothesis, theory, and law.	
A. Yes, because they represent the structure of scientific knowledge.	SD D U A SA
B. Yes, because they are the fundamentals of scientific inquiry.	SD D U A SA
C. No, knowing the definition of and relationships between these terms does not help much in learning scientific knowledge.	SD D U A SA
D. No, because hypothesis, theory, and law lack definite meaning.	SD D U A SA

Please read carefully the following story about two scientists before answering the last two questions.
****

It is the year 2016. "A" and "B" are professors at a biotechnology center, and they are researching the selection and transfer of organic genes. If their project succeeds, humans will be free from congenital limitations. In addition to the total prevention of hereditary diseases, people will be free to choose and transfer eugenic genes. The human world will never again have congenital hereditary deficiencies. The research is already into the last step, but the general public opposes it, and even the institution itself has the intention of cutting back the budget.

In fact "A" is already starting to question the continuation of the research. "A" is a devoted Christian, believing that God will open doors for everyone. Thus, even if people are born with various diseases and deficiencies, the diversity and unpredictability of humankind are what has created history. "A" doesn't believe that scientific development should change the core essence of a human being. Therefore, when socio-cultural values and beliefs of science are in conflict, choice should be made based on socio-cultural values because the ultimate values of science rely upon the "person" him/herself.

However, "B" doesn't think this way. "B" believes that the nature of science is absolutely objective, and that socio-cultural values are just like the public preference, always changing with the social environment, and are a very subjective representation of values. In other words, research that is rejected by today's socio-cultural values could become an aspiration of tomorrow. Therefore, it is unworthy and foolish to abandon the constant objective nature of science just for a fleeting subjective value.

"B" and "A" start to argue over this matter. Finally, "A" chooses to withdraw from the research, but "B" chooses to continue developing it. Since giving up the well-developed research techniques would be very regrettable, "A" changes research interest to genetic selection and transfer of plants, in an attempt to choose a topic accepted by the dominant socio-cultural values. "A" eventually successfully transfers the anticancer genes from Taxus mairei to rye, creating anticancer rye.

Looking back, "A" does not regret withdrawing from the project and believes that although the nature of science could be objective, the manifestation of the values should eventually return to the fundamental essence of human beings. "B", persisting in continuing the original project, has received success on animal live-forms research, continuing on to do research on humans. "B" does not regret the choice either and even works harder on the project because of the belief that this story does not end here. The entire nature and value of the investigation will unfold in the future. It is left for history, rather than the contemporary socio-cultural values, to judge.

14. From the perspective of science education, what can college students learn from these two scientists?	
A. Scientist “A”—scientists should have a conscience when doing research.	SD D U A SA
B. Scientist “A”—consider both scientific research and social values simultaneously.	SD D U A SA
C. Scientist “A”—scientific research cannot be totally divorced from socio-cultural values.	SD D U A SA
D. Scientist “A”—respect the diversity of people.	SD D U A SA
E. Scientist “B”—scientific research should be completely detached from personal beliefs.	SD D U A SA
F. Scientist “B”—scientific research should be completely detached from social subjective values.	SD D U A SA
G. Neither of them provides a good example to learn from because science courses should not involve value-choices.	SD D U A SA

15. From the perspective of the nature of science, what aspects of A and B’s thinking do you agree with?	
A. Scientist “A”—scientists should have a conscience when doing research.	SD D U A SA
B. Scientist “A”—consider both scientific research and social values simultaneously.	SD D U A SA
C. Scientist “A”—scientific research cannot be completely divorced from socio-cultural values.	SD D U A SA
D. Scientist “A”—respect diversity in human beings.	SD D U A SA
E. Scientist “B”—scientific research should be completely detached from personal belief.	SD D U A SA
F. Scientist “B”—scientific research should be completely detached from subjective values.	SD D U A SA
G. Scientist “B”—persisting with the highest value of science—pursuing the truth.	SD D U A SA
H. Both, since they both have scientific spirit though they are influenced by personal values.	SD D U A SA

I. Neither, neither are objective enough since they are influenced by their personal beliefs and values. SD D U A SA

APPENDIX B

Research Experience Questionnaire

Please think back over your past and present research experiences. Think of all the duties and tasks that you have been given, and what your role was in these experiences.

How many different research projects have you been a part of?

