SECONDARY SCIENCE TEACHERS' UNDERSTANDING OF THE NATURE OF SCIENCE AND ITS RELATIONSHIP TO EVOLUTION THEORY

A Dissertation Presented to the
Faculty of the College of Education
University of Houston

In Partial Fulfillment
of the Requirements for the Degree

Doctor of Philosophy in Curriculum and Instruction

by

Stephanie Toro

May 2018

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Abstract

Background: Nature of Science (NOS), a critical component to the understanding of scientific theories such as evolution, is often misunderstood by teachers due to a lack of instruction for future educators that explicitly addresses NOS of concepts. Science education researchers have not always reached a consensus regarding methods to ensure this high understanding of NOS. Some studies show that direct instruction and pedagogical training are more important than science content knowledge for the overall understanding of NOS. **Purpose:** The purpose of this study is to explore the relationship between secondary science teachers' understanding of NOS, and the understanding and acceptance of evolution. Additionally, this research will answer if there is a significant difference between teachers with an education degree, science degree, or completion of a NOS related course for the three subscales: understanding of NOS principles, understanding of evolution and acceptance of evolution. **Methods:** Using a previously adapted survey, the understanding of NOS, the understanding and acceptance of evolution, was assessed using Pearson's product moment correlation for a sample of 187 secondary science teachers across the United States. Additionally, one way MANOVA tests explored the different scores on the three subscales between teachers with different educational backgrounds. **Results:** The three subscales had a moderate statistically significant correlation. The MANOVA analysis showed that teachers with both a science content and science education degree performed significantly better on the three subscales of the survey. **Conclusions:** Teacher preparation programs should focus on coursework that creates both content and pedagogy experts such as dual bachelor science and masters in teaching programs. This combination is more likely to have a greater

understanding of NOS and evolution, as well as a greater acceptance of evolution theory. A larger sample with more respondents participating in a NOS course is needed to determine the effect of explicit NOS instruction.

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Chapter I

Introduction

Science is an important aspect of humans' everyday lives. Yet many people in today's society are not aware what science actually is. Many fail to identify or define science and describe its characteristics, let alone its function and role in society. Science is knowledge that allows one to understand, explain, apply, and predict natural phenomenon observed in our surroundings (Chiappetta & Koballa, 2010). Unfortunately, the general public fails to understand science because the teachers fail to teach science in a meaningful way that focuses on science as an enterprise. Students learn many science concepts and facts, but they have no context to connect those ideas to value their importance or even apply these to scientific skills such as inquiry or problem solving. Many attribute this to a lack of understanding of the Nature of Science (NOS). NOS refers to the "epistemology and sociology of science, science as a way of knowing, and includes the values and beliefs inherent to scientific knowledge and its development," according to Lederman, Abd-El-Khalick, Bell, and Schwartz (2002). Rutledge (2005) describes it similarly as the the "assumptions, characteristics, and methods of scientific inquiry." Teachers serve as the link to students' understanding of science and its characteristics, as well as scientific view of evolution.

Much research has suggested that there is a link between the understanding of the NOS and the understanding and acceptance of evolution (Berkman & Plutzer, 2010; Lombrozo, Thanukos & Weisberg, 2008). These studies have found that higher understanding of NOS or perhaps taking more science content courses may lead to a better acceptance of evolution. Unfortunately, teachers enter the profession through a variety of career and educational paths and thus may not be well versed in either NOS concepts or evolutionary principles depending on their program's requirements.

Purpose of the Study

Several studies have suggested a link may exist between the understanding of NOS, the understanding of evolution, and the acceptance of evolution (Lombrozo, Thanukos, & Weisberg, 2008; Nelson, Nickels, & Beard, 2000; Rutledge & Warden, 2000; Trani, 2004). In the United States it is not that uncommon for life science or biology teachers to not accept evolution as a scientifically valid theory (Berkman & Plutzer, 2010). Many science education teacher preparation programs emphasize the importance of NOS. Teachers that have a strong background in NOS are more likely to develop and deliver effective evolution units than teachers without such a background. This research aims to explore what factors influence respondents' understandings of NOS, the understanding of evolution, and the acceptance of evolution. The variables specifically being analyzed in this research include the following: participation in a science education program, participation in a science degree program, completion of a NOS related courses such as history or philosophy of science.

Research Questions and Hypothesis

This research will survey a sample of secondary science teachers on their understanding of NOS principles, and both their attitude toward and understanding of evolution theory concepts. The survey will include demographic questions to determine whether respondents have an education degree, hold a science degree, completed a NOS related course, or are a biology teacher. The following research questions will be addressed for secondary science teachers:

1. Is there a relationship between the understanding of NOS principles, understanding of evolution theory and acceptance of evolution theory?
2. Is there a significant difference between teachers with an education degree, science degree, or completion of a NOS related course for the three subscales: understanding of NOS principles, understanding of evolution and acceptance of evolution?

Based on previous research, it is predicted that the science teachers with completion of science content related and science education degrees as well as the completion of a NOS related course should have a greater understanding of NOS and understanding and acceptance of evolution theory relative to teachers that do not have both a pedagogy and science content degree and the completion of a NOS related course.

Chapter II

Literature Review

This section of the paper will present and discuss the following:

1. United States students' science performance both internationally and nationally;
2. A brief summary describing the nature of science (NOS) and its importance in science education;
3. Research related to teachers' understanding of NOS; and
4. Evolution in the science classroom and its relationship to NOS.

The United States' Science Performance Both Internationally and Nationally

This section of the literature review will focus on the science performance of the United States as follows:

1. The United States' science performance compared to other nations;
2. The understanding of the nature of science in the United States; and
3. The comparison of the acceptance of evolution in the US with other nations.

The United States' science performance compared to other nations. In international studies that compare countries' performance in the science and math subjects, the United States continues to move further down in the rankings. An alternative interpretation may be that the United States is not moving down, but maintaining the status quo. Instead, other countries are willing to make the radical changes in their education reform necessary to move up in the rankings and exceed the current status of the United States (Chiappetta & Koballa, 2010). The *Trends in International Mathematics and Science Study* (TIMSS) by National Center for Education Statistics compares the performance of students in the fourth and eighth grade for math and science from the United States with students from other countries. The tests have been performed in 1995, 1999, 2003, 2007, and 2011 with over 60 countries and jurisdictions participating in the 2011 study. The results summarized in 1997 found that eighth grade students in the United States scored in the middle of 41 countries that participated in the study in 1995. In 1995 TIMSS also assessed the performance of high school seniors, in which the students of the United States scored toward the bottom 25 % (Chiappetta & Koballa, 2010). In 2007 the United States scored 11th of 35 countries with Singapore, China, and Japan among the top in the rankings.

The Organization for Economic Co-operation and Development (OECD) also recognized the need to compare the reading, math, and science abilities among 15-year-old students of different countries. For the 2006 Program for International Student Assessment (PISA) test, the United States scored directly in the middle of 57 countries that participated in the survey with an average score of 489 out of 1000 (OECD, 2007). Again, Japan and China were near the top, as well as other countries that did not participate in the TIMSS research such as Finland, Canada, Estonia, Liechtenstein, Switzerland, and Belgium; all scored higher than the United States in the 2006 PISA report. The PISA test, like the TIMMS, shows similar findings with even more countries. The United States should be concerned, since the scores also correlate with some of the main international economic competitors.

The understanding of nature of science in the United States. Nature of Science (NOS) is an aspect of science education that is poorly understood by the public and even educators. In today's culture the general public lacks scientific literacy and as a result has a poor understanding what constitutes science. According to the National Research

Board's survey of the American public as part of its *Science and Engineering Indicators* study in 1996, Americans may have a high interest in the areas of science, but fail to adequately understand what science is and how it operates (McComas, Clough & Almazroa, 1998). Of the 2000 adults surveyed only two percent had answers categorized as Level I, which is the highest level of science understanding. Those categorized as Level 1 have an understanding that science concerns the "development and testing of a scientific theory." Only 21 % were classified as Level II, respondents with a minimal understanding that experiments require control groups. Level III lack the understandings of the first two groups, but they do still believe that science is based on careful and precise measurements. The most dismal finding was that 64 % of the participants were classified in the lowest category, Level IV, who lacked any comprehension of the nature of science. Many scholars have linked the poor understanding of science, and thus a weak grasp of NOS, to both an actual comprehension of evolutionary concepts and a low acceptance of evolution.

The comparison of the acceptance of evolution in the US with other nations. The understanding and acceptance of evolution as a scientific concept in the United States is experiencing the same decline in international rankings as our performance on the PISA and TIMSS for general scientific understanding (McComas, Clough & Almazroa, 1998; Miller, Scott & Okamoto, 2006). The decrease in scientific literacy and understanding of the NOS is most likely a direct link to acceptance of socially controversial topics of evolution and climate change. This misconception of NOS and its purpose and function in society is manifested greatly during political debates for the inclusion of evolution in public school science curricula, or the claim that climate change is a hoax. Topics are made to appear as trivial and matters of opinion, when in actuality the scientific community is united on these controversial issues because of the overwhelming evidence. Perhaps another important consideration is that science makes no attempt to answer the great questions, such as the meaning of life, or to find an answer to all questions. Science does not provide moral judgment and is not based on beliefs like religion. Lack of scientific literacy in NOS leads to a misinformed public that debates creationism, intelligent design, and evolution, although they are separate domains of knowledge based on different and uncomparable principles (McComas, Clough & Almazroa, 1998).

In a 20-year study of 34 countries, which includes 32 European nations, Japan, and the United States, the United States ranked the lowest in the acceptance of evolution besides Turkey. In those 20 years, the United States acceptance rating decreased from 45 to 40 %. However, the percentage overtly rejecting evolution went down. This suggests more Americans were reporting an ambivalent response in their approval of evolution (Miller, Scott & Okamoto, 2006).

Nature of science summary and its importance in science education

This section of the literature review explores the nature of science and some of its key attributes, as well as the importance of nature of science in science education. The focus of this section includes the following:

1. A brief overview of the nature of science (NOS);
2. Misconceptions of scientific theory as colloquial theory;
3. The dual property of science as both durable and tentative;
4. The lack of a single universal scientific method;

5. The biased objective nature in science; and
6. The importance of NOS for science education.

A brief overview of NOS. NOS refers to the assumptions, characteristics and methods of scientific inquiry (Rutledge, 2005). Lederman (1992) describes NOS as the "epistemology and sociology of science, science as a way of knowing, of the values and beliefs inherent to scientific knowledge and its development." Understanding the nature of science is a key component of scientifically literate society according to the reform documents of the American Association for the Advancement of Science (AAAS) and the National Research Council (NRC) (Chiappetta & Koballa, 2010). The National Science Education Standards emphasize the necessity of learning science through inquiry-based investigation (National Research Council, 1985). Because science knowledge is obtained through inquiry based investigative means, it should be taught and learned as such. Learning with inquiry can vary on many levels, but regardless it involves active learning in which the students are answering scientific questions through observation and/or data analysis (Wheeler & Bell, 2012). It allows the students to use the skills of hypothesizing, investigating, observing, explaining and evaluating. By incorporating inquiry into teaching methods, students not only learn the concepts better, but also they learn the processes of science.

Those in science education reform believe there is a link between an understanding of NOS and their ability to separate scientific evidence from personal or religious beliefs (National Academy of Science, 1998; Osif, 1997; Rutledge & Warden, 2000). If students and adults have better understanding of the nature of science, many of the arguments against the theory of evolution may dissipate. Scientists who actually perform empirical research do have a united opinion on this controversial topic and support it with the best evidence available (National Academy of Sciences, 1998). Through a better understanding of what science actually is and how it operates people can then realize that theories such as evolution are not trivial. They do not attempt to answer the same questions as religious beliefs such as creationism or intelligent design. There are many facets to NOS, and only a few of the major and more relevant to the theory of evolution will be discussed here.

Within the science education community there is not always agreement upon what exactly constitutes NOS. Throughout the years of academic research relating to NOS the conceptions of NOS itself have been very tentative and dynamic, just like scientific knowledge itself. Similar to other research this study's use of "NOS" will replace that of the more grammatically appropriate "the NOS" to indicate that there is not one singular agreement of the conceptions of NOS. Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) feel the discourse on the specific definitions and aspects that are included in NOS education do not concern or influence the NOS instruction in the K-12 classroom. Regardless of the specifics being analyzed by higher academia there is agreement of general NOS topics that are relevant for the K-12 science classroom. These include the following: science is tentative yet durable; science is based on empirical evidence; science is theory laden and subjective due to social and cultural influences; scientific knowledge is based on both observations and inferences; science lacks one prescribed method; and the important non-hierarchical difference between scientific laws and theories as contributors to scientific knowledge (Lederman, Abd-El-Khalick, Bell, and Schwartz, 2002).

Misconceptions of scientific theory as colloquial theory. Often in the media one will hear a politician or television analyst characterize a scientific theory as being "just a theory" and therefore not correct. The characterization of scientific theories as "just a theory" can be attributed to the lack of comprehension of NOS. Theories are concise and coherent explanations of mechanisms for observed events in nature (Ben-ari, 2005; Espinoza, 2012). They are generalizations of repeated observations or experiments, which have power for both prediction and retrodiction and are thus supported by evidence. Because of the nature of theories, the more falsifiable a theory, the stronger the theory is in science (Ben-ari, 2005). According to Kuhn (1996), the potential to be wrong is what makes a theory valuable. For example, a vague theory based on astrology can never be tested or provide any evidence to suggest this theory is valid. No evidence can also be found that will suggest that this theory is false either and is therefore not falsifiable. Because there are no methods in which to prove this theory false, it is not based on scientific knowledge.

The dual property of science as both durable and tentative. Science is a body of knowledge that is always growing and changing with the addition of new ideas, observations, and experiments (AAAS, 1990; Ben-ari, 2005; McComas, 1998; National Academy of Science, 1998). Many students view science as absolute and determined, but it is far from that. It is tentative and open to change as the scientific community adds new information. Even though the accomplishments of a select few great scientists are often glorified, the wealth of knowledge has largely been a collaborative effort based on the work of previous thinkers. A salient example of this tentative nature is the progression of organism classification into today's six kingdoms from the initial two kingdoms established by Linnaeus in the 1600s. Throughout the centuries as technology improved and more information was observed for various organisms, more kingdoms were added to better classify life. The sixth kingdom is newly established within only the past decades. This demonstrates both the tentative nature of science and the necessity of collaboration over spans of time.

Although science is tentative, it is durable (AAAS, 1990). Another misconception of science is the colloquial use of the word *theory* does not mean the same as in the phrase, *a scientific theory*. Scientific theories are explanations that are durable and have been tested. Theories are durable in the context that until one case provides counter evidence, the theory is accepted as the best explanation in science. Colloquially, people think theories do not carry much weight and are just conjectures based on belief, lacking sound empirical evidence. A theory carries more power if it has the potential to be falsifiable, and has yet to have any evidence discrediting it. Often teachers themselves have not had the opportunities to practice science or have not had formal training in the nature of science. These teachers as a result propagate false concepts of scientific theories to students. This means many of the high school students enter the classroom with years of false or incomplete ideas about science and how it works.

The lack of a single universal scientific method. Perhaps one of the more atrocious misconceptions of science that still pervades American culture is the idea of "The Scientific Method." Textbooks are the most culpable. However, many teachers are also guilty of leading students astray (McComas, 1998). According to McComas (1998), often students' only hands-on experiences of science are through experimentation in such a manner that all other processes of science are omitted. Students follow a recipe of steps to observe some obvious outcome of an experiment and fail to make predictions and generalizations or to even indulge in creativity to design their own methods of solving a problem. Even though experiments are one avenue to gain scientific knowledge, they are not the only method in which science constructs its understandings.

Instead scientists are equipped with a skill set that allows them to use the appropriate tools as necessary. Scientists observe, infer, predict, measure, experiment, analyze and calculate in no prescribed order (McComas, 1998). Some science is inductive in nature such as the formation of theories based on observations of specific natural phenomenon (Ben-Ari, 2005). Other times it is deductive, and theories are used to predict the future or to reflect on historical events.

Careful examination of some of the greatest scientific findings reveals methods that are not the typical "scientific method" that ends with the performance of an experiment. As Watson (2005) reveals in a TED conference, he and his partner Crick set out to build models, only build models. Their methods involved much thought "experimentation" with intense reasoning and logic based on the concepts of organic chemistry known at the time. They did not actually create or design an experiment. Yet their model of DNA structure was powerful in the foundation of modern biology. The same is true of Darwin and Wallace's idea of evolution by natural selection (Ben-Ari, 2005; McComas, 1998; National Academy of Science, 1998). As McComas (1998) explains, "[Darwin] was aware that observation without speculation or prior understanding was both ineffective and impossible" (p. 64). Natural selection is not a theory from experimentation or even from successful prediction, but instead a historical approach of retrodiction, an attempt to explain the past.

Science strives to be objective, but human bias is unavoidable. Darwin's methods provide more than just an example of the lack of a single scientific method, but it also highlights that science is not as objective as society may think. According to Ben-Ari (2005), "observations are theory laden." Darwin correctly describes any observation of nature as always grounded in the observer's human bias with the influence of previous knowledge or awareness of current theories (McComas, 1998). Humans are limited, and thus impose a bias on their own conjectures and interpretations of their observations. Scientific knowledge is constructed with a bias of the person's prior understandings and experiences of the natural world (American Association for the Advancement of Science (AAAS), 1990). Not only does this subjective nature of science apply to observations, but also interpretations of data or experiments, which are influenced heavily by the scientists performing such interpretations. Even the questions being asked by scientists, which drive the direction of the research are influenced by culture and bias.

After describing science as subjective, it may seem contradictory to state that scientific knowledge relies on evidence that is consistent and repeatable and attempts to be objective. In order for concepts to be accepted in the scientific community, they must have sound empirical evidence and aim to be as objective as possible, despite the human bias of interpretation of observations. Scientists are naturally skeptical and require verification of all aspects of science: laws, principles, facts, and theories. A theory that does not have evidence or cannot be repeated, yielding the same outcome by others, will not be accepted as the best explanation. This is the sole purpose of a theory: to explain the mechanism by which some phenomenon occurs (AAAS, 1990, Ben-ari, 2005). Thus the scientific community, through verification, helps to diminish some of the subjectivity of science.