How many hours per week do you work on research projects?

How many semesters have you worked on research projects (include undergraduate work)?

1) During your research experiences, you may have been involved in the development or choosing of a research question. For example, you may have done one or more of the following.

a) discuss how to formulate a research question
b) develop your own research question
c) adapt an existing research topic using different materials or subjects
d) adapt an existing research topic under new conditions
e) follow an existing research question
f) participate in discussions to define a research question
g) brainstorm ideas for a research topic in a group
h) Give feedback to a others about an existing research question
i) Adjust a research question in response to feedback.

Were you involved with the development or choosing of a research question? Yes No

Describe the tasks that you have done with regards to developing a research topic or research question.

2) During your research experiences, you may have been involved in designing or developing a procedure for a research project or study. For example, you may have done one or more of the following.

a) Select the investigative methods that will be used in the project or study
b) participate in discussions to design the research procedures
c) follow a procedure determined by other researchers
d) adapt an existing procedure for use with different materials, subjects, or experimental conditions
e) Select the appropriate measuring device for the study.
f) design a new questionnaire, tool, measuring technique for the study
g) chose a questionnaire, tool, or measuring technique from an array of choices
h) Independently design the procedure for a study.
i) Design the procedure for a study with help or feedback from other researchers.
j) Considered ethical concerns while designing a procedure.
k) modified a procedure based on a pilot study or initial results.
l) brainstorm the type of data that you will collect in order to determine procedure
m) Adjust your procedures in response to receiving feedback

Were you involved with the designing or developing of a procedure for a research project or study? Yes No

Describe the tasks that you have done with regards to designing or developing of a procedure for a research project or study.

3) During your research experiences, you may have been involved in forming, developing, or justifying a hypothesis for a research project or study. For example, you may have done one or more of the following.

a) develop your own formal hypothesis for a study
b) participate in discussions where a working hypothesis is developed
c) develop an operational definition of a term or concept used in the study
d) participate in discussions where an operational definition is developed
e) work with an existing operational definition
f) Construct an argument to defend your hypothesis

Were you involved with the forming, developing, or justifying a hypothesis for a research project or study? Yes No

Describe the tasks that you have done with regards to forming, developing, or justifying a hypothesis for a research project or study.

4) During your research experiences, you may have been involved in conducting background research or preforming a literature review for a research project or study. For example, you may have done one or more of the following.

a) Locating journal articles or other primary sources that have been requested
b) Conduct a journal search for relevant articles
c) Analyze sources for applicability
d) identify gaps and inconsistencies in existing evidence
e) identify various perspectives relating to the topic
f) identify opinions and bias in articles
g) determine when sufficient background research has been conducted
h) Synthesize the results of previous research
i) Participate in discussions about the historical background of the project
j) Writing a research proposal
k) Writing a literature review

Were you involved with conducting background research or preforming a literature review for a research project or study? Yes No

Describe the tasks that you have done with regards to conducting background research or preforming a literature review for a research project or study.

5) During your research experiences, you may have been involved in collecting data, performing lab or field experiments, or conducting interviews for a research project or study. For example, you may have done one or more of the following.

a) collect data using proper lab or field techniques
b) transcribe interviews with subjects
c) manipulate the conditions of an experiment to maximize yield
d) interacting and having discussions with scientists in the research setting
e) interacting and having discussions with other students in the research setting
f) Had data and results checked by a second researcher
g) Worked with other researchers on a project
h) Reflect on the appropriateness of the procedure while collecting data

Were you involved with conducting collecting data or running an experiment or study for a research project or study? Yes No

Describe the tasks that you have done with regards to collecting data or running an experiment or study for a research project or study.

6) During your research experiences, you may have been involved with looking at the data, performing statistical or other analysis, or interpreting the results for a research project or study. For example, you may have done one or more of the following.

Analyzing Results

a) perform a statistical analysis to determine significance
b) interpret the results with respect to existing theories
c) develop a new theory to explain the results of the study
d) analyze the results of the study by comparing them to the working hypothesis
e) analyze the results of the study by comparing them to existing theories
f) discuss the results with others to determine the meaning
g) Reflect on how the data is used to make knowledge claims
h) Use the results to compare different models of the phenomenon
i) Reflect on how the data is used to justify knowledge claims
j) discuss limitations of the study
k) Propose alternative explanations

Were you involved with looking at the data, performing statistical or other analysis, or interpreting the results for a research project or study? Yes No

Describe the tasks that you have done with regards to looking at the data, performing statistical or other analysis, or interpreting the results for a research project or study.