The importance of NOS for science education. In this country there is a growing epidemic of not understanding science and its processes, not just by politicians or everyday citizens, but by teachers as well. Often educators focus too much on the content and never bother to teach students what science is and is not, as well as how it works. The National Research Council (NRC) and American Association for the Advancement of Science (AAAS) have long had standards to help correct this erroneous behavior with the goal of creating a scientifically literate country. Decades of research has identified this problem, as well as methods to improve the average United States citizen's understanding of science. The national science standards reflect this research. The research and standards both emphasize the need to increase NOS instruction, inquiry based learning, and the discussion and study of socio-scientific issues (SSI). NOS is not so much conceptual, but more a state of mind. Teaching science from these perspectives will not only engage students in a better synthesis of scientific concepts, but also help improve their personal cognitive and moral development by teaching them skills used in character education to make scientifically informed decisions on current issues such as genetically modified food, climate change, the anti-vaccination movement or cloning and stem cell research (Espinosa, 2012; Khishfe, 2012).

Science education involves more than just teaching concepts, but it must also include the process and skills of science, which many educators and schools often overlook. Science education must integrate NOS instruction and extend skills that are not only useful in the science classroom or a future career, but also for personal development of the student. A curriculum enriched with explicit NOS instruction will also help develop skills considered useful for character education to allow students to live responsible and productive lives and to be able to make informed decisions on critical issues (Khishfe, 2012). According to Khishfe (2012), "making informed decisions would enable citizens to play a more active and effective role in society and would increase citizens' awareness of the dimension their personal choices and decisions play in delivering sustainable development" (p. 68).

NOS instruction is vital not only for students' understanding of science, but also their application to a socio-scientific issue (SSI) based curriculum. SSI instruction helps students learn to debate, discuss, and negotiate social dilemmas with conceptual ties to science. A student who is able to apply a scientific way of thinking based on NOS techniques to "individual and social purposes" is engaging in a SSI curriculum (Khishfe, 2012; Sadler, Chambers, & Zeidler 2004). Students must have a firm understanding of what science is and what science is not, in order to be able to successfully assume a stance and scientifically support their position (Chiappetta & Koballa, 2010). These skills are rooted in a NOS curriculum and SSIs provide an avenue for students to utilize their scientific thinking, reasoning, and other decision-making skills. SSIs may include topics such as climate change, stem cell research, genetically modified food, or more local issues such as dealing with a neighborhood sewage drainage concern for local waterways. All SSI issues are open-ended and debatable depending on the evidence constructed (Sadler & Zeidler, 2005). Students will learn how to express their point of view using reasoning and sound objective evidence, as well as to be open minded to new or other reasoning. Perhaps they will revise their own construction of the issue. Thus a

SSI-based curriculum rooted with NOS components prepares students for their role as a citizen in society as they interpret and communicate issues in a larger context.

Research on Teachers' NOS Knowledge

This section of the literature review will focus on NOS research as it relates to teachers' understandings and will include the following topics:

1. The current status of teachers' understanding of NOS; and
2. The research on variables that influence teachers' understanding of NOS
    a. The lack of importance of authentic science experience;
    b. The improvement of NOS understanding due to explicit instruction;
    c. The inclusion of history and philosophy of science courses;
    d. The influence of explicit instruction in professional development; and
    e. The necessity of long-term modeling and instruction.

The current status of teachers' understanding of NOS. Perhaps one of the more challenging aspects of studying the understanding of NOS is that so few people, including teachers and scientists, have adequate knowledge to assess whether NOS is even a contributing factor to the improvement in science curriculum and instruction (Lederman & Lederman, 2014). Researchers have intuitively assumed that in order for students to learn NOS and apply these concepts in their daily lives, their teachers must be competent in their own understanding of NOS and be able to explicitly apply and integrate these into their curriculum (Carey & Stauss, 1968). Carey and Stauss (1968) used the Wisconsin Inventory of Science Processes (WISP) to assess the conceptual knowledge of NOS of 17 prospective secondary science teachers at the University of Georgia and found that as a collective group this cohort did not have a strong understanding of NOS and that a course explicitly teaching NOS was necessary. A later study in 1970 by Carey and Stauss with experienced teachers also did not indicate that the teachers possessed a better framework of NOS principles than the preservice teachers. Since the 1960 study, many other studies have concluded that teachers have inadequate understanding of NOS concepts (Aguirre, Haggerty, & Linder, 1990; Bloom, 1989; Kimball, 1968; Koulaidis & Ogborn, 1989).

Much research has focused on the role of the teacher to impart NOS knowledge to their students. Yager and Wick (1966) studied eight experienced teachers using the same inquiry-based curriculum and found a significant difference between the students' understanding of NOS for different teachers. Even though the curriculum and the learning objectives were the same, differences results from the teaching style whether teachers used more direct instruction methods or engaged in more questioning and critical thinking of the students reflective of NOS integrated into teaching methods. Teachers must understand their content if they are expected to convey their subject matter. Thus it is important to address the factors that cause individual teachers to have a strong command of their perception of NOS. Unfortunately, this has been problematic to study, as few people, including teachers, have an adequate understanding of NOS (Lederman & Lederman, 2014).

The research on variables that influence teachers' understanding of NOS. Carey and Stauss (1968, 1970a) found that demographic variables such as grade-point average, math credits, specific courses, and years of teaching experience did not affect teachers' understanding of NOS. In another study of 35 prospective secondary science teachers and 221 prospective elementary science teachers by Carey and Stauss (1970b), WISP scores were examined in correlations with demographic variables such as high school science courses, college science courses, college grade-point average, and science grade-point average. They again found no relationship. Billeh and Hasan (1975) had similar findings that educational qualifications or teaching experience did not affect individual teacher's gains on their Nature of Science Test (NOST) after a four-week course in a science subject matter that included 12 lectures directly related to NOS.

The lack of importance of authentic science experience. Not only does teaching experience seem to not affect NOS understanding, but some research indicates that even scientists do not a possess a complete understanding of science. Kimball's (1968) studies compared scientists and science teachers on NOS understanding and found no significant difference. Schwartz, Lederman, and Crawford (2004) found that providing teachers scientific research opportunities did not necessarily increase their understanding of science either. Often it is assumed that practitioners of science not only have a strong understanding of science as an entity, but also are more capable of teaching than those employed as science teachers. Bell, Blair, Crawford and Lederman (2003) studied highly motivated and capable high school juniors and seniors that participated in an eight-week apprenticeship program with a mentor scientist. Despite the mentor scientists' belief that their mentees learned a significant amount regarding inquiry and NOS, the students failed to have any improvement relating to NOS concepts, based on their pre and post-test responses to the VNOS-C (Appendix G). The apprenticeship lacked explicit instruction of NOS and led to the false illusion of students' growth perceived by the mentor scientists.

The improvement of NOS understanding due to explicit instruction. Much research has indicated that authentic scientific experiences are not sufficient to instill an acceptable comprehension of NOS for either students in an apprenticeship program or teachers collaborating with scientists (Morrison, Raab, & Ingram, 2009). In order to increase knowledge of NOS, students and teachers must be exposed to explicit instruction of NOS either as an isolated concept or integrated into other scientific subject matter (Abd-El-Khalick, 2001; Khishfe & Abd-El_Khalick, 2002). Khishfe and Lederman (2007) found that regardless of whether the NOS instructional material was integrated or isolated, the gains were not significantly different. The key is the explicit instruction. In Billeh and Hasan's (1975) study, teachers undergoing explicit NOS instruction were separated into four groups based on content matter: chemistry, biology, physical science, and physics. The biology teachers were the only group that did not receive any lectures related to NOS and thus were the only group that did not have changes in their NOS score.

The inclusion of history and philosophy of science courses. Carey and Stauss (1968, 1970a, 1970b) concluded from their studies that teacher preparation method courses did increase scores on the WISP exam and suggested that history and philosophy of science courses be included in teacher preparation programs, a finding that many other education researchers have concluded. Kimball (1968) observed that philosophy majors scored higher on his Nature of Science Scale (NOSS) than practicing scientists or science teachers. When historical aspects were explicitly taught to science teachers, there were significant gains in the understanding of NOS between pre- and post-test scores as seen in the studies of Lavech (1969). He applied this design to 26 teachers with 11 in the experimental group receiving instruction that included a historical perspective and 15 in the control group that lacked such instruction. Not only were the improvements in the understand of NOS scores on the Test on Understanding Science (TOUS) significantly higher for the post-test from the pre-test, but this growth was not attributed to any confounding variables such as teaching experience, subjects taught, undergraduate majors, previous in-service participation or length of teaching experience in the same subject (Lavach, 1969).

Lin and Chen (2002) created a program for 63 prospective chemistry teachers, exposing only the experimental group to historical perspectives that included case studies, debates, and discussions. Teachers in the experimental group had significant increases in their scores, especially in the area of their knowledge of creativity in science, theory-bound nature of observations, and the purpose and value of scientific theories in relation to scientific laws. Abd-El-Khalick (2005) also observed that pre-service secondary science teachers enrolled in a philosophy of science course developed more intense understanding of NOS than their colleagues that only enrolled in science methods courses.

The influence of explicit instruction in professional development. There are several themes that all of these professional development experiences share in their abilities to improve the instruction of science teachers. First, professional development must be long term using a cohort. Teachers need opportunities to learn through constructivist approaches and then allowed ample time to attempt strategies in their classrooms, as well as reflect on those with mentors and peers. The programs that did not allow for these conversations between mentors and peers did not lead to long-term changes in the teachers' practices. It also seems that teachers need to have explicit instruction themselves for both content and pedagogical content, in order to effectively integrate student-centered NOS and inquiry based methods of instruction. These should be modeled for them as well.

The necessity of long-term modeling and instruction. In another professional development approach elementary school teachers participated in a summer workshop, which not only taught NOS content, but also modeled methods of teaching in the K-6th grades (Akerson, Cullen, & Hanson, 2009). Teachers were able to reflect on these practices and discuss how they implemented their understanding and strategies throughout the school year through workshops. The researchers videotaped teachers in the field to customize the workshops accordingly. Both the summer and school year workshop sessions were part of creating a community of practice (CoP), so that teachers could share their thoughts, ideas, and curriculum development. After reviewing video interview transcripts, lesson plans, student work, and scores on the Views of Nature of Science Questionnaire-Form VNOS-D2 (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002), the researchers selected three teachers for a case study analysis. Based on the case study the two teachers that finished with adequate understanding of NOS were able to effectively integrate NOS into their curriculum. The teacher that maintained misconceptions of NOS, even at the end of the study, failed to effectively convey and teach concepts to her students.

There were several key concepts of the CoP that led to the success of the teachers' understandings of NOS and their ability to include aspects into their instruction (Akerson, Cullen & Hanson, 2009). First, the CoP allowed teachers an opportunity to share ideas over a long period of time and develop a positive learning environment with colleagues. The intensive summer workshop provided an opportunity for the content to be taught, in addition to activities that could be used with students. The teachers then were able to reflect on both the content and the methods, as they taught during the school year. This provided the follow-up that many professional development programs fail to guarantee that the skills being reinforced were retained and used in their instructional practice.

In another study by Posnanski (2010) to increase the understanding and practice of elementary science teachers, research subjects participated in a two-year professional development program called Project NEST. All 22 teachers worked within K-8 schools. The institute involved a one-week summer session and 10 sessions of three hours each during the school year. At the end of the summer program, teachers wrote Action Research Plans describing how they would integrate NOS based on their understandings from the summer sessions into their curriculum during the school year. A university science educator, three scientists, and two mentor teachers led the program. They not only provided content instruction, but they also modeled inquiry-based activities and NOS-based interventions and activities. Teachers' understandings of NOS was assessed through pre- and post-scores on the Views of Nature of Science questionnaire (VNOS-C), classroom observations, interviews, program evaluation surveys, and action research plan documents. Data were analyzed separately by Posnanski and two graduate students and then again as a group.

Quantitatively it was found that 18 of the participants had increased scores on the VNOS-C survey (Posnanski, 2010). The other four began with high scores and thus retained those high scores. All 22 participants reported the overall experience beneficial and most identified many strengths of the program, including the following: field trips, inquiry based activities modeled, and opportunities to share ideas. Of the initial 22 participants only eight were observed in the classroom. While these observations showed that all eight integrated NOS into their classroom instruction, it seemed that some would revert back to strategies that did not integrate NOS if they taught a lesson that was not included in their Action Research Plan written at the end of the summer session. Interestingly, there was less NOS included in lessons observed that were unannounced compared to the ones that were announced. This reveals a bias of the participants to attempt to impress the observer. However, the observational data do suggest that the amount of instructional time spent on NOS did increase. Also, the observers noted that even when the teachers did not include tenets of NOS, they often used inquiry-based approaches.

Aspects of this program that led to the success of teachers' increased understanding and ability to implement NOS into their instruction include the constructivist approach of the professional development (Posnanski, 2010). The teachers felt that a long-term program allowed them to build a community in which they could share their ideas and practices. They were given opportunities to take activities and concepts taught in the summer, put them into practice during the school year, and reflect on those experiences. Many teachers actually replicated in their own classrooms the same activities utilized in their summer session with explicitly instruction of NOS and methods of teaching NOS in the classroom. Also many teachers felt the written Action Research Plans helped solidify their thoughts beyond just ideas and actually developed a plan to implement NOS methods into their daily teaching.

Evolution in the science classroom and how it relates to NOS

This final section of the background research will discuss evolution as it relates to the science classroom and will include the following topics:

1. The importance of evolution to the modern biology/life science course;
2. The advancement of evolution teaching using NOS instruction;
3. The current status of evolution teaching in the high school setting;
4. The pedagogy versus content debate related to teacher preparation for evolution instruction;
5. The explicit evolution instruction within a NOS framework for teachers;
6. The acceptance and knowledge of evolution and NOS among teachers; and
7. The acceptance and knowledge of evolution and NOS as it relates to religious beliefs.

The importance of evolution to the modern biology/life science course. The necessity to teach evolution in a high school biology class is obvious to the science community and those with a strong understanding of biological concepts (National Academy of Science, 1998; Osif, 1997; Rutledge & Warden, 2000). Those who are not within the scientific community believe a high school biology class can be taught without an evolution unit, thus avoiding a topic that is culturally and religiously controversial. However, evolution is not by any means a controversial subject scientifically speaking. Many perceive evolution to be an individual unit that is isolated from the rest of biological studies. The development of the theory of evolution by natural selection is a defining moment in history for modern biology (National Academy of Science, 1998). It is an important milestone that has influenced all aspects of biological studies since.

Many fail to realize that genetics is nothing more than molecule evolution and that the study of ecology is to study the changes of organisms with the environment. Evolution is a fundamental unit for any high school biology class and therefore must be taught in such a manner to avoid confusions and misunderstandings (National Academy of Science, 1998).

The advancement of evolution teaching using NOS instruction. To be functioning world citizens in society, students must have an understanding of how to use scientific reasoning and when to be skeptical of information provided by the media, politics, and the open source of the Internet. The teacher must not shy away from these controversial topics, but directly address them. In a high school biology class, evolution is one of the fundamental themes and should be integrated into each unit in the course, similar to NOS (National Academy of Sciences, 1998). To dismiss the discussion of evolution by natural selection as just a colloquial theory and in its relationship with religion will serve a serious injustice to the student. Students will never fully understand modern biology, if they do not appreciate the value of evolution. Many students perceive that science and religion are antagonistic doctrines pitted against each other, and only one can survive. The conflict of science and religion is relatively novel to this century and is often dramatized. Most students do not realize the church was the center of scientific studies for most religions. Mendel was a monk; Einstein was religious; and even modern evolutionary scientists, such as Joan Roughgarden, published books both on her scientific evolution concepts and her religious beliefs. It is important students realize that there is scientific knowledge based on accepted repeatable evidence that explains observed phenomenon, while religion is non-science and based on beliefs and is concerned with morals and values. The two are different entities and need not be pitted against each other. However, in science class students must learn the nature of science and understand knowledge that is within a scientific framework.

A successful evolutionary unit in a life science or biology course is heavily integrated with nature of science concepts (National Academy of Science, 1998). Before beginning the unit, it is essential for students to have a strong understanding of the nature of science, so that they will appreciate the value and significance of evolution for modern biology. Otherwise they may leave high school biology with the idea that evolution is "just a theory" (Ben-ari, 2005). It is also necessary that students realize that science and religion both have characteristics and philosophies that make them fundamentally different from each other. Students need to be informed on what constitutes a scientific theory, so that they can appropriately interpret information they encounter in society (Espinoza, 2012; National Academy of Science, 1998). A strong understanding of the nature of science will help students realize that evolution is an integral part to modern biology. Students will appreciate evolution and its application in other areas of biology.

The current status of evolution teaching in the high school setting. Teaching evolution in the secondary classroom may be one of the great content related topics that teachers, new or experienced, may encounter, especially in the life science and biology classrooms (Berkman & Plutzer, 2010). Bishop and Anderson (1990) found that religious convictions could be a significant factor affecting whether the teacher will accept evolution or not. Their study provided non-biology majors instruction in both NOS and evolution and found no significant changes in the post-test scores for the acceptance of evolution, similar to other studies that also found that biology teachers or undergraduate biology students reject evolution because of their religious beliefs (Aguillard, 1999; Downie & Barron, 2000; Osif, 1997). Instead, the participants that reject evolution endorse creationism. In addition to teachers with strong religious beliefs, the high school biology curriculum must sometimes battle with restrictive board of education policies, school administration, prominent and powerful community members, and textbooks (Eglin, 1983; Roelfs, 1987; Shanker, 1989; Tantina, 1989). Other studies have indicated that teachers with higher NOS understanding or those who have taken more science courses, especially those related to evolution will have a better understanding and acceptance of evolution (Berkman & Plutzer, 2010; Lombrozo, Thanukos & Weisberg, 2008). Interestingly teachers who spend a significant amount of time and are successful at communicating evolution to their students are well trained in NOS pedagogical methods. Those that have low knowledge of NOS and evolution typically have low acceptance of evolution (Bishop & Anderson, 1990).

Regardless of the restrictions evolution may face in the high school biology classroom, it has been considered as the central theme in the curriculum framework according to AAAS (1990), National Association of Biology Teachers (1995), and NRC (1985). Sadly, only 57% of biology teachers consider evolution to be a unifying theme, perhaps due to their lack of understanding of NOS and evolution (Moore, 2000). However, those with a strong understanding of NOS know that it is an unavoidable topic. Select teachers, who claim not to teach evolution, may not realize that they are indirectly teaching evolution in the genetics, ecology, cells, or even human anatomy and physiology units. Unfortunately, this ignorance highlights a lack of understanding of NOS and a dearth of true comprehension of modern biology. According to Berkman and

Plutzer (2010), only 28 % of schools in their study covered evolution concepts according to national science guidelines. The majority of schools may cover evolution, but do so in such a watered down approach that leads to many misconceptions on behalf of the students. Without strong instruction on scientific principles, it is ambiguous to students what is considered scientific, and many non-science alternatives are supported and endorsed (Berkman & Plutzer, 2010).

The pedagogy versus content debate related to teacher preparation for evolution instruction. Some thought has been given as to why teachers, despite having strong background in science, feel obligated to give equal time or be fair to non-science accounts of creation in their science classrooms, which should focus only on the scientific concepts. Some teachers, despite having a major in science or desire to teach science, still lack the confidence to teach evolution as the central concept to modern biology in their classrooms. Berkman and Plutzer (2010) conducted a focus group study of four different types of colleges that represent a diverse group on many variables: a larges state university with funding for scientific research and labs, a small regional public university that trains prospective teachers, a private liberal arts college associated with the Catholic Church, and a historically black college. One of the major findings of their focus group meetings consistent among all four samples is that future biology teachers are not focused on the mastery of the content as much as learning the skills of teaching such as classroom management and teaching styles. They even attribute 90 % of teaching to classroom management and only 10 % to content mastery. These future teachers believe most content can be sufficiently learned from a teaching manual or unit guide, as long as they have the skills to teach.

Despite these perceptions of these prospective teachers, previous research including 900 high school biology teachers indicates that content knowledge is critically important to the successful teaching of evolution (Berkman & Plutzer, 2010). They found that the teachers that taught evolution in a straightforward scientific approach and did not include non-science alternatives, or even allowed the consideration of these alternatives in the scope of their classroom, had more science credits overall and were likely to have taken courses on evolution in college. They also found that the teachers that were ambiguous and allowed misconceptions to persist were more likely to personally rate their own knowledge of evolution as lower (Berkman & Plutzer, 2010). They concluded that knowledge and confidence in their understanding of evolution directly related to teaching of evolutionary concepts in the classroom that aligned with that of NGSS and other national science entities. Berkman and Plutzer (2010) also recognize the difficulty of providing such meaningful mastery of content to increase teacher expertise, since future teachers must balance both their science major and the pedagogical courses for teacher certification. They also acknowledge that such mastery does not occur once they enter the teaching profession due to time restraints and availability of effective professional development.

The explicit evolution instruction within a NOS framework for teachers. Nelson, Nickels, and Beard (2000) found that in order for their undergraduates to effectively learn evolutionary concepts, professors must teach evolution within a context of NOS and the general principles of NOS as well. Many of their students were non-science majors with preconceived misconceptions and biases about science, creationism, and evolution. They deduce the parallels between these non-science major undergrad courses and high school biology courses and predict similar pedagogical methods could prove successful for high school science teachers.

They established a six-week residential program for experienced high school teacher that lasted for six years, 1989-1994, which had a footprint of 180 teachers. Consequently these teachers trained other teachers to initialize similar programs from 1992-1997, which has included over 650 teachers indirectly affected. Aspects of the program that proved successful to the summer institute were the fall and spring follow up sessions and the continual support provided to teachers to help them implement strategies in their own curriculum and instruction. This reflects previous research that in order for teachers to successfully integrate NOS into their pedagogical practice there must be collaboration and mentorship that is on-going (Akerson, Cullen, & Hanson, 2009; Nelson, Nickels, & Beard, 2000; Posnanski, 2010).

After such summer institutes, Nelson, Nickels, and Beard (2000) found several significant improvements in science teachers' approach to both NOS and evolution in their classrooms. Prior to the institute, teachers reported only four class days of instruction on NOS topics, yet after their participation this increased to over 14 days. The time spent addressing evolution concepts also increased from 19 class periods to 32, with many reporting an additional 6.5 days the following year. Nelson, Nickels, and Beard (2000) conclude that the teachers were more comfortable with both evolution and NOS, as they were more competent in their instruction and able to clearly link evolution to NOS. They also observed an overall "pedagogical paradigm shift" in which teachers involved their students more in the scientific inquiry process with inclusion of more open-ended labs and critical thinking activities. They were comfortable with results that may not always work as planned and allowed for thoughtful discussion of these results in a scientifically meaningful manner that models real world scientific thinking and processes.

Teachers' Acceptance and Knowledge of Evolution and NOS. A few studies have attempted to study the relationship between the acceptance of evolution, understanding of evolution and understanding of NOS (Rutledge & Warden, 2000; Trani, 2004). In Rutledge and Warden's study (2000) 989 biology public high school teachers from Indiana were sent surveys with three subscales: acceptance of evolution, understanding of evolution, and the understanding of NOS. They received 552 of the surveys, which was a 52 % return rate. Teachers in Indiana had a moderate acceptance of evolution with an average score of 77.59 (*SD* = 19.83) out of a maximum of 100 on a scaled survey. Rutledge and Warden (2000) assigned points to the degree with which respondents agreed with statements of evolution theory. There were five options for respondents to choose: strongly agree, agree, undecided, disagree, and strongly disagree. The components that were least accepted included statements on the testability of evolutionary theory and the evolution of man. These same teachers had a moderate score for the knowledge of evolution theory with an average score of 71 % correct (*SD* = 4.05) on a multiple choice test of factual concepts related to evolution. On the understanding of NOS subscale they scored an average of 59.49 (*SD* = 12.46) with a maximum of 85 possible. Less than 70 % of the teachers did not understand the following concepts: the goals or scope of science, that science is tentative by design, the inability of science to address ultimate causation, characteristics of scientific theories, the limits of science, or scientific methodology. More than 85 % of the teachers had strong understanding for the necessity of the repetition of experimental events in the scientific inquiry process and over 82 % were able to separate scientific knowledge from religion.

Rutledge and Warden (2000) correlated the scores for each of the three subscales of their instrument and found that there was a significant correlation between teacher acceptance of evolution with their understanding of evolution (r = 0.71). They also found a correlation between teacher acceptance of evolution and their knowledge of NOS (r = 0.76). These correlations suggest that teachers who are more knowledgeable in their content matter such as evolution and NOS are more likely to have a better attitude toward evolution. This may be indicative that those with a thorough comprehension of NOS do not feel conflicted or confined by religious beliefs, as they have a better grasp on science as a body of knowledge that differs, not competes with religion. This research also indicates that pre-service teachers may need to be exposed to curriculum that requires NOS courses and others that will make them content specialists.

The acceptance and knowledge of evolution and NOS as it relates to religious beliefs. Trani (2004) used similar methods to Rutledge and Warden's survey (2000), but included in the research question a component that assessed the strength of the individual teacher's religious beliefs. For this study 79 schools in Oregon out of 80 agreed to participate with surveys mailed to the schools with a 66 % response rate for the surveys themselves. Each school was only mailed three surveys color coded as follows: green for the most experienced teacher, yellow for the least experienced teacher, and pink for the teacher closest to the average number of years teaching at that school. This survey unlike those of Rutledge and Warden (2000), also included a section that asked questions on the teacher's religious beliefs and the classroom teaching of evolutionary theory.

Oregon biology teachers had a high acceptance of evolution with an average score of 85.9 with the maximum being a 100 (Trani, 2004). There was also a high understanding of evolution as well with a score of 17.51 out of 21, approximately 83 % of questions were correct. However, there was not as a high of an understanding of NOS with only an average of 66.08 % of the questions correct. The teachers surveyed in Oregon reported that evolutionary theory was a major role in their courses and that creationism was minor topic in the curriculum. After statistical analysis of the data, there were positive correlations between the presentation of evolutionary theory in the classroom and the acceptance of evolution ($r = 0.72$) and the acceptance of evolution and the understanding of evolution ($r = 0.70$). There was a negative correlation between religious convictions and the acceptance of evolutionary theory ($r = -0.80$). While these numbers indicate that Oregon teachers are relatively strong in both their acceptance and understanding of evolution, there is still the 16 % of the teachers surveyed that do not present evolution in their classrooms and lack adequate NOS or evolution knowledge. This is disconcerting regarding the biological education of their students.

Some researchers have even defined the strength of one's religious convictions as "religiosity" (Lombrozo, Thanukos, & Weisberg, 2008). Their study consisted of 96 undergraduate students at a large west coast public university. Students received course credit for completing the 18-page questionnaire that consisted of seven parts. This sample was 67 % female with a mean age of 20. Religiosity was significantly negatively correlated ($r = 0.43$, $p < 0.01$) with the acceptance of evolution and religiosity was not significantly correlated with any *other* variable. Unlike previous research of Carey and Stauss (1968, 1970a) the number of science courses did have a significant correlation with the NOS understanding score ($r = 0.27$, $p < 0.05$). The NOS score was also correlated with the acceptance of evolution ($r = 0.40$, $p < 0.07$). This could be an artifact that those with more science courses have a better knowledge of NOS and are more likely to have a positive attitude. Lombrozo, Thanukos, and Weisberg (2008) performed the correlation again controlling for education and attitude and still found that NOS knowledge and evolution acceptance were correlated ($r = 0.31$, $p < 0.01$). Interestingly the researchers found that many of the undergraduate students struggled to understand scientific theories and had difficulties defining or describing the functionality of theories in science. Based on these correlations, Lombrozo, Thanukos, and Weisberg (2008) concluded that when teaching evolution, it is important to directly and explicitly teach NOS concepts to introduce evolution, as well as throughout the context of the content matter.

Instrument measuring the understanding of NOS and understanding and attitude towards evolution

Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) noted that more than 20 standardized measures have been created in the forty years prior to 2002 to assess the understanding or views of NOS by teachers and students. This study focuses on the development of an instrument that has been used with three subscales to specifically examine the relationship between the understanding of NOS and evolution theory, and the attitude towards evolution theory. This section of the methods will describe the historical development as well as the validity and reliability of the following three subscales:

1. The understanding of NOS subscale;

2. The understanding of evolution theory subscale; and
3. The attitude of evolution theory subscale

The understanding of NOS subscale. Rutledge and Warden (2000) also modified a scale created by Johnson (1985) to assess teachers' understanding of NOS (Appendix A). The Johnson's (1985) original version contained 20 statements with a five point Likert scale ranging from strongly agree to strongly disagree to provide a varying degree of correctness of their knowledge of conceptions of NOS. After exposing the scale to a jury of five experts in the fields of evolutionary biology, science education, and philosophy of science Rutledge and Warden (2000) narrowed down the items to 17. Revisions to the statements were made based on feedback from the members of the jury. Double-barreled statements were avoided. Additionally, statements were both positively and negatively worded. Responses that supported a high level of understanding of the nature of science were scored with a five, while a low to no understanding were scored as a one. Overall scores ranged from 85 suggesting a strong understanding of the nature of science to 17 representing a very weak understanding. Cronbach's internal consistency reliability coefficient was a strong 0.94 for the understanding of the nature of science.

The understanding of evolution theory subscale. Rutledge & Warden (2000) modified Johnson's (1985) instrument to create a 21 item subscale that assesses the understanding of evolutionary theory and related concepts that included content related to natural selection, extinction process, homologous structures, coevolution, analogous structures, convergent evolution, intermediate forms, adaptive radiation, speciation, evolutionary rates, the fossil record, biogeography, environmental change, genetic variability, and reproductive success (Appendix B). This subscale resembled a multiple choice assessment with five answer options. Scores for this subscale were calculated with one point for each item answered correctly for a range of 0, indicating no understanding of evolutionary theory, to 21, demonstrating a high understanding of evolution. Content validity was assessed through item analysis by a jury of experts in the field of evolutionary biology, science education, and philosophy of science (Rutledge & Warden, 2000). Items from the original instrument created by Johnson were assessed by the jury panel for whether the questions contributed to the validity of the purpose of this subscale, measuring the understanding of evolution. During the process questions were revised as necessary for purpose of clarity. Internal consistency was high, evaluated through Cronbach's reliability coefficient, at 0.78.

The attitude of evolution theory subscale. Rutledge and Warden (1999) developed the *Measure of Acceptance of the Theory of Evolution (MATE),* an instrument containing 20 scaled items that addressed foundational concepts of both evolutionary theory and the nature of science (Appendix C). These included the following: the process of evolution, the available evidence of evolutionary change, the ability of evolutionary theory to explain phenomena, the evolution of humans, the age of the earth, the independent validity of science as a way of knowing, and the current status of evolutionary theory within the scientific community. Rutledge and Warden (1999) designed items that avoided common item construction errors that reduce clarity such as lengthy statements and double-barreled statements. Both positively and negatively stated items were included on the five point Likert scale of *strongly agree, agree, undecided, disagree, and strongly disagree* to ensure that respondents read questions carefully. Responses were then scored with a five for a strong acceptance of evolution and a one for a low acceptance of evolution, which created a range of scores from 20-100. Several statements are opposites of each other to assess the consistency of the respondent. For example, the statement, “Evolution is a scientifically valid theory” is the opposite of the statement “Evolution is not a valid theory.”

A jury of five university professors with expertise in fields of evolutionary biology, science education, and the philosophy of science assessed the content validity of the instrument by rating each item on a scale of one to five (Rutledge & Warden, 1999). An item that scored a five signified the reviewer was confident that the item contributed to the measurement of the intended content, the acceptance of evolution. A rating of one indicated that the reviewer did not feel the item was a significant contributor to assessing the acceptance of evolution and statement was invalid. Several statements were revised according to jury member feedback to improve clarity of the items, and not statement that scored a composite rating of less than 3.5 was included in the final instrument. The average rating of the items included was 4.7.

Additionally, construct validity was analyzed through the use of statistical tests of factor analysis (Rutledge & Warden, 1999). For their sample of 552 Indiana public school biology teachers there was only a single factor with an eigenvalue greater than one in a principal components factors analysis test. This single factor accounted for 71% of the variation among the 20 items in the instrument. All 20 of the statements had factor loading values greater than 67%, which indicates the significant contributions of each item to the single factor. This validity check demonstrated that all the items measured one construct, attitudes toward evolution. The *MATE* was determined to have high reliability with a Cronbach alpha of 0.98, which has a range of 0 (low reliability) to 1.00

(high reliability) (Rutledge & Warden, 1999). Cronbach is a conservative measure of reliability, so the high score of 0.98 indicates that this instrument achieves reliable results among respondents. Similar to the item analysis for construct validity, all 20 items had a corrected item total correlation greater than 0.5 (0.65), indicating that each item significantly contributed to the overall reliability of the instrument. Rutledge and Warden concluded that this instrument had high validity and reliability for public high school biology teachers, being focused and homogenous, assessing only a single construct.

Summary of Background Research

After conducting background research regarding teachers' acceptance of evolution, as well as their knowledge of NOS concepts and evolution, it is apparent that many variables may be involved to contribute to the outcomes. However, one theme that does stand out is the necessity of direct instruction of NOS in college level science courses or inclusion of specific NOS courses in teacher preparation programs. However, some research has indicated that specific science courses are not influential in changing the results, as well as some courses that included NOS. There needs to be further study to determine if the inclusion of NOS is important to teachers' appropriate teaching of evolution concepts.

Chapter III

Materials and Methods

Rationale for this study

The purpose of this study is to learn which demographic variables regarding background education are correlates as well as predictors of teachers with a strong understanding of NOS and evolution theory, as well as a positive attitude toward evolution theory. Through a modified questionnaire that was originally developed by Rutledge and Warden (2000), the following research questions will be addressed for secondary science teachers:

1. Is there a relationship between the understanding of NOS principles, understanding of evolution theory and acceptance of evolution theory?
2. Is there a significant difference between teachers with an education degree, science degree, or completion of a NOS related course for the three subscales: understanding of NOS principles, understanding of evolution and acceptance of evolution?

Instrument to Measure the Understanding and Acceptance of Evolution and the Understanding of NOS

The instrument was developed by finding pre-existing surveys, analyzing them, developing revised surveys, piloting these surveys in two ways, and then finalizing the surveys to be used in this dissertation. This section of the methods will address the following:

1. Field testing of instrument

2. Instrument to measure the variables that influence the understanding of NOS and evolution theory, and the attitude towards evolution theory.

Field testing of instrument. The instrument as developed by Rutledge and Warden was field tested in two different forums to receive feedback regarding the instrument's validity to accurately measure what it intended, as well as the overall ease of completion of the assessment tool. This section of the methods will address the following two forms of field testing:

1. Description of the pre-study focus group of experts, and
2. Description of the pilot study for a graduate level survey methods course.

Description of the pre-study focus group of experts. Using the instrument created by Rutledge and Warden (2000) as a guide, a mock version was drafted and sent to a focus group of seven colleagues who were either enrolled in a university doctoral curriculum and instruction program specializing in science education or were biology teachers with a doctoral degree in a biological science field. These colleagues served as pre-study focus group in which respondents completed the questionnaire as designed by Rutledge and Warden (2000) with no modifications. Upon completion of the questionnaire, the pre-study focus group were interviewed to provide clarification on their responses, as well as to obtain feedback on the instrument overall. The purpose of this pre-study was not to analyze the results, as this is a small, statistically insignificant, biased sample of convenience. However, those included in the pre-study focus group had some level of expertise either in science education or biology. Lederman et al. (2002) similarly field tested their instrument among a small group of those expected to be expert in their understandings of the topics in the questionnaire.

Description of the pilot study for a graduate level survey methods course. Additionally, the modified instrument was then presented as part of a class assignment to develop, distribute, and analyze a questionnaire or survey for a university graduate level survey methods course. The course included graduate level students from a variety of fields and not just science education, but all were enrolled in the department of education at the university. As part of the assignment, students developed their instruments and shared them with fellow students in the course in a workshop approach. The students in the course and the professor provided invaluable feedback prior to the distribution and administration of the instrument to address the content validity of the items for each of the 3 subscales, as well as the clarity of the construction of each statement.