7) During your research experiences, you may have been involved with reporting the results of a research project or study. For example, you may have done one or more of the following.

a) Write the results section of an academic paper
b) Present the results at an academic conference
c) Present the results to an advisor or supervisor
d) Compose an academic paper as the primary author.
e) Compose a section of an academic paper as a secondary author.
f) Participate in discussions concerning the content of an academic paper.

Were you involved with reporting the results of a research project or study? Yes No

Describe the tasks that you have done with regards to reporting the results of a research project or study.

Have you completed a thesis or dissertation?

Have you begun working on a thesis or dissertation?

Have you completed an independent research project for a class either alone or as part of a group? If so please describe.

APPENDIX C

Demographics Questionnaire

1. What is your gender? M F

2. What is your birth date? Month_____ Day ______ Year_______

3. What is your ethnicity?

a. African American
b. Asian American
c. Caucasian (White)
d. Hispanic
e. Native American
f. Middle Eastern
g. Mixed _____________
h. Other _____________

4. Is English your first language? ___________________________

5. What is your highest level of education?

a. Less than high school
b. High School
c. Technical School
d. Some College
e. Bachelor's Degree
f. Some graduate work
g. Master's Degree
h. Doctoral Degree

6. What academic program are you enrolled in here at WSU (i.e. engineering, math, education)? ____________________________

7. In what country (or countries) were you raised? ________________

8. How many science classes have you completed in high school? __________________

9. How many science classes have you completed at the undergraduate college level?______________

10. How many science classes have you completed at the graduate college level?______________

11. Are you employed as a GSA, GRA, or GTA? ___________

12. What is the name of the professor (or professors) that you work with as a GSA, GRA, or GTA? _________

Please rate your level of agreement to questions 13-15 using the following scale.
SA = Strongly Agree A = Agree N = neutral D = Disagree SD = Strongly Disagree

13. I consider myself to be a scientist. SA A N D SD

14. My job as a GSA, GRA, or GTA involves doing science. SA A N D SD

15. My major is a science major. SA A N D SD

Please add any comments if you wish:

APPENDIX D

Informed Consent

You are invited to participate in a study on nature of science beliefs and research experiences. Since we are educational psychologists, we conduct research that helps us discover all the different ways people learn. You were randomly selected as a possible participant in this study, since our goal is to survey graduate students that are employed as graduate assistants.

If you decide to participate, you will be asked to complete three short surveys that will take approximately 45 minutes total. These surveys inquire about your beliefs about how science knowledge is generated and used. They also inquire about your experiences in science investigations. Your responses will remain anonymous and confidential. This information will help us understand how students think, feel, and function in scientific situations. The more we can understand the world from a student's perspective, the better we can prepare new teachers to be better instructors in the classroom.

No risks are anticipated in this study. We will be careful to separate any personal identifying information (e.g., name) from the data once we have linked the surveys together. That is, <u>all information will remain completely confidential and anonymous.</u>

Participation in this study is entirely voluntary. Your decision whether or not to participate will not affect your future relations with Wichita State University. If you decide to participate, you may withdraw from the study at any time without affecting your status as a student.

If you have any questions about this research, please ask us. If you have additional questions during the study, we will be glad to answer them. You can contact us, Marlene Schommer-Aikins or Jason Morphew at Wichita State University, Wichita, KS (978-3326). If you have questions pertaining to your rights as a research subject, or about research - related injury, you can contact the Office of Research Administration at Wichita State University, Wichita, KS 67260 - 0007, telephone (316) 978-3285.

You will be offered a copy of this consent form to keep. You are making a decision whether or not to participate. Your signature indicates that you have read the information provided above and have voluntarily decided to participate.