The information learned from both the pre-study sample of experts and the graduate students in the survey methods course helped in the creation of the pilot survey for the class assignment with minor modifications to Rutledge and Warden's (2000) instrument. Using the Internet based platform for administering research surveys, Qualtrics, a link to the Qualtrics survey was shared on social media platforms such as Facebook and Twitter and had a total of 22 respondents. The sample for this pilot study was statistically small and a sample of convenience. The respondents in the pilot study anonymously completed the survey, which did include demographic questions that provided a picture of both their science and pedagogy preparation prior to being a teacher. Respondents were more representative of a diverse background than either the pre-study focus group of experts or the graduate students in the survey methods course.

Upon analysis of the pilot survey, post feedback was provided from the graduate students in the survey methods course on the construction and design of the items for each of the three subscales based on the data received. The focus of the feedback was important not only for extrapolating trends from the data that resulted, but also to analyze the validity of the components of the instrument itself. Furthermore, the feedback also provided valuable feedback about the construction and design of the instrument.

Instrument to measure the variables that influence the understanding of NOS and evolution theory, and the attitude towards evolution theory. This section of the methods describes the following steps in the development of the final instrument for this study:

1. Demographic block to understand important characteristics about teachers.
2. The understanding of NOS block.
3. The understanding of evolution block.
4. The acceptance of evolution theory block.

Demographic block to understand important characteristics about teachers. The demographic questions aim to collect data about the participants' background in formal science instruction and pedagogical training, as well as their teaching experience (Appendix D). These questions include whether they completed a degree in education or science, as well as the level of that degree, bachelors, masters, or doctorates. Additional questions related to an education degree include whether they have participated in a nature of science course or a history/philosophy of science course. Further questions related to a science degree include whether they have participated in any authentic science research other than experiences that may be included in their coursework. Finally, the demographic block includes a series of questions related to their teaching experience.

This includes the length of time they have been teaching, the grade levels they teach, and the courses that they have taught.

The understanding of NOS subscale. The understanding of NOS block contained 18 statements regarding key NOS concepts (Appendix G). Rutledge and Warden had used 17 of the 20 statements originally developed by Johnson (1985) and modified the wording for better clarity. An additional statement, "A scientific theory may be elevated to the status of scientific law with enough evidence," was added to assess the understanding of the relationship between scientific theories and laws, a well agreed upon component of NOS (Lederman et al 2002). Other topics addressed in this subscale included the following: science is an empirical based endeavor; the lack of a uniform scientific method; the relationship between hypothesis, theory, and law; and the importance of observations for scientific findings. In this section each of the statements was presented as a true or false choice to demonstrate the respondents' knowledge of NOS and not a five point Likert scale that suggested their degree of agreement with the statement. Statements were written as both positive and negative forms to improve the respondents' attentional focus.

As previously observed by both the pre-study focus group of experts and the peer review panel of graduate students in the survey methods course, the clarity of the statements was lacking, especially to those of the peer review panel that did not necessarily have a science education background. Previous research by Lederman et al. (2002) also suggests that NOS forced-choice assessments similar to this are problematic in that the questions are written in language unfamiliar to that of the developer of the instrument, who is well versed in NOS concepts. The addition of four free response questions from the views of nature of science survey (VNOS-C) developed by Lederman et al. (2002) were included to assess the reliability of the forced-choice responses. While the original VNOS-C (Appendix H) survey contained seven total free response questions, only the four that pertained specifically to the forced-choice statements from the Rutledge and Warden (2000) instrument were used. Respondents are instructed to write as much as they want about each topic and to use specific examples when relevant.

The understanding of evolution subscale. The understanding of evolution contained 12 multiple-choice questions assessing topics of evolution theory (Appendix F). Topics assessed included description and definition of evolution theory, homologous structures, intermediate forms, radioactive dating, transition of fish to mammals, transition of marine to terrestrial life forms, reproductive isolation mechanisms, climate changes impacts on extinction, habitat fragmentation's effects on decreased genetic diversity, the fossil record as evidence, and the history of natural selection including Lamarck and Darwin's ideas. The number of questions from the initial survey by Rutledge and Warden (2000) were revised and reduced from the original 21 questions due to criticism of the length of this subscale from the pre-study focus group of experts and the peer review panel of graduate students in the survey methods course (Appendix F). Using the individual item analysis scores from Rutledge and Warden's (2000) understanding of evolution subscale the three questions with the highest and the three questions with the lowest scores were examined for their relevance based upon interviews from the pre-study focus group.

All but one of those six questions were omitted. Question 24, which had a low score of only 52%, was kept due to consistent feedback that this was an important question regarding the description of evolution theory and was essential to assessing one's knowledge of evolution. Question 34 had the lowest score of only 43.8% answering correctly that the presence of rainforest fossils in Canada is due to a climate shift, while 47.6% chose the presence due to drifting continents as their answer. This question was problematic as there are examples of fossils that are currently located in climates due to drifting climates. The other low scoring question, #41, was about the evolutionary success of organisms based on their life history attributes. The highest scoring questions included #26, 28, 35, which respectively assessed the topics of mutations, first land animals, and meiosis as the process that leads to genetic variability.

The attitude of evolution theory subscale. The subscale measuring teachers' attitude toward evolution (*MATE*) theory includes 20 statements about the scientific theory of evolution, with which the respondents must either agree or disagree (Appendix E). These statements were directly adopted from Rutledge and Warden (2000) with no modifications. Similar to the understanding of NOS block, Rutledge and Warden (2000) also utilized a five point Likert scale, which based on feedback from the pre-study focus group of experts and the peer review panel of graduate students in the survey methods course was awkward and unnecessary. Statements were constructed as both positive indicating an acceptance of evolution theory or negative suggesting a lack of acceptance of evolution theory. Also several statements were opposites of each other to assess the reliability of the respondent to answer consistently and attentively. For example, the statement, "Evolution is a scientifically valid theory" was the opposite of the statement "Evolution is not a valid theory."

In summary the instrument has four sections. The first is the demographic block with 12 questions. The next three blocks are randomized to reduce order effects. The understanding of NOS subscale with 17 items, the understanding of evolution with 12 questions, and the MATE with 20 items. The total number of questions was 61 questions.

Sampling and Analysis Procedures

This section of the methods will address the following topics regarding the sampling and analysis procedures:

1. Description of sample.
2. Distribution of the survey.
3. Description of data analysis.

Description of sample. A national data set of secondary science teachers was obtained from Market Data Retrieval (MDR). MDR has a database that allows researchers the ability to email potential respondents based on a variety of demographic variables. For this study MDR provided the email contact information for approximately 2500 public and private school teachers at the secondary level for the following subjects: biology, life science, chemistry, physical science, physics, general science, earth and space science, and environmental science teachers.

There were 257 respondents to complete the survey in its entirety. Respondents that did not finish the entire survey were excluded from the data analysis. To verify participants' responses, a follow up email was sent to confirm both their email for the monetary incentive was correct as well as the level and area of the academic degrees earned. Through pilot studies it was observed that respondents do not always carefully distinguish between their science degrees and education degrees when selecting from a forced choice set of options. The follow up questions were open-ended. Only respondents that participated in a quality control of the data were included in the final data analysis. This reduced the final sample size to 187 respondents. The sample of 187 respondents was composed of 65.2% women and 33.7% men. The race/ethnicity of respondents was 86.6% white. The age of respondents ranged from 22 to 69 years old with a mean age of 44.79 years.

Distribution of the survey. This section of the methods will address the following:

1. Description of the instrument using Qualtrics.
2. Communication with respondents.

Description of the instrument using Qualtrics. The survey was delivered electronically through Qualtrics, which is advertised as the world's leading research and insight platform. Qualtrics permits the researcher to control over many important aspects of the survey delivery process, while allowing respondents to participate by a link to the survey. For this particular research, responses can remain confidential and protect the identity of the participants. Qualtrics also monitors the amount of time spent to answer questions and limit the time spent, to protect the integrity of the results and prevent participants from looking up responses on the Internet.

The survey has four blocks in Qualtrics with only the demographic block not randomly counterbalanced and always set in the first block. The demographic block serves as a means to exclude participants that are not desired for this survey. The demographic block is not randomized and is set as the first block for all respondents. With the Qualtrics platform, demographic questions are presented according to answers to previous questions. For example, if the participant does not have an education degree and responds, “no,” they will be sent to the next main question and will not be shown more specific questions concerning those with an education degree. Therefore, the Qualtrics platform allows only the questions that are relevant to the participant to be shown in a sequence that flows appropriately as depicted in Appendix D.

The other three blocks are adapted from the instrument created by Rutledge and Warden (2000) which includes the understanding of NOS, the understanding of evolution theory, and the attitude toward evolution theory. These three blocks are randomized to control for order effects and eliminate any bias that may occur due to exposure to a particular section first. Each question was presented individually on the screen.

Qualtrics records the amount of time each respondent spends to provide quality control for those that may be taking an excessive amount of time due to Respondent Bias. The average time to complete the survey was 89.93 minutes. The relationship between the duration of time to complete the survey and the scores on the three subscales was investigated using Pearson product-moment correlation coefficient. Initially there was no significant correlation between the duration of time to complete the survey and any of the three subscales as shown in Table 1. However, there were two outliers that severely skewed the data, according to a scatter plot created in SPSS as shown in Figure 1. After removing these two outliers, the average time to complete the survey decreased to 31.68 minutes. There still was no significant relationship between the duration of time to complete the survey and the score on the understanding of evolution theory subscale, the one most susceptible to Respondent Bias effects due to the ease of finding correct answers on the Internet. Although, there was a significant relationship between the duration of the survey and the scores on the understanding of NOS, and the measure of attitude towards evolution subscales as shown in Table 1. However, this relationship was negative, which indicates those that took longer possibly due to researching correct answers, actually scored lower on these two subscales. This provides some confidence that respondents did not research correct answers on the Internet and answered honestly to the best of their ability.

Table 1

Pearson Product-Moment Correlation Between Duration of Time to Complete Survey and the Three Subscales

Relationship	MATE	NOS	EVOL
Duration time with Outliers	-.049	-.069	-.029
Duration time without Outliers	-.161*	-.145*	-.111

Note. * $p < .05$ (2 tailed).

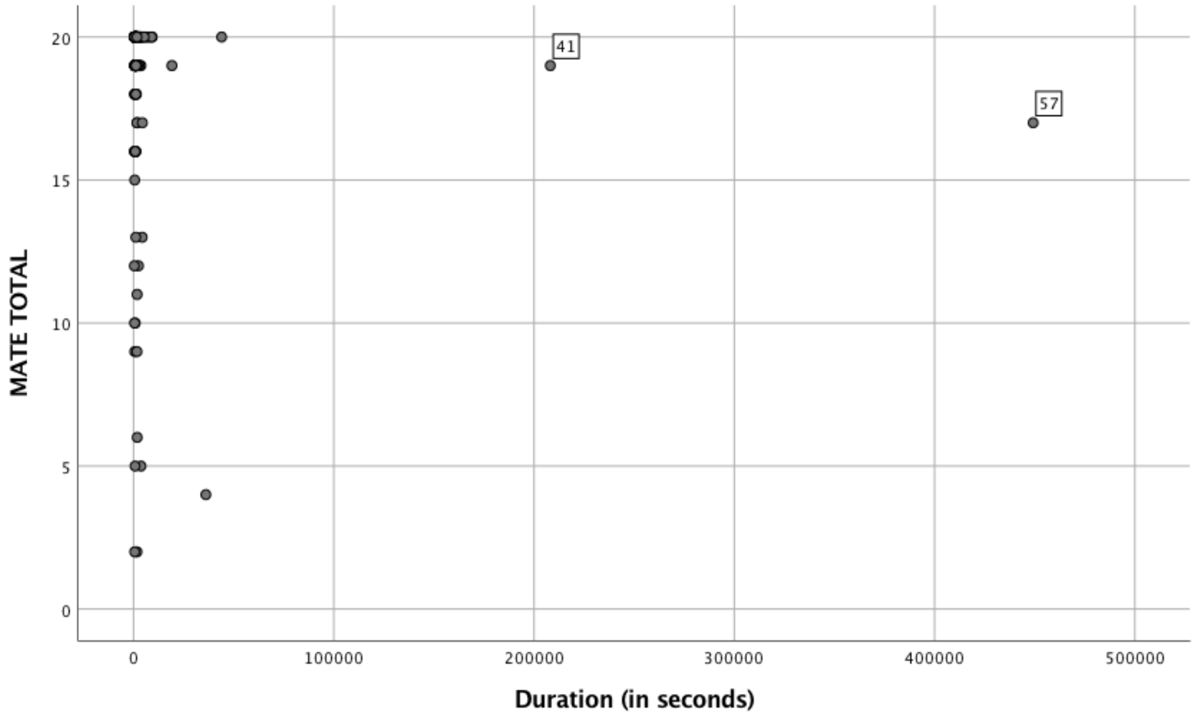

Figure 1. Duration of completion scatter plot. Scatter plot showing outliers for the duration of time to complete the survey. There are two outliers. Respondent 41 and 57 both took an extremely longer amount of time to complete the survey than other respondents.

Communication with respondents. Potential respondents were contacted by email requesting their participation in this survey with the link to Qualtrics provided. Once respondents participated and completed the survey, they were removed from the list. A second email two weeks after the initial contact was sent to remind potential respondents of the survey. A third and final email was sent one month after the initial email to confirm respondents' college degrees as several people did not provide clear responses through a open response form. Respondents were made aware that participation was completely voluntary with no impacts to their well-being. Respondents were also told that the purpose of the study is to assess their views and attitudes towards NOS and evolution theory and as such there were no wrong answers. A monetary incentive was provided for those that successfully completed the survey and provided follow up information. Upon completion of the survey participants received a $5 Amazon gift card.

Description of data analysis. This section of the methods will address the methods use to analyze the data including the following sub-categories:

1. Scoring of different subscales.
2. Reliability measures.
3. Statistical analysis.

Scoring of different subscales. Qualtrics collects all data anonymously and then organizes the data into a spreadsheet that can be exported into Excel. In the demographic portion scores were coded into numerical data for statistical analysis. Respondents were also given grouped according to completion of an education related degree, science content degree, and participation in a NOS related course. The groupings consisted of the following: only a science content related degree, only an education related degree, both a science content and education related degree, and those with a science content degree, education degree, and completion of a NOS course. Other grouping options were omitted due to the lack of occurrence. There were only three cases of respondents that did not fit any group meaning they lacked any of the relevant degrees or coursework. Also excluded were those with a science education related degree and the completion of a NOS related course, since there were only nine cases. These groups were assigned a code for later use in MANOVA statistical analysis.

The scores for each subscale, understanding of NOS, understanding of evolution theory, and attitude of evolution theory will be coded appropriately, since statements for the understanding of NOS and attitude of evolution theory were written as both positive or negative statements to improve reliability of respondents' answers. For the understanding of NOS answers that supported an understanding of NOS were assigned a value of one and answers that indicated a weak understanding of NOS concepts were assigned a value of zero. For this subscale the composite scores ranged from 0-17. The coding procedure was similar for the attitude of evolution theory subscale as well with answers indicating a positive view of evolution were assigned a value of one and those suggesting a negative view a value of zero. The composite scores for the attitude toward evolution theory could range from zero indicating a negative acceptance of evolution theory and 20 suggesting a strong acceptance of evolution theory. The understanding of evolution theory resulted in a range of 0-12 based on the number of correct answers to the 12 multiple choice questions. The composite scores for the understanding of evolution theory could range from zero indicating a negative understanding of evolution theory and 12 suggesting a strong understanding of evolution theory. Data was then uploaded into SPSS and coded, so that further statistical testing can be performed.

Reliability Measures. This instrument utilizes several methods to ensure the reliability of the answers provided by the respondents. For the understanding of NOS and the attitude of evolution theory subscales both employ statements that are written as positive or negative statements. This prevents a respondent from quickly agreeing with all statements or marking all statements in the same direction. Additionally, within the attitude of evolution theory subscale statements that were contradictory to each other were included to guarantee the respondents were consistent with their attitudes of evolution theory. There are concerns with the reliability and validity of forced-choice

NOS assessments that suggest a free response or further interviews with respondents may be necessary to validate the forced-choice assessment.

Statistical analysis. Prior to any analysis of the research questions, the demographics of the sample was analyzed to gain a better understanding of the breakdown of the teachers in the sample to ensure that enough variation was obtained or to at least better understand potential limitations. Demographic variables included in this table of descriptive statistics include typical variables such as age, gender, and self reported race, but will also include those more specific to this research. These include the following: degree in a science field and the level of that degree, degree in an education or teaching related field and the level of that degree, number of years teaching, type of science taught, and the completion of a NOS or history/philosophy of science course.

Using a Pearson product-moment correlation the first research question aims to understand if there is a relationship between the scores of the three subscales of the instrument, understandings of NOS, attitude towards evolution theory, and understanding of evolution theory. To determine if there is a relationship between the scores of each of the three subscales of the instrument a Pearson bivariate correlation matrix was inspected. If any of the three subscales have a Pearson product-moment correlation coefficient greater than 0.7, these scales will be combined into a composite score for the remaining analysis of the data. This assumption is on the basis that each of those highly correlated subscales are related enough to reduce multiple data analysis and the potential for Type I error (Pallant, 2007).

The second research question used multivariate analysis of variance (MANOVA) tests aimed to assess the performance on the three subscales based on the following three attributes: teachers with a science degree and those without a science degree, teachers with an education/pedagogy degree and those without an education/pedagogy degree, and teachers that have completed a history of science of philosophy of science course. Respondents were previously coded into groupings based on the criteria above. These groupings will be treated as predictors for the performance on the three subscales, which are the dependent variable. The use of MANOVA statistical analysis will determine if there is a difference among the different grouping which include the following, science content related degree only, education related degree only, science content and education degrees, science content and education degrees as well as completion of a NOS course. Additionally, from this statistical analysis one can interpret which group performed better on the three subscales.