______________________________________ ____________________
Signature of Research Participant Date

Marlene Schommer-Aikins, PhD__ ____________________
Signature of Investigator Date

Jason Morphew, BS ____________ _____________________
Signature of Investigator Date

APPENDIX E

Table 2: Descriptive Statistics and Psychometric Properties

	N	Min	Max	M	SD	Skew
Belief in self as a scientist	50	1	5	2.60	1.21	.54
Belief in job as science	50	1	5	2.74	1.07	.34
Belief in major as a scientific field.	50	1	5	2.02	.94	.89
Number of research projects	48	0	20	4.19	4.87	2.31
Hours per week	48	0	35	9.19	9.91	1.05
Semesters of research	48	0	16	4.75	4.02	.77
Age	50	21.00	59.00	28.60	7.77	2.24
Number of High School science classes	50	0	10	4.38	1.86	.88
Number of undergrad science classes	50	0	30	7.48	8.58	1.68
Number of graduate level science classes	50	0	20	1.96	4.20	2.92
Number of high epistemic demand activities	50	0	13	4.92	4.53	.45
Number of medium epistemic demand activities	50	0	27	12.98	9.35	-.04
Number of low epistemic demand activities	50	0	24	11.10	7.71	.01

APPENDIX F

Table 3: NOS Dimension, Reliability, and Item Number Assessed by VOSE

Dimension	α	Item[a]
Tentativeness	.79	1A, 4A, 4B, 4C[b], 4D[b]
Empirical evidence	.13	1H[b], 1F
Objectivity and subjectivity	.69	1C, 1D, 1E, 1F, 1G
Use of creativity	.86	3A, 3B, 3C[b], 3D[b], 3E[b]
Nature of observations	.68	8A, 8C[b], 8D[b]
Epistemology of theories	.65	5A[b], 5B[b], 5C, 5D, 5E, 5F
Epistemology of laws	.65	6A[b], 6C, 6D, 6E
Comparison of laws and theories	.74	7A[b], 7B[b], 7C, 7D
Scientific method	.63	9A[b], 9B[b], 9C, 9D, 9E, 9F[b]
Sociocultural influence	.82	2A, 2B, 2C[b], 2D[b]

[a] The number represents the main statement, while the letter represents the philosophical position

[b] The corresponding items are reverse scored to calculate aligned NOS beliefs

APPENDIX G

Table 4: Descriptive Statistics and Psychometric Properties for overall NOS and NOS subscales

	N	Min	Max	M	SD	Skew
Creativity	50	6.00	25.00	16.70	4.31	-.37
Tentative	50	8.00	25.00	19.40	3.24	-.77
Empirical	50	2.00	10.00	6.50	1.79	-.65
Objectivity	50	5.00	19.00	11.96	3.26	-.41
Observations	50	5.00	15.00	9.62	2.46	.16
Theories	50	10.00	24.00	17.54	3.29	-.22
Laws	50	5.00	19.00	10.52	2.57	.33
Compare_TandL	50	4.00	18.00	10.42	2.46	.14
SicMeth	50	8.00	22.00	14.82	3.29	-.19
Sociocultural	50	4.00	20.00	13.44	3.12	-.63
NOS_Score	50	91.00	160.00	130.92	13.43	-.57

APPENDIX H

Table 5: Descriptive Statistics for number of different types of research activities

	N	Min	Max	M	SD	Skew
Number of question formulation activities	50	.00	9.00	3.78	3.02	.37
Number of hypothesis developing activities	50	.00	6.00	2.82	2.14	.31
Number of literature review activities	50	.00	11.00	5.70	4.39	-.08
Number of data collection activities	50	.00	8.00	3.70	2.73	.05
Number of data analysis activities	50	.00	11.00	5.00	3.85	.17
Number of reporting findings activities	50	.00	6.00	2.88	2.12	-.03
Total number of different types of research activities	50	.00	51.00	23.88	16.39	-.02

APPENDIX I

Table 6: Summary of Intercorrelation for NOS score and NOS subscores as a function of science classes taken and number of research projects

	Cre	Ten	Emp	Obj	Obs	The	Law	Comp	Sci	Soc
HS class	.08	.21	.03	.04	-.06	-.19	.03	.00	.13	-.25
Und class	.09	.14	-.13	-.05	-.10	-.04	.20	.12	.07	-.26
Grad class	.05	-.01	-.10	-.06	-.14	.02	.10	.19	.22	-.10
Num projects	.16	.37*	.10	-.13	.35*	-.19	.04	.03	-.15	.23
Hrs per wk	.22	.29*	-.01	-.19	.03	-.35*	-.06	.07	.16	-.12
Semesters	.19	.34*	-.01	-.17	.31*	-.27	-.00	.00	.06	.10