Chapter IV

Results

This chapter of this study will focus on a description of the results that pertain to the two research questions previously mentioned for this study and analysis of the descriptive statistics of the sample. Through a Pearson product-moment correlation the relationship among the scores for the three subscales: understanding of NOS, understanding of evolution, and the MATE was analyzed for secondary science teachers. Through MANOVA tests the difference in scores for the three subscales among teachers with different educational backgrounds was analyzed. For a summary of the research questions, data collection and data analysis, refer to Table 2. This section will address the following:

1. Descriptive Statistical Analysis of Sample
2. Relationship Among the Three Dependent Variables
3. Analysis of Differences Between Groupings of Respondents for the Three Subscales

Table 2

Summary of the research questions, data collection instruments, and data analysis

Research Question	Data Collection Instrument	Data Analysis
Is there a relationship between the understanding of NOS principles, understanding of evolution theory and acceptance of evolution theory?	Scores for understanding of NOS, understanding of evolution and MATE	Pearson product-moment correlation
Is there a significant difference between teachers with an education degree, science degree, or completion of a NOS related course for the three subscales: understanding of NOS principles, understanding of evolution and acceptance of evolution?	Scores for understanding of NOS, understanding of evolution and MATE for individual groupings of teachers based on educational background	MANOVA

Descriptive Statistical Analysis of Sample

This section of the results will discuss the analysis of the descriptive statistics of the sample. Additionally, an analysis of the normality of the dependent variables will be addressed. The demographic block of the instrument collected the following information that served as potential independent variables or predictors: type of degree, level of degree, completion of a nature of science related course, overall number of years teaching, number of years teaching life science, and level of life science taught. The three subscales, the understanding of NOS and the understanding of evolution theory, and measure of attitude toward evolution (MATE) are the dependent variables.

Description of sample's independent variables or predictors. Of the 187 respondents 73.8% had a science education related degree of some level with 26.2% not having any degree related to science teaching or instruction. The majority of the science education degrees were at the graduate level with 57.2% of all respondents having completed a master's degrees as shown in Table 3. Only 11.8% had a bachelor's degree and 4.8% had a doctorate degree related to the science education field as shown in Table 3. Even though the majority of the respondents did have a degree in science education, only 19.8% of them completed a nature of science related course including history or philosophy of science courses. This was determined by the answer to a free response question in which respondents were asked to identify the type of NOS course in addition to the forced answer choice response. Respondents that named a course that was not a NOS related course such as biology or geology were not coded as having taken a NOS course. Of the teachers that reported completing a NOS related course, 63.8% were teachers with a bachelor's degree in a science content and participated in a graduate level science pedagogy program. In summary almost three-fourths of this sample had a science education related degree with many of them participating in a post-secondary teaching related program, but only one-fourth of the sample had completed a NOS related course.

Table 3

The Percentage of Respondents with Type of Degrees in Science Content or Science Education

Type of Degree	No Education Degree	Bachelor Degree in Education	Master Degree in Education	Doctoral Degree in Education	Total
No Science Degree	1.60 (3)	5.35 (11)	16.04 (30)	1.60 (3)	24.60 (46)
Bachelor Degree in Science	17.65 (33)	4.28 (8)	36.36 (68)	2.67 (5)	60.96 (114)
Master Degree in Science	5.35 (10)	2.14 (4)	4.81 (9)	0.53 (1)	12.83 (24)
Doctoral Degree in Science	1.60 (3)	0.00 (0)	0.00 (0)	0.00 (0)	1.60 (3)
Total	26.20 (49)	11.76 (22)	57.22 (107)	4.81 (9)	

Note. Number of cases are included in parenthesis

About three-fourths of the respondents in the sample had a science content degree. In order to qualify for this distinction respondents must have indicated the area of their science degree. This only includes those with hard science degrees such as physics, biology, chemistry, earth science, and other that are similar. It did not include majors such as psychology or anthropology. Of the 75.4% that had a science content degree, the majority had a bachelor's degree with only 14.43% having a graduate science content degree as shown in Table 3. It is interesting to note that there are less graduate degrees for a science content related fields than those earning advanced degrees in science education related fields. In conclusion the majority o this sample had at least a bachelor's degree in a science content major.

This sample had many respondents who had multiple degrees in both science content and science education related fields. In fact, 95 of the 187, which is slightly more than half, of the participants had a degree of some level in both fields. The largest category of respondents in the entire sample are those with a master's degree in science education and a bachelor's in science content, which composed more than a third of the sample, 36.36% as shown in Table 3. This indicates that many teachers in this sample participated in post-secondary master's licensure program as reported by the free response question to describe the type of education degree or program. This sample appears to have highly qualified teachers based on the definition of highly qualified as teachings with degrees in pedagogy or science content.

An overwhelming majority of the sample were biology or life science teachers with 88.2% reporting teaching life science at some level. Of the 187 respondents in this sample, 104 of them reported a degree in biology, which is approximately 55.6%. All of the biology or life science teachers had experience teaching at the secondary level. These educators have been teaching life science or biology for an average of 11.992 years, but an overall average of teaching any science course for 16.447 years. Therefore, this sample was very targeted towards life science teachers with the potential for strong content knowledge related to biology.

Analysis of normality of the dependent variables. The subscale measuring the respondents' knowledge of NOS had a maximum of 17 points possible, with 1 point for each response that demonstrated an understanding of NOS principles. The understanding of NOS had a normal distribution with a mesokurtic curve as depicted by the histogram shown in Figure 2 with most respondents clustered around the mean of 12.74 (*SD* = 2.22). The Normal Q-Q plot shown in Figure 3 provides a visual representation of the proximity of the observed values to the expected values for a normal distribution. The location of the data points roughly follows the straight sloped line in the normal Q-Q plot indicating normality of the NOS scores. The mean score for the understanding of NOS was 12.74 (*SD* = 2.22), which translated into a percent score of a 74.94% understanding of NOS. The scores ranged from a minimum of six to a maximum 17, a perfect score. There were four respondents earning the maximum possible. The distribution for the NOS subscale was normal with less variation on the higher end of the scores.

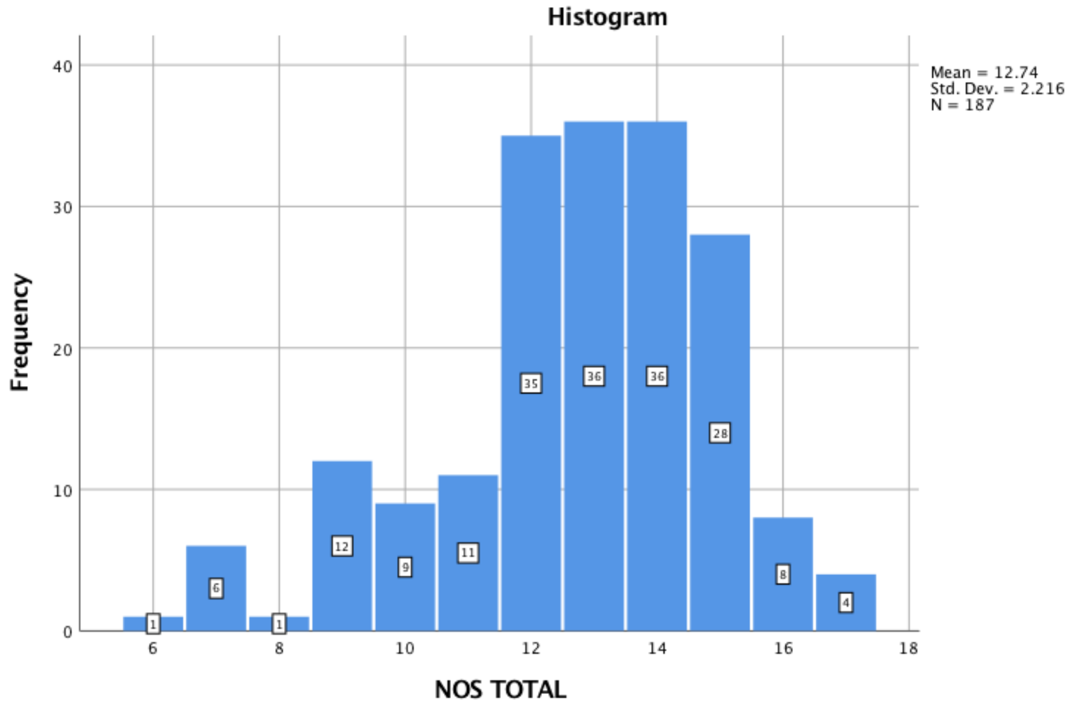

Figure 2. Understanding of nature of science histogram. Histogram showing the distribution of scores for the understanding of NOS subscale.

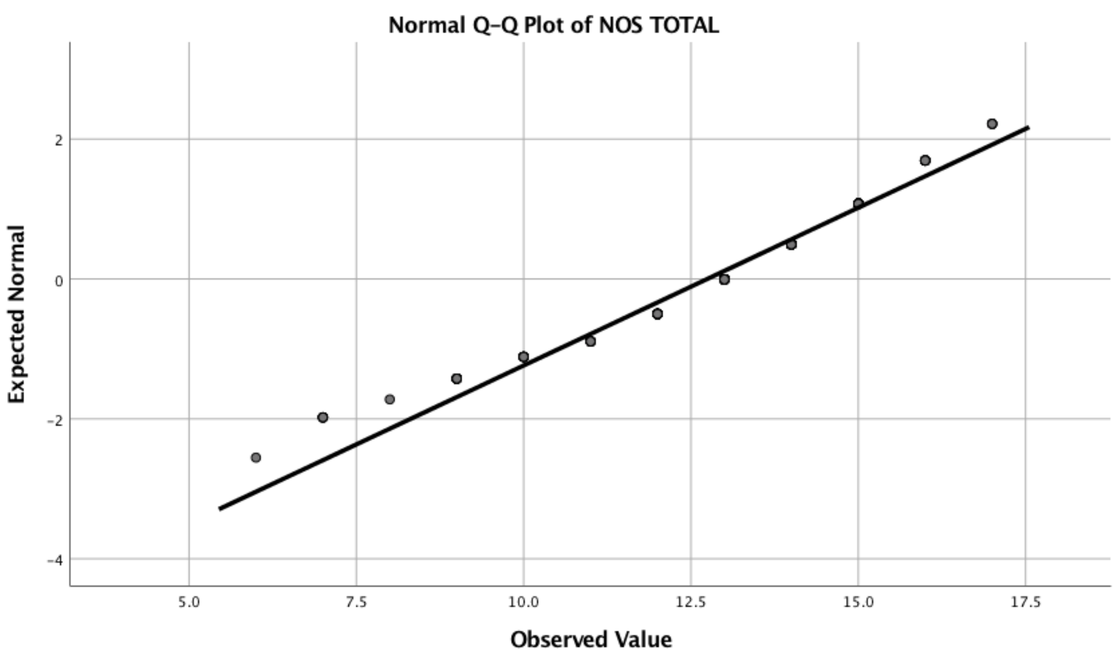

Figure 3. NOS subscale Normal Q-Q plot. Normal Q-Q plot for the scores of the understanding of NOS subscale demonstrating the normal distribution of the scores.

Even though the 88.9% of the sample were biology teachers, the understanding of evolution theory was not as high (M = 8.44, SD = 2.75). There were 20 respondents that recorded a perfect score on this section answering correctly all 12 of the multiple choice factual based questions. The mean score translates into an average score of 70.33%, when translated into a percentage. This implies that on average the understanding of evolution is not very strong, considering more than half of the sample had a biology degree. Additionally, this was the lowest scoring of the three dependent variables. Like the understanding of NOS, the data for the knowledge of evolution theory dependent variable also appears to have a normal distribution that is moderately skewed toward higher scores based on the histogram in Figure 4. The normal Q-Q plot in Figure 5 shows a scatter plot of the observed scores and the expected normal revealing that most data points are relatively close to the predicted standard line indicating normality in the data. Similarly, to the NOS subscale, there is normal distribution, but there is less variation among the upper extreme of scores resulting in negative skewness.

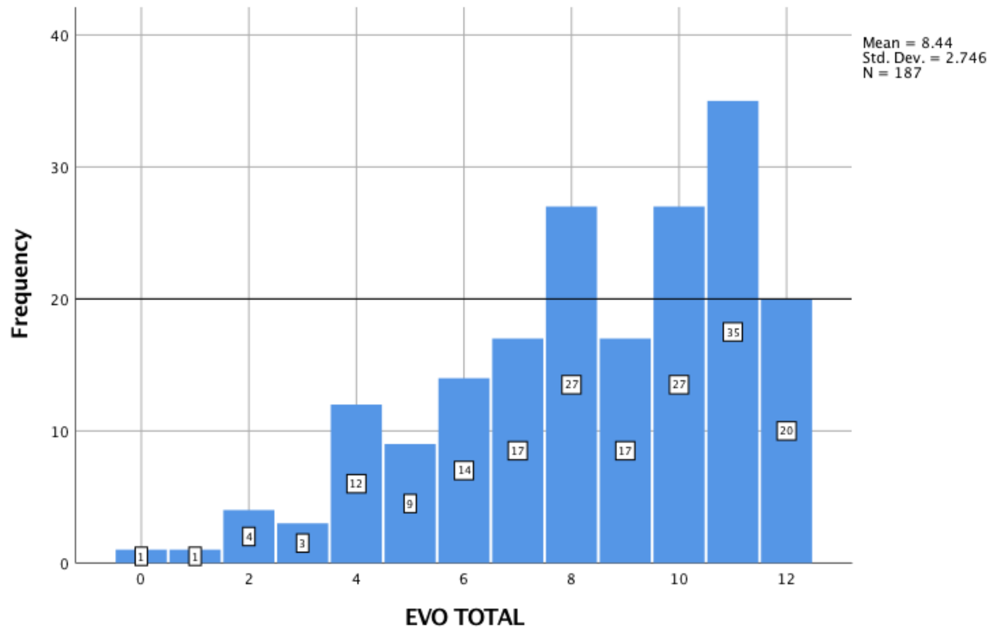

Figure 4. Understanding of evolution subscale histogram. Histogram showing the distribution of scores for the understanding of evolution theory subscale.

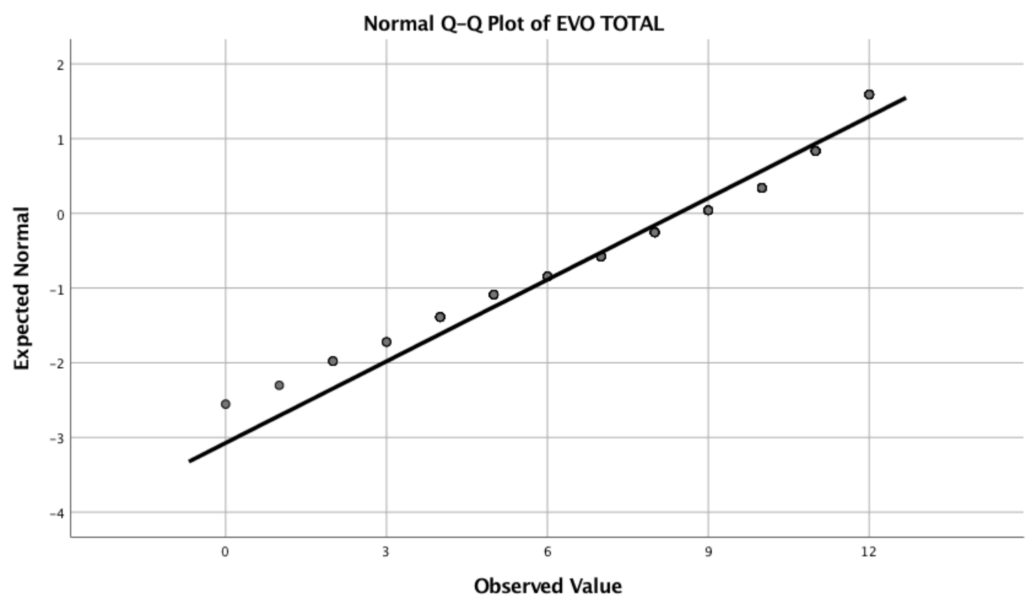

Figure 5. Evolution Normal Q-Q plot. Normal Q-Q plot for the scores of the understanding of evolution theory subscale demonstrating the normal distribution.

Even though respondents scored low for the knowledge of evolution theory, the scores for the MATE subscale were relatively high for the 20 questions (*M* = 18.60, *SD* = 3.40). The total score for the MATE was recorded by one point for each answer that favorable towards evolution theory for a total of 20 points. The respondents had a 93% favorable attitude towards evolution theory, when calculated as a percent, which was the highest score of all three dependent variables. A surprising 124 of the 187 respondents, which is 66.3%, recorded a 20 out of 20 for a favorable attitude towards evolution theory, making this sample very skewed towards a positive acceptance of evolution theory. Therefore, this dependent variable lacks a normal distribution as shown by the histogram in Figure 6.

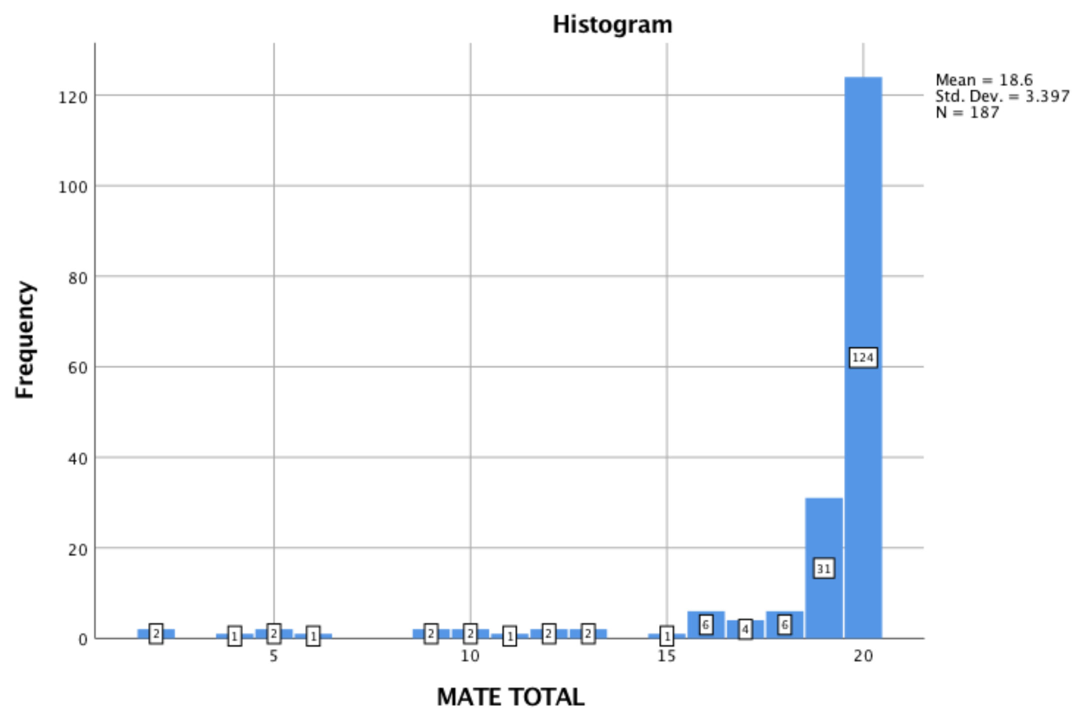

Figure 6. MATE subscale histogram. Histogram showing the distribution of scores for the MATE subscale.