*p < .05

Note: Cre = belief about Creativity, Ten = Tentative, Emp = Empirical Nature, Obj = Objectivity, Obs = Nature of observations, The = Nature of Theories, Law = Nature of Laws, Comp = Relationship between theories and laws, Sci = Nature of scientific method, Soc = Sociocultural

APPENDIX J

Table 7: NOS beliefs by first language and belief in self as a scientist

	1	2	3	4
Belief	M (SD)	M (SD)	M (SD)	M (SD)
Nature of Theories	17.26 (2.71)	18.87 (3.34)	13.5 (4.04)	17.88 (3.13)
Sociocultural influence	14.13 (3.49)	14.07 (1.62)	10.75 (4.57)	11.63 (2.26)
Overall NOS	133.87 (11.93)	131.13 (11.95)	109.25 (19.67)	132.88 (7.94)

Note: Group 1 English first language, belief in self as scientist. Group 2 English first language, no belief in self as scientist. Group 3 English not first language, belief in self as scientist. Group 4 English not first language, no belief in self as scientist

APPENDIX K

Table 8: Summary of Intercorrelation for NOS score and NOS subscores as a function of number of different research activities in each area

	Cre	Ten	Emp	Obj	Obs	The	Law	Comp	Sci	Soc
Question Formation	.22	.29*	.21	-.05	.27	-.16	-.09	-.03	-.06	.18
Hypothesis Formation	.19	.27	.15	-.02	.29*	-.15	-.11	-.06	.07	.19
Literature Review	.26	.27	.11	.04	.19	-.19	-.12	.01	-.04	.22
Data Collection	.18	.32*	.27	-.01	.36*	-.02	-.08	.03	.05	.23
Analyzing Data	.20	.36*	.20	-.05	.30*	-.14	-.07	-.02	.00	.26
Reporting Findings	.02	.12	-.01	-.06	.18	-.29*	-.06	-.05	.06	.00
Total Research Activities	.21	.31*	.18	-.02	.29*	-.17	-.10	-.02	.01	.22

*$p < .05$

Note: Cre = belief about Creativity, Ten = Tentative, Emp = Empirical Nature, Obj = Objectivity, Obs = Nature of observations, The = Nature of Theories, Law = Nature of Laws, Comp = Relationship between theories and laws, Sci = Nature of scientific method, Soc = Sociocultural

APPENDIX L

Table 9: Summary of Intercorrelation for NOS score and NOS subscores as a function of number of research activities at high, medium, and low epistemic demand

	High ED	Medium ED	Low ED
Cre	.24	.20	.16
Ten	.41**	.28*	.24
Emp	.22	.15	.15
Obj	-.04	-.01	-.07
Obs	.41**	.28*	.22
Theo	-.10	-.19	-.22
Law	-.08	-.09	-.10
Comp	-.05	-.05	-.02
Sci	-.09	.02	-.01
Soc	.34*	.17	.14
Total NOS Score	.28*	.17	.11

*p < .05. **p < .01.
Note: Cre = belief about Creativity, Ten = Tentative, Emp = Empirical Nature, Obj = Objectivity, Obs = Nature of observations, The = Nature of Theories, Law = Nature of Laws, Comp = Relationship between theories and laws, Sci = Nature of scientific method, Soc = Sociocultural

APPENDIX M

Table 10: Predictors of overall NOS score and NOS subscores

Criterion Variable	Predictor Variable	R^2	b-weight	F change	sig
Total NOS score					
	Number of high epistemic demand activities	.11	1.10	5.55	.02
	Belief that job is "doing science"	.09	3.74	4.92	.03
Tentative					
	Number of high epistemic demand activities	.20	.42	11.68	.001
	Belief that job is "doing science"	.08	.94	4.96	.03
Observations					
	Number of high epistemic demand activities	.20	.25	11.63	.001
Theories					
	Belief that job is "doing science"	.19	1.20	11.02	.002
	Hours per week	.09	-.10	5.68	.02
Laws					
	Belief that major is a "scientific field"	.10	.77	5.20	.03
Sociocultural					
	Number of high epistemic demand activities	.13	.80	6.96	.01
	Number of medium epistemic demand activities	.12	-.30	7.44	.01

Notes: N = 50