Relationship Among the Three Dependent Variables

The relationship between the three dependent variables, which are the subscales of the instrument measuring the understanding of NOS, understanding of evolution theory and attitude towards evolution by the MATE instrument, was investigated using

Pearson product-moment correlation coefficient. All three of the subscales were found to have positive significant correlations between each other as shown in When the scores of any of the subscales increase, there is a strong likelihood that the other scores will also increase indicating either one of the subscales is affecting the others or there is a common factor influencing all of the subscales.

Table 4. The strongest positive correlation existed between the understanding of evolution theory and the understanding of NOS as shown in the scatter plot of the two variables in Figure 7. There were also positive correlations between the MATE scores and the understanding of NOS, as well as the MATE scores and the understanding of evolution theory, although these correlations were only of a moderate correlational strength. Since the MATE subscale had such a high mean, the scores may be skewed in such a way to prevent a stronger correlation from developing. Regardless the correlation between the variables indicates that there is a positive relationship between these three subscales that should be investigated. When the scores of any of the subscales increase, there is a strong likelihood that the other scores will also increase indicating either one of the subscales is affecting the others or there is a common factor influencing all of the subscales.

Table 4

Pearson Product-Moment Correlation Between the Scores for Each of the Three Subscales: Understanding of NOS, Understanding of evolution, and the MATE

Subscale	Understanding of NOS	Understanding of Evolution	MATE
Understanding of NOS	1	.504**	.332**
Understanding of Evolution	.504**	1	.357**
MATE	.332**	.357**	1

Note. **Correlation is significant at the 0.01 level (2-tailed)

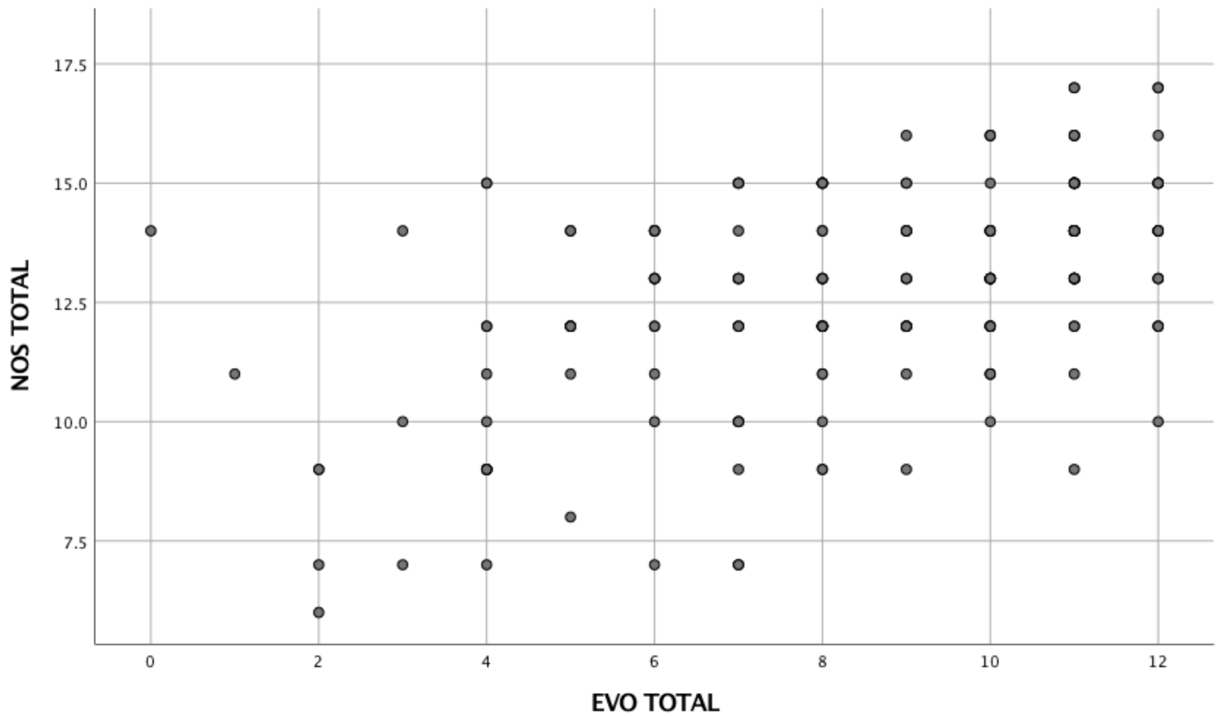

Figure 7. Scatter plot between understanding of NOS and evolution**.** Scatter plot showing the moderate correlation between the understanding of NOS and the understanding of evolution theory.

Analysis of Differences Between Groupings of Respondents for the Three Subscales

A one way between-groups multivariate analysis of variance was performed to investigate the differences on their performance on the three different subscales of understanding of NOS, understanding of evolution theory, and the MATE among teachers with different educational backgrounds. As shown in Table 5 the respondents were grouped according to their educational background, which served as the independent variable for the MANOVA. Groups will henceforth be referred to as their group name shown in Table 5. The number of cases for each of these groupings was either more or very close to the suggested value of 30 to reduce the impact of any future violations of normality or equality of variance, as shown in Table 5. Those with a science education related degree and the completion of a nature of science related course were excluded, as there were only nine cases. Additionally, there were only three cases of those who were had none of the criteria. There were no respondents with a science content related degree and the completion of a NOS related course. In conclusion only the four groups listed in Table 5 are included, which had a sample size of 174 respondents.

Table 5

Grouping of Respondents According to their Educational Background for MANOVA Analysis

Group Name	Description	N
ED	Respondents with only a science education related degree	34
SCI	Respondents with only a science content related degree	45
BOTH	Respondents with both science education and science content degrees	68
ALL	Respondents with both science education and science content degrees and completed at least one NOS related course	27

MANOVA analysis with the MATE dependent variable included. Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity. The inclusion of the MATE scores as one of the three dependent variables led to some violations of the preliminary testing. Multicollinearity was assumed among the three dependent variables, since all three had significant moderate correlations as shown in

Table 4. However, testing for multivariate normality using the Mahalanobous distance test revealed a maximum score of 26.20, which is higher than the recommended 16.27 for statistical analysis with three dependent variables. Additionally, Levene's test of equality of error variance also showed significance for the MATE subscale indicating that the scores had very little variance. This was previously observed in earlier analysis of the MATE scores. As a result, the MANOVA tests including all three dependent variables violated the assumption of homogeneity of variance-covariance matrices using Box's Test, which showed significance $p = .000$. With the large number of cases for each grouping, violations of normality or equality of variance do not have as much an influence. Therefore, the analysis of the MANOVA with all three dependent variables was performed with careful consideration that despite some violations, it did have enough cases. There was a statistically significant difference between the four groups on all three combined dependent variables, $F\ (9, 409) = 7.65$, $p = .000$; Wilks' Lambda = .69, partial eta squared = .12.

Table 6

Means of Scores for the Measure of Attitude Towards Evolution Subscale with a Maximum Score of 20 possible for the Four Different Educational Background Groups

Group Name	Mean	Standard Deviation	N
ED	16.41	5.24	34
SCI	18.11	4.22	45
BOTH	19.47	1.44	68
ALL	19.74	.53	27

Considering the results of the dependent variable separately, all three dependent variables reached statistical significance using a Bonferroni adjusted alpha level of .017, even the MATE, F (3, 170) = 8.02, p = .000, partial eta squared = .12. Using Tukey's HSD post hoc test on the MATE subscale there were statistical significant differences of the means between the ED and BOTH groups, as well as the ED and ALL groups, p = .000. The difference between the means of the MATE subscale for the ED and BOTH groups was 3.06, and the difference between the means of the MATE subscale for the ED and ALL groups was 3.33. As shown in Table 6, there was no statistical difference between the SCI, BOTH, and ALL groups for the MATE scores.

MANOVA analysis with the MATE dependent variable excluded. As previously mentioned in these results, the scores on the MATE were skewed towards the upper extreme, had little variation, and lacked a normal distribution, since 124 of the 187 responses scored a perfect 20 on this subscale. This led to violations in some preliminary statistical testing as mentioned in the above section. Despite the number of cases, which minimizes the violations, the scores on the MATE were excluded from MANOVA testing and only the differences among the four groups on the understanding of NOS and the understanding of evolution theory will be further addressed. By excluding the MATE as a dependent variable, assumptions of normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity were addressed with no violations observed. There was a statistically significant difference between the four groups on the combined dependent variables, F (6, 338) = 10.51, p = .000; Wilks' Lambda = .71, partial eta squared = .16. When investigating the dependent variables separately, both the understanding of NOS, F (3, 170) = 10.68, p =

.000, partial eta squared = .16 and the understanding of evolution, F (3, 170) = 18.74, p = .000, partial eta squared = .25 showed significant differences between the groups using a Bonferroni adjusted alpha level of .017.

Differences among groups for the understanding of NOS subscale. To further see how each of the groups differed individually on the understanding of NOS, the Tukey's HSD post hoc test was performed. The means do not appear to be visually much different from each other as shown in Table 7, yet the differences between means are statistically significant as shown in Table 8 between ED and BOTH, ED and ALL, SCI and BOTH, and SCI and ALL. The BOTH group, those with degrees in science education and science content, and the ALL group, those with both degrees and completion of a NOS related course, scored significantly higher on the understanding of NOS subscale than the groups that had only a degree in science content or science pedagogy. There was no statistical significant different between the ED and SCI groups, as well as between the BOTH and ALL groups. In summary those with both a science content degree and a science education degree performed higher on the understanding of NOS subscale, regardless if they completed a NOS related course.

Table 7

Means of Scores for the Understanding of NOS Subscale with a Maximum Score of 17 Possible for the Four Different Educational Background Groups

Group Name	Mean	Standard Deviation	N
ED	11.29	2.64	34
SCI	12.29	2.12	45
BOTH	13.46	1.63	68
ALL	13.63	2.15	27

Table 8

Difference in Means of Scores for the Understanding of NOS Subscale for the Four Different Educational Background Groups

Group Comparison	Difference in Means	Significance	95 % Confidence Interval	
			Low	High
ED & BOTH	2.16	.000	3.29	1.04
ED & ALL	2.34	.000	3.72	.96
SCI & BOTH	1.17	.019	2.20	.14
SCI & ALL	1.34	.041	2.64	.04

Differences among groups for the understanding of evolution theory subscale. To further see how each of the groups differed individually on the understanding of evolution theory subscale, the Tukey's HSD post hoc test was performed. As shown in

Table 9, the means for the ED group appear different, specifically much lower than the means of the other three groups, SCI, BOTH, and ALL. None of the other three groups visually appear to have different means for the knowledge of evolution theory subscale. In fact, the means of the ED group are the only statistically significant different group compared to the others, $p = .000$, as shown in Table 10. The other three are not statistically different from each other. In conclusion, those who have at least a science content degree outperformed those without a science content degree for the understanding of evolution theory subscale.

Table 9

Means of Scores for the Understanding of Evolution Theory Subscale with a Maximum Score of 12 Possible for the Four Different Educational Background Groups

Group Name	Mean	Standard Deviation	N
ED	5.82	2.79	34
SCI	8.58	2.47	45
BOTH	9.28	2.09	68
ALL	9.63	2.37	27

Table 10

Difference in Means of Scores for the Understanding of Evolution Theory Subscale for the Four Different Educational Background Groups

Group Comparison	Difference in Means	Significance	95 % Confidence Interval	
			Low	High
ED & SCI	2.75	.000	4.16	1.35
ED & BOTH	3.46	.000	4.75	2.16
ED & ALL	3.81	.000	5.40	2.21

Chapter V

Conclusions

This section of this study will focus on a discussion of the results and implications of those results as they relate to the research questions: relationships between the scores on the three subscales and how different educational backgrounds perform on the three subscales. This section will address the following topics:

1. Generalizability of Sample Based on Demographic Variables.
2. Discussion and Implications of Sample's Independent Variables.
3. Discussion of the Dependent Variables, the Scores of the Three Subscales.
4. Discussion of the Correlations Between the Three Dependent Variables
5. Discussion of the MANOVA Analysis
6. Implications of the Results on Teacher Preparation Requirements
7. Limitations of this Study
8. Improvements for Future Studies

Generalizability of Sample Based on Demographic Variables

Basic demographic variables of gender, race, and age were assessed for their generalizability with the United States' population of secondary science teachers, which is similar to the audience targeted in this study. The sample of 187 respondents was composed of 65.2% women and 33.7% men. These percentages reflect a similar breakdown reported in 2015 by the National Academies of Sciences, Engineering, and Medicine sample of 211,000 science teachers. The National Academies of Sciences, Engineering, and Medicine (2015) reported approximately 70% of middle school science teachers are females with more male representation in high schools with only 54% being female. Additionally, the race/ethnicity of respondents was 86.6% white, which again does not differ greatly from national studies reporting 90% or more of science teachers as white (National Academies of Science, Engineering, and Medicine, 2015). In this study, the age of respondents ranged from 22 to 69 years old with a mean age of 44.79 years. This is also comparable with data reported by the National Academies of Sciences, Engineering, and Medicine (2015) finding that most secondary science teachers are over 40 years old. Based on these comparisons gender, race, and age will not be considered as potential factors influencing the results henceforth in this discussion, since these demographic variables were analogous to descriptive studies of the demographics of secondary science teachers in the United States.

Discussion and Implications of Sample's Independent Variables

While there was generalizability for the demographic variables of age, race, ethnicity, and gender, there are several other characteristics of this sample that make it not generalizable. In particular, these all relate to the educational background of the sample. This section will discuss the differences in the educational background of this sample for the following specific topics:

1. Comparison of the percentage of teachers with science content or pedagogy degrees.
2. Comparison of teachers with advanced degrees in this study.
3. Variables the teachers in this study did not differ from previous studies.
4. The ole of NOS coursework and overall understanding of NOS in this study.

Comparison of the percentage of teachers with science content or pedagogy degrees. In this sample almost all of the teachers had either a science content or pedagogy degree, which is higher than other samples making it not as comparable to the general population of science teachers. According to the National Academies of Science, Engineering, and Medicine (2015) report of 211,00 science teachers, many science teachers do not have a science content, pedagogy or engineering based degree. In their study which compiled data from several databases including the National Center for Education Statistics' 2007-2008 Schools and Staffing Survey (SASS) and the 2012 National Survey of Science and Mathematics Education (NSSME), they specifically found that only 41% of middle school teachers and 82% of high school teachers had a bachelor's degree in science, engineering or science education. As shown in Table 3, only 1.60% of this sample had neither a bachelor's degree in science or science education, which indicates it is not generalizable to other studies. In conclusion 98.4% of the teachers in this study have either a science content or science education degree, which is considerably different from data reported in other studies and indicates this sample is highly educated.

According to the National Academies of Science, Engineering, and Medicine (2015), 35% of the teachers from their studies are more likely to have alternative certification than the average teacher. In this sample 73.8% had a formal science education degree. While it was not directly asked about teacher's licensure in this survey, it can be assumed that those with a pedagogy degree did not follow an alternative licensing path to teaching. Thus the remaining 26.20% without a science education degree most likely entered the teaching profession through an alternative method. This is lower than the data collected from the National Academies of Science, Engineering, and Medicine (2015), which suggests that our sample may again be different than the general population of secondary science teachers in the United States. In summary this sample has more teachers with science teaching degrees than other studies, perhaps less following a degree program route to teaching licensure than an alternative method.

Comparison of teachers with advanced degrees in this study. Not only do more of the participants appear to have science content or science education degrees separately, but many of them have degrees in both fields. In this sample 95 of the 187 respondents had degrees in both science content and science education related program as shown in Table 3. This does not seem to be a characteristic that other studies report. Only eight of those with degrees in both fields had a double bachelor's, which indicates in this sample that 87 had advanced graduate degrees in either one or both areas. Additionally, it was observed that our sample had a large number of advanced graduate degrees with 62% having a graduate degree in education and 14.4% with a science content graduate degree. According the National Science Foundation's Science and Engineering Indicators Study (2012), in 2007 58% of science teachers had a master's degree or higher. This sample had more teacher teachers with dual degrees and more advanced degrees compared to other studies.

Variables of the teachers in this study that did not differ from previous studies. This study was not limited to only biology of life science teachers, but the majority, 88.2%, of the teachers reported either teaching or having previously taught life science or biology. Also 104 of the 187, 55.6% of the entire sample had a biology related degree, which also may indicate why the sample was skewed for several of the dependent variables. It is important to recognize that biology teachers may have an advantage in topics related to evolution theory, especially since this sample had a large proportion of biology degrees. However, similar studies analyzing the relationship between NOS and evolution also predominantly target biology teachers (Rutledge & Warden, 2000; Trani, 2004). Thus it was concluded that it was appropriate for this sample to have a high number of biology majors and biology teachers.

The amount of time teaching a life science or biology course was similar to other previous studies with the average number of years teaching biology being as 11.99 years. The National Academies of Science, Engineering, and Medicine (2015) found that approximately half of science teachers in the United Stated had taught for more than 10 years. This sample does not appear different in teaching experience from the general science teacher population in the United States. Therefore, it seems that this sample differs from other studies by having teachers with more degrees of either type, including advanced degrees and more teachers with dual degrees in science content and pedagogy, but it does not differ for the teaching experience.

The role NOS coursework and overall understanding of NOS in this study. This study also inquired participants of their completion of a NOS related course, as did other previous studies (Rutledge & Mitchell, 2002). However, only 19.8% of the respondents reported completing a NOS of related course. This is not a large portion of the sample and thus a larger data set that includes more teachers with NOS specific coursework is needed. Future studies could specifically target teachers who have competed NOS related coursework as part of a degree program compared to teachers in a degree program that did not require a specific NOS course.

In this survey, respondents not only answered a forced question regarding their completion of a NOS related course, but also identified the name of the course. By looking at the responses in the free response portion, it was apparent that many of the respondents may not know what a NOS related course was. For example, several respondents who answered yes to completing a NOS related course, listed biology, geology, or a natural science as the specific name of the NOS course. This implies that these participants do not know what NOS is and were confusing NOS with natural science. Given that the population in the United States has an adequate understanding of NOS as shown by the 2000 adults survey revealing 64% lacked any comprehension of NOS, it is not surprising that respondents did not understand this question on the instrument (McComas, Clough & Almazroa, 1998). It may be necessary to have follow up studies in which respondents report their completion of NOS related courses through means other than just a forced answer choice or a free response, but perhaps require interviews to verify their responses to describe the content and focus of the course.

Discussion of the Dependent Variables, the Scores on the Three Subscales

Measure of attitude towards evolution (MATE) scores. The respondents had a 93% favorable attitude towards evolution theory with the score calculated as a percent, which is much higher than scores measured by previous research using the same MATE assessment. This is higher than the 77.59% favorable response recorded in the study of Indiana teachers by Rutledge and Warden (2000) and the 85.9% in the study of Oregon teachers by Trani (2004) both used the same MATE instrument. Additionally, this is much higher than the 40% reported by Miller, Scott, and Okamoto (2006), which used a different instrument and studied the general population of the United States and not just science teachers, as part of an international comparison study of among 32 European nations, Japan, and the United States. The United States was ranked as the second lowest approval ratings of evolution theory besides Turkey in this study. While it is expected that life science teachers would score higher on the MATE than the general population in the United States, there may factors that influenced the results to be heavily skewed towards the upper extreme scores.

Perhaps one reason for the elevated scores on the MATE in this study is the elimination of the Likert five-point answer choice, which was previously used by other researchers for the MATE. Statements were either “agree” or “disagree”, which forced respondents to make a decision on their attitude towards evolution. Based on preliminary studies from focus groups and pilot studies, participants felt the five-point Likert scale was unnecessary and in actuality it was a dichotomous decision. Furthermore, it was reported that the word “strongly” felt odd to them because many reported they simply either agreed or disagreed with the statement. They may not have personally cared enough about the issue to rank this as a strong, passionate emotion. They indicated it did not mean they accepted evolution any less because they chose “agree” versus “strongly agree.” It was concluded that only “agree” and “disagree” were sufficient to capture whether respondents accept evolution. Thus studies that distinguished between a range of agreement may not report as high of an agreement as this study indicates.

Additionally, no “undecided” or “neutral” option was provided for the MATE. This may have elevated the scores because those that were ambivalent to evolution were forced into making a dichotomous decision. As observed by Miller, Scott, and Okamoto (2006), Americans are increasingly becoming more ambivalent towards evolution with less overtly accepting or rejecting evolution theory. This study did not provide an answer choice to capture the ambivalence. When not presented with that option, however, respondents were forced to choose, which may have led to an inflated positive scores for the attitude towards evolution. Nevertheless, if respondents in this study felt ambivalence towards evolution they overwhelming leaned towards a more positive attitude than a viewpoint that rejected evolution theory, thus indicating this sample indeed had a higher acceptance of evolution theory.

Another factor that may be influencing the elevated scores for the MATE could be related to the educational background of the sample. As Rutledge and Mitchell (2002) demonstrated in their study, teachers with more than 40 hours of coursework in biology were significantly more likely to report a positive attitude towards evolution. Of the 187 respondents in this sample, 104 of them reported a degree in biology, which is approximately 55.6%. In this sample 88% reported being a life science or biology teacher. This may mean that this sample is more likely to be accepting of evolution, simply because of education background or subject taught. Additionally, this sample has more teachers reporting that they earned a degree in science or science education than the studies by the National Academies of Science, Engineering, and Medicine (2015) as previously mentioned in the discussion of the generalizability of the independent variables of the sample. There are also more advanced degrees for either science content or science education related degrees and with some respondents having graduate degrees in both. Given that this sample had more science degrees specifically biology, more education degrees, as well as many earned graduate degrees, the results for the MATE may be skewed very positively for an acceptance of evolution theory and did not have a strong normal distribution, as a result.

Understanding of NOS subscale's scores. For the understanding of NOS the mean score was 12.74 (*SD* = 2.22), which translates to an average score of 74.94%. There were only four respondents earning the maximum possible points of 17. This is higher than the scores Rutledge and Warden (2000) measured in their sample of Indiana teachers, which had an average of 69.99% and those measured in Oregon by Trani (2004), which had an average of 66.08%. Research suggests that teachers need to be taught NOS, which means that teachers participating in a degree that focus on science pedagogy may be more likely to have a stronger understanding of NOS principles due to exposure to instruction of NOS (Abd-El-Khalick, 2001; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2007). More than 73% of teachers in this sample had a science pedagogy degree, which may affect the elevated NOS of scores observed in this present study. Only 19.8% of teachers had completed a NOS related course though, which may not be enough to determine the affect on the understanding of NOS scores. Regardless of a low proportion having completed NOS coursework, this sample had more teachers with a science education degree, which may have influenced the elevated NOS scores compared to other studies.

Understanding of evolution subscale's scores. The teachers in this sample only scored an average of 70.33% on the evolution theory knowledge portion of the instrument. This is not as high as the teachers in Trani's (2004) study where the teachers earned an 83.38%, but similar to the results measured by Rutledge and Warden (2000), which was a 71%. This may be a result that this portion of the instrument was shortened so length of the instrument did not discourage participants from completing the survey. To prevent any change in the relative scores by removing the more difficult or the easier questions, items were removed based on the scores in Rutledge and Warden's (2000) study. In other words, the questions that were most often answered correctly were equally removed from this instrument as the ones that were these least answered correctly to preserve the typical average score.

Discussion of the Correlations Between the Three Dependent Variables

All three of the dependent variables had statistically significant correlations. However only the understanding of NOS and the understanding of evolution theory had a strong correlation, $r = .504$, $p = 0.01$. The other two correlations were only a moderate level, which may be because the lack of normality of the MATE dependent variables, due to 124 of the 187 respondents earning a perfect score on this subscale. There was enough of a correlation to show there was a relationship between the three dependent variables and that further investigation is needed to explore how they are related and impacted the independent variables. The moderate correlation of the dependent variables also allowed for MANOVA statistical analysis, since the dependent variables are correlated but not so much that the variables lack singularity.

The findings of these studies are similar to others that show there is a connection between a teacher's knowledge of NOS and knowledge and attitudes toward evolution theory (Lombrozo, Thanukos & Weisburg, 2008; Nelson, Nickels & Beard, 2000; Rutledge & Warden, 2000; Trani, 2004). In Nelson, Nickels, and Beard's (2000) after direction instruction of evolution with a NOS framework, teachers reported not only being more comfortable wit these topics, but also more competent in their teaching. Rutledge and Warden (2000) found strong positive correlations between the MATE and the knowledge of evolution, r =0.71, and the MATE and knowledge of NOS, $r = .76$.

While the correlations in this study were only moderate and not as strong as these previous findings, it most likely is due to the fact that the scores on the MATE were heavily skewed towards the upper extreme with 124 of the 187 respondents getting a perfect score. Trani (2004) also found a strong positive correlation between the MATE and the knowledge of evolution, $r = .70$. Just as previous studies have shown there indeed is a relationship between the understanding of NOS, the understanding of evolution, and the acceptance of evolution.

Discussion of the MANOVA Analysis

The MANOVA analysis was used to answer the second research question regarding how different educational backgrounds impacted the scores on the three subscales. This section will discuss the analysis and implications of those statistical analysis regarding the following topics:

1. Statistical issues with MANOVA.
2. Overall discussion of the differences between the groups.
3. Discussion of the group differences for the MATE subscale.
4. Discussion of the group differences for the understanding of NOS subscale.
5. Discussion of the group differences for the understanding of evolution subscale.

Reasons for statistical issues with the MANOVA analysis. The one way between-groups multivariate analysis of variance had some statistical violations for preliminary tests, when all three of the dependent variables were involved. The violations included the test for multivariate normality, equality of error variance, and assumptions of homogeneity of variance-covariance matrices. Although there were close to 30 or more cases for each of the four groupings, which some suggest is sufficient numbers to minimize the effects of the violations from the preliminary testing. As a result, the MANOVA was performed both with and without the MATE subscale scores, since the MATE subscale was the issue of concern. The MATE subscale, as previously discussed, showed a lack of normality, since 124 of the 187 scores were perfect scores supporting a positive acceptance of evolution theory. The results were positively skewed with very little variance. Once removing the MATE subscale, there were no violations for further MANOVA statistical testing. The remaining two subscales both demonstrated normality in their data sets. This sample has some differences from the general population regarding the percentage with science content and science education degrees, and advanced graduate degrees. These may be influencing the MATE scores and thus causing the violations.

Overall discussion of the differences between the groups. Through MANOVA tests the different groups were found to be statistically different in their performance for the combined dependent variables relating to the knowledge of NOS and evolution theory, but not the MATE scores. Further investigation on a case by case basis reveals there were seven cases in which respondents scored higher than 90% on all three dependent variables subscales. Of these seven cases, six of the respondents were teachers with both a science content and science education degree. Only two of that six with dual degrees reported completing a NOS related course. While this is not statistical data, it does help support the importance for teachers to have a strong understanding of content and pedagogy. Additionally, it shows the importance of explicit instruction during a teacher's preparation through a dedicated course for NOS as indicated by previous researchers as necessary (Abd-El-Khalick, 2001; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2007).

Discussion of the group differences for the MATE subscale. On further analysis of the differences between the groups for the MATE subscale it was shown that the ED group had statistically lower acceptance ratings than the BOTH and ALL groups, indicating that a science education degree did not influence the performance on the MATE. The ED group was not statistically different from the SCI group. This suggests that having both science content and science pedagogy degrees leads to a higher acceptance rating of evolution theory over just an education degree. Those having only a science degree did not show any significant differences from any of the other groups. The education degree by itself is not impacting the MATE scores.

These findings that both content and pedagogy coursework is important for teachers' attitudes towards evolution is comparable to that of other similar research. Nelson, Nickels, and Beard (2000) felt that teachers need to teach evolution within a NOS framework and offered summer institutes. Participating teachers drastically increased their volume of time committed to teaching evolution in their classrooms by increasing the instructional days from 19 to 32 and an additional 6.5 days the following year. Other studies have also shown that when teachers receive NOS related instruction their acceptance of evolution increases (Berkman & Plutzer, 2010; Lombrozo, Thanukos, & Weisberg, 2008). Whereas those with low knowledge of NOS and evolution will have a low acceptance of evolution (Bishop & Anderson, 1990). Thus, it is having both the content to understand the concepts and the NOS background to appreciate the significant role of evolution in biological studies, that leads to a more positive attitude towards evolution theory, as shown by the results of this study.

Discussion of the group differences for the understanding of NOS subscale. The NOS subscale showed similar findings to the MATE subscale. Again those that had both a science content and science education related degree scored significantly higher on this subscale that measured knowledge of NOS. There were no statistical differences between the ED and SCI group, indicating that just having one of the two types of degrees is not sufficient to increase the NOS understanding score. The ED and SCI groups were both statistically lower than the BOTH and ALL groups. There was, however, no difference between the BOTH and ALL groups, which does suggest that a specific NOS course does not have an impact on increasing the NOS subscale score. The lack of statistical difference between the BOTH and ALL groups may be due to a limited number of cases that had completed a NOS related course in addition to having degrees in both fields. A larger sample size with more participants that completed a NOS course may have alleviated this issue. According to this data set, those with both degrees have a higher understanding of NOS, not the completion of a NOS related course as predicted.

These results indicated the necessity to create teachers that are content and pedagogy experts. It has been shown that in order for teachers and their students to understand topics such as evolution, a greater understanding of NOS is required. Yet the research on how to improve the understanding of NOS has been conflicting in the literature. Kimball (1968) showed there was no difference between science teachers and scientists on NOS scores, which is similar to the finding by Schwartz, Lederman, and Crawford (2004) that giving teachers scientific research experiences did not have a change on their NOS scores. Some studies have shown that an increase in the number of science courses does lead to an increase in NOS (Berkman & Plutzer, 2010; Carey & Stauss (1968, 1970a). Careful exploration should investigate to see if these content courses taught science within a NOS framework. Billeh and Haan (1975) found in a controlled experiment that teachers presented content without a NOS framework did not have the gains of the groups that did, thus indicating similar to this study that NOS scores improve with both science content and pedagogy coursework for pre-service teachers.

This sample did not have many respondents that completed a specific NOS related course, which may be the reason there was not a difference between this group's scores. A significant amount of research has shown that an isolated NOS course did not have a significant difference in the gains in NOS scores when compared to NOS integrated into scientific subject matter (Abd-El-Halick, 2001; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2007). The important factor is that NOS instruction is happening in some form. A sample with a larger proportion of teachers completing a NOS course would be needed to give more confidence in this finding that a specific NOS course is not significant impacting the NOS scores. Additionally, an exploration of the coursework reported and follow up interviews may be needed, since it was revealed that respondents did not clearly understanding of the term, NOS, and thus had difficulties describing courses. In summary based on the results of this study the effects of a specific NOS are inconclusive at this time.

Discussion of the group differences for the understanding of evolution subscale. The analysis of the understanding of evolution theory subscale revealed findings that are different than the other two dependent variables. For this subscale the

ED group's score was statistically lower than all of the other groups. There were no other differences between groups that were statistically significant. This suggests that teachers with only an education related degree do not have the necessary content knowledge to demonstrate a high understanding of evolution theory. The important factor to have increased scores for the knowledge of evolution theory is to complete a science content degree.

In order to understand evolution and perhaps other fundamental scientific concepts, teachers need to have mastery of their content. Many teachers complete education programs that focus more on pedagogy than the actual content with the assumptions that teachers can learn it as go. In fact, pre-service teachers do not value the necessity for content mastery reporting that they felt teaching was only 10% content master (Berkman & Plutzer, 2010). Yet in this same study, it was found that the teachers with more science credits teachers spent more time evolution, more straightforward and did not include non-science alternatives in their instruction. The teachers that rated their knowledge as lower were the ones that presented ambiguity and allowed misconceptions to persist in their instructional practice. Thus it is absolutely necessary for teachers to have a strong command of their subject matter.

Implications of the Results on Teacher Preparation Requirements

This research aims to further understand the relationship between teachers' understandings of NOS and how it impacts their attitudes toward and knowledge of evolution theory. Evolution theory, which is the basis of modern biology study, is currently poorly understood by the American general public and often is not taught well that enables for student understanding in biology classes (Miller, Scott, & Okomoto, 2006). Previous research has studied many different angles of the topic of NOS and its effect on other aspects of science education including the acceptance knowledge of evolution theory. Previous research has also explored what demographic variables influence teachers' understandings of NOS including completion of a NOS or history/philosophy of science course, pedagogical training, and scientific knowledge (Abd-El-Khalik, 2005; Billeh& Hasan, 1975; Carey & Stauss, 1968; Carey & Stauss, 1970a; Carey & Stauss, 1970b; Lederman, 1992; Lederman, 2007; Morrison, Raab, & Ingram, 2009). However, this study attempts to see how these demographic variables serve as predictors for the three subscales: understanding of NOS, attitude toward and the understanding of evolution theory.

The findings from this research reveal the necessary background coursework to better prepare teachers to positively impact students' learning of evolution theory. According to the present study, having both a science content and science education degree led to an increase in scores for the MATE and the understanding of NOS subscale. It was determined that having only an education degree was not sufficient to lead to a strong understanding of evolution theory. Slightly more than 50% of this sample had duel degrees in both field with 36% having a participated in a post-secondary degree in science teaching after completing a science content bachelor's degree. The scores on these subscales were either higher or on par with scores from previous studies, which may be a result of the number of respondents with background in both content and pedagogy. Programs to prepare science teachers need to consider providing both the content and pedagogy necessary for teachers to have mastery of their subject and have a comprehension of science as an enterprise.

As shown in Lavech's (1969) study, no other variables other than the inclusion of NOS in the educational background influenced teachers' understanding of NOS. The instruction of NOS must be included in pre-service teacher programs. Additionally, Berkman and Plutzer (2010) argue that this mastery needs to occur before teachers enter the classroom due to lack of opportunities to reflect and assimilate concepts into their instructional practice. Also the availability of time and access to quality professional development that can lead to long term last effects is limited. It has been shown that in order for changes to permanently integrate into a teacher's practice there is a need for long term mentoring with opportunities for practice, reflection, and growth (Akerson, Cullen & Hanseon, 2009; Nelson, Nickels, & Beard, 2000; Posnanski, 2010). Thus teacher induction programs should specifically include both content courses that utilize a NOS framework in addition to pedagogy courses dedicated to NOS.

In addition to the design pre-service teacher programs, this research helps impact educational policy. First standards should include NOS related standards and encourage them to be integrated into the instructional practice, not just a separate content topic to be covered. Second educational policy can consider the requirements for secondary science teaching certification. Teachers should be required to complete NOS related courses that include more than just the content of NOS, but how to teach science content within a NOS framework. Additionally, teachers should be required for teaching certification to demonstrated content mastery of their subject. Teachers will not develop pedagogical content knowledge without direct instruction of content and opportunities to reflect on their instructional practices of that content. Curriculum leaders will want to adopt practices that encourage teachers to approach instruction of science with a NOS mindset and abandon methods that focus on content only. It is evident through this research that much can be changed about how teachers approach the science instruction and that this needs to be reflected in standards, educational leadership, and certification requirements.

Limitations of this Study

As with all studies, the one at present had several limitations that need to be considered carefully. This section will address the following limitations:

1. Issues with Likert scale answer format.
2. Issues with interpretations of the NOS subscale's statements.
3. Issues with length of instrument.
4. Issues with internet based distribution and timing.

Issues with Likert scale answer format. Rutledge and Warden (2000) originally had a five-point Likert scale to allow for strength of agreement, which seems unnecessary as to whether they have an understanding of NOS. After discussion with a panel of graduate students in a survey methods course and with a pre-study focus group, the NOS knowledge measures were changed from a scaled-response format to a correct/incorrect answer format. This reflects that these measures are not attitude scales (agree to disagree) but measures of established content knowledge. This also eliminates the possibility of someone with a higher understanding of NOS having a more average score due to an artifact of the scaled design. In addition, the change allows for improved statistical analysis methods. Previous researchers utilizing a similar survey often average the results of all responses for statements within the understanding of NOS subscale to provide a single score for each respondent (Rutledge, 2005; Rutledge & Warden, 2000; Trani, 2004). However, Likert scale data should not be treated as interval-ratio data, since it is categorical data (S. Day, personal communications, Spring 2015; Ramos, personal communications, Fall 2015). These previous studies would compare averages among groups of participants in a manner that may misrepresent the data.

After similar feedback from a panel of graduate students in a survey methods course and with a pre-study focus group, the attitude towards evolution theory measures were changed from a scaled-response format to a correct/incorrect answer format. There was very little gradient in the degree of agreement with the statements from the pilot study. Compared to the other two subscales, which are knowledge based, it would be statistically appropriate to assess the attitudes of the respondents towards evolution theory with a five-point Likert scale. However, calculation of averages of Likert scale data may not accurately represent the respondent's actual attitude of evolution theory and instead give the appearance of a more neutral attitude. Furthermore, using a Likert answer format does pose an issue of categorical data being averaged into a composite score that is then correlated to other data points that are not categorical data (S. Day, personal communications, Spring 2015; Ramos, personal communications, Fall 2015).

Further, more issues with averaging Likert scale data are problematic in that there is no baseline established for what constitutes an adequate understanding of NOS or an attitude of a positive acceptance towards evolution theory (Lederman et al., 2002). Researchers do not know the numerical values to assign labels to scores for NOS assessments, mainly because qualitative measures are not always included to clarify the respondents' understandings of NOS or attitudes of evolution theory (Lederman, 1986). Qualitative measures can not only help improve the ability to assign numerical values or assign labels such as adequate or inadequate, but also improve the content validity of the items in the instrument.

Issues with interpretations of the NOS subscale's statements. In the interviews with a pre-study focus group of experts and discussions with a panel of graduate students in a survey methods course it was apparent that the understanding of NOS subscale was the most problematic in terms of content validity and the instrument's ability to measure what it intended. These findings are similar to the critiques of Lederman et al. (2002) regarding instruments to assess the views and understanding of NOS. The assumption that the respondents interpret the statements similar to that of the interpreters is a major validity threat (Lederman et al., 2002; Aikenhead, Ryan, & Fleming, 1989; Lederman & O'Malley, 1990). Conception of NOS is a topic poorly understood and taught to students and pre-service teachers, so it is illogical to assume that a sample representative of the population of science teachers in the United States would have the same vocabulary or word usage compared to experts designing the instrument. Often the items include jargon that is familiar only to those with a high degree of understanding of NOS and appears ambiguous and unclear to those that have not yet been exposed to formal discussions on NOS.

Similar to previous research, only through interviews of a pre-study focus group of experts and discussions with a panel of graduate students in a survey methods course were the misinterpretations and misunderstandings made evident (Lederman et al., 2002). The discussions with the peer review panel of graduate students in the survey methods course were particularly enlightening to tease out these ambiguities, since they were not experts or familiar with conceptions of NOS. Therefore, results to the pilot study more likely an artifact of the instrument than a valid representation of the respondents' understanding of NOS. Several of the statements required clarification from the peer review panel and required qualifier words. It was observed that the wording and vocabulary in the version utilized by Rutledge and Warden (2000) was significantly changed from the original version designed by Johnson (1985), perhaps as a result of qualitative interviews or discussions.

In addition to the risk that participants do not understand the jargon of NOS forced choice instruments, it is apparent from this study that many teachers do not understand term, nature of science, itself. The fact that many teachers cannot correctly identify NOS courses indicates that many teachers are not prepared to integrate NOS into the curriculum and just are ignorant of an important science pedagogical concepts shown to enhance the teaching of science.

Issues with length of instrument. Both the pre-study focus group of experts and discussions with the panel of graduate students in a survey methods course felt the length of the pilot study was too long and discouraged completion by respondents. While the pilot study did not attempt to reach a large audience, for this study a much larger sample size is desired. As with any Internet distributed survey such as this, a low response rate is anticipated regardless of the specifics of the instrument. A lengthy and repetitive survey discourages survey completion and may reduce the response rate even more. For the pilot study the number of questions from the initial survey by Rutledge and Warden (2000) was revised and reduced from the original 21 questions to 12 multiple-choice questions. The pre-study focus group of experts provided feedback for the selection of the 12 multiple-choice utilized in the pilot study. Questions were considered on their relevance to the content knowledge taught in the evolution unit of a high school biology class based on the Next Generation Science Standards.

Issues with internet based distribution and timing. There are several limitations to the survey methods employed in this research. First and foremost is the ability to collect the data. Given the nature of Internet surveys, only approximately 10% of those contacted through email responded to the survey. It is difficult to assess how many of the original 2500 emails were successfully targeted as many emails bounced back due to teachers no longer working at the school associated with the email address. There also was little incentive for participants to complete the survey, other than a small monetary $5 Amazon gift card.

Another potential limitation of the survey distribution via the Internet is the ability for respondents to be dishonest and cheat on answers. Internet surveys can help protect anonymity that is often not felt with face to face surveys. The integrity of answers could be compromised as respondents, despite the anonymous nature of the survey, may have felt pressure to answer the questions correctly and may have utilized the Internet to research their answers. Qualtrics records the amount of time for respondents to complete the questions. Correlations between the duration participants spent completing the survey and the scores does not indicate that those taking longer amount of times led to higher scores on any of the dependent variables.

Improvements for Future Studies

There are several improvements that should be considered if repeating this study to replicate results for other sample of teachers or a different audience. Additionally, there are several considerations for future studies to learn more about the relationship between the three subscales: understanding of NOS, understanding of evolution, and the MATE. There also is additional information to be learned about the factors that influence secondary science teachers understanding of NOS, understanding of evolution, and their acceptance of evolution. This section will address the following:

1. Sampling improvements.
2. Test format issues.
3. Inclusion of qualitative NOS assessments.
4. Inclusion of interviews.
5. Future studies beyond teachers' understanding and acceptance of NOS and evolution theory.

Sampling improvements. One of the major issues with this study is that the number of participants that reported completing a NOS related course was low. For future studies it may be useful to target samples of teachers that have completed a program that specifically requires a NOS related course. It may be useful to find two different programs with similar structure with the exception of the NOS course and determine how the teachers' scores change for the three dependent variables before and after completion of the NOS related course.

Test format issues. While it still may not seem appropriate to include a five-point Likert scale answer choice format. For the MATE it may be useful to add a third option that allows participants that are ambivalent on evolution related topics to choose an undecided option. For sake of symmetry in the subscales the undecided option could be added to the understanding of NOS, however more testing needs to be performed to determine if this is necessary. According to feedback from focus groups and pilot studies prior to this present study, the understanding of NOS were statements that were of a true or false nature and not a matter of agreement. Therefore, an undecided option may not make sense for this subscale.

Inclusion of qualitative NOS assessments. Currently the VNOS-C (see Appendix G) is a well verified and trusted qualitative assessment for assessing the understanding of NOS principles. Previous researchers have determined that NOS concepts are so poorly understood that measuring NOS knowledge through a forced choice assessment is problematic due to the differences in science literacy on the topic between researcher and respondent. While the VNOS-C does clarify and provide insight to the participants understanding of NOS, it poses other issues. While both assessments are well established, the two do not directly relate with each other. In fact, one can argue that the forced choice NOS assessment used in this survey measures NOS, as well as methods and inquiry going beyond just the agreed upon principles of NOS. Careful consideration of how the two assessments align will need to be performed by a panel of experts to determine which principles of NOS are assessed by each question to guarantee that both assessments are measuring similar aspects of NOS. Otherwise it may be possible to have two different scores that are not comparable for the two instruments.

Inclusion of interviews. One way to avoid the issue of utilizing a qualitative assessment such as the VNOS-C that does not directly correlated with the forced choice assessment used in this present study, is to interview a subset of the sample. A solid standard interview protocol needs to be developed to guarantee that the interviewer does not provide too much explanation of the concepts or leads the participants towards a respond, but only enables the respondents to explain their reasoning and expand on their thoughts of NOS. Additionally, the interview process would allow a quality check on the reporting on the type of degrees and the type of NOS related courses. Participants struggled to provide necessary details and were vague in their descriptions of their degrees and coursework. It was not always clear whether participants completed a science content or science education degree or if they actually completed a course that would be considered a NOS related course.

Future studies beyond teachers' understandings and acceptance of NOS and evolution theory. In addition to the items included in this survey, future versions of the survey could include questions that probe how much time teachers spend on evolution topics throughout the school year. Follow up studies could investigate further through a case study approach to observe teachers' practices in the classroom and their approach to teaching evolution in the classroom. These classroom observations could be correlated to their scores on the three subscales to determine if there is a difference in the teaching of evolution. This gives value to the research of studying teachers' performance on the three subscales, to determine if performing better on these assessments translates to better teaching of evolution in the classroom. This can be further expanded to include observations of students learning of NOS and evolution, as well as students performance on instruments similar to the three subscales included in this present study.

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Appendix A

Rutledge and Warden (2000)'s Instrument Measuring the Understanding of NOS Subscale

For the following items, please indicate your agreement/disagreement with the given statements using the following scale.

A	B	C	D	E
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

42. The goal of science is the improvement of man's quality of life.

43. Scientists must limit their investigation to the natural world.

44. The scientist is limited to the investigation of phenomena, which are directly observable by the senses.

45. A theory has been corroborated by many scientific facts.

46. Scientists must be accepting of all findings of their fellow researchers.

47. If an experiment yields results, which are contradictory to one's hypothesis, one should find other ways to corroborate the hypothesis.

48. The theory of evolution must deny the existence of a creator-God

49. A hypothesis is a guess based on a premonition.

50. Scientific experiment must be repeatedly performed to be considered valid.

51. Any scientific finding that contradicts religious doctrine should be discarded.

52. A hypothesis must be capable of being tested in order for it to be in the realm of science.

53. To make any scientific determinations about historic occurrences in nature, there must be direct human observation.

54. As a result of scientific methods, definite conclusions can be made to the absolute and ultimate cause behind an event.

55. Science can never reach absolute truth about a particular phenomenon in nature.

56. Science is well prepared to investigate the validity of miracles.

57. A hypothesis, which has been validated by an experiment, is elevated to the level of theory.

58. A fact in science is a truth, which can never be changed.

Appendix B

Rutledge and Warden (2000)'s Instrument Measuring the Understanding of Evolution Theory Subscale

For the following questions, circle the letter that is the best answer.

21. The evolutionary theory proposed by Charles Darwin was:
    A. Change in populations through time as a result of mutations
    B. The spontaneous generation of new organisms
    C. The passing on of genes from one generation to the next
    D. Change in populations through time as a response to environment change
    E. The development of characteristics by organisms in response to need

22. The wing of the bat and the forelimb of the dog are said to be homologous structures. This indicates that:
    A. They have the same function
    B. Bats evolved from a lineage of dogs
    C. They are structures which are similar due to common ancestry
    D. The lib bones of each are anatomically identical
    E. They have a different ancestry but a common function

23. Using radioactive dating techniques, the first life seems to have appeared on the earth about:
    A. 10 thousand years ago
    B. 270 million years ago
    C. 3.3 billion years ago
    D. 4.5 million years ago
    E. 10 billion years ago

24. Which of the following phrases best describes the process of evolution?
    A. The development of man from monkey-like ancestors
    B. The change of simple to complex organisms
    C. The development of characteristics in response to need
    D. Change of populations through time
    E. The change of populations solely in response to natural selection

25. Marine mammals have many structural characteristics in common with fishes. The explanation that evolutionary theory would give for this similarity is:
    A. Fish and mammals are closely related
    B. Fish evolved structures similar to those already existing in mammals
    C. Marine mammals evolved directly from the fishes
    D. Marine mammals never developed use of limbs
    E. Marine mammals adapted to an environment similar to that of the fishes

26. An alternation in the arrangement of nucleotides in a chromosome, possibly resulting in either a structural or physiological change in the organism, is called:

A. Gene drift
B. Gene flow
C. A mutation
D. Natural selection
E. A recessive gene

27. It is though that there was a rapid evolutionary rate once animal life invaded land from the oceans. The explanation given for this rapid evolution is:

A. There were many potential habitats for new forms to fill
B. The land was a perfect haven for life
C. There were many climatic changes occurring at that time
D. Radiation from the sun caused many mutations
E. The ocean was too stable and limited to allow for evolution to occur

28. The first animals to settle on land probably had which one of the following characteristics?

A. They were quite mobile to escape from predators
B. They were partially dependent upon water for survival
C. They were capable of completely adapting to the terrestrial environment in their life span
D. They had wings for flight from one habitat to another
E. They were quite adept at feeding on specific terrestrial plants

29. Two islands are found in the middle of the Pacific Ocean, isolated from an other landmass. These two islands were at one time connected by a land bridge and are of recent origin. They have identical plant and animal life and are separated by 50 miles of ocean. Assuming different selection pressures, which of these island populations would be most likely to be reproductively isolated, possibly allowing for species divergence?

A. Dandelions, with airborne seeds
B. Coconuts with floating seeds
C. Birds
D. Butterflies
E. Mice

30. The population of Florida panthers has been drastically reduced by the actions of man. Which of the following most likely threaten their ability to continue to evolve in response to the pressures of their environment:

A. There is no longer the prospect of over-reproduction.

B. There is no longer the prospect of a struggle for limited resources
C. There is a lack of genetic variation for selection to act upon
D. There is no longer the prospect of a trait conferring a reproductive advantage
E. There is no longer the prospect of genetic drift occurring

31. A sudden major climatic change would most likely initially result in:
A. A rapid increase in adaptive radiation
B. A rapid increase in extinction rates
C. A sharp increase in numbers of species
D. An increase in mutation rates
E. Plants and animals developing new characteristics in order to cope with environmental changes

32. The most compelling evidence for large-scale evolutionary change or macroevolution is:
A. Kettlewell's release-recapture experiment with peppered moths
B. The fossil record
C. The occurrence of mass extinctions
D. Domestication of plants and animals
E. The observed increase of mutation rates across all species

33. When first proposed, Darwin's theory of natural selection did not fully explain how evolution could occur. This was due to:
A. Darwin's failure to recognize the tendency of organisms to over-reproduce
B. Darwin's initial overemphasis of the significance of genetic drift
C. The fact that accurate mechanisms explaining genetic inheritance were not widely known
D. The absence of accurate descriptions of the embryological development of most plants and animals
E. The absence of biochemical techniques to determine the genetic similarities between species

34. The presence of tropical rain forest fossil forms in Canada can best be explained by:
A. A shifting of environmental requirement by these type of species
B. A major climatic shift on the earth
C. A drifting of continents in a northward direction
D. An uplifting of lowland areas
E. A long term constancy of climate

35. Individuals within a species tend to be genetically different. The primary mechanism generating this individual variability is:

A. Meiosis
B. Mitosis
C. Polyploidy
D. Duplications
E. Asexual reproduction

36. The extinct species *Archaeopteryx* had characteristics of both birds and reptiles. This is an example of a(n):

A. Convergent species
B. Trace fossil
C. Archetype
D. Intermediate form
E. Polymorphic species

37. The earliest fossils found in the geologic record are:

A. Fungi
B. Bacteria
C. Small photosynthesizing plants
D. Seed plants
E. Protozoa

38. Radiometric dating techniques rely on the fact that:

A. The bony portions of organisms decompose at a known rate
B. Organisms which lived earlier in time will tend to be found in sediment below organisms which lived more recently
C. The magnetic field of the earth has reverse its polarity at known time intervals in geological time
D. The earth contains elements which change into other elements at a constant rate
E. During the decomposition process organic matter is converted into radioactive elements at a known rate

39. Which of the following best represents Lamarck's ideas on the evolutionary process?

A. Survival of the fittest
B. Inheritance of acquired characteristics
C. Neutral drift
D. Punctuated equilibrium
E. Assorted mating

40. Which of the following is NOT a part of Darwin's theory of natural selection?
    A. Individuals of a population vary
    B. Organisms tend to over-reproduce themselves
    C. There are limited resources for which individuals compete
    D. Modifications an organism acquires during its lifetime can be passed to its offspring
    E. Variations possessed by individuals of a population are heritable

41. The life histories of five birds of the same species are listed below. The most evolutionary successful bird is the one that:
    A. Lives 5 years, lays 12 eggs in a lifetime, 4 hatch
    B. Lives 2 years, lays 8 eggs in a life time, 5 hatch
    C. Lives 6 years, lays 2 eggs in a life time, 2 hatch
    D. Lives 4 years, lays 7 eggs in a life time, 6 hatch
    E. Lives 5 years, lays 4 eggs in a life time, 3 hatch

Appendix C

Rutledge and Warden (2000)’s Instrument Measuring the Attitude of Evolution Theory Subscale

For the following items, please indicate your agreement/disagreement with the given statements using the following scale.

A	B	C	D	E
Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

1. Evolution is a scientifically valid theory.
2. Organisms existing today are the result of evolutionary processes that have occurred over millions of years.
3. The theory of evolution is based on speculation and not valid scientific observation and testing.
4. Modern humans are the product of evolutionary process, which have occurred over millions of years.
5. There is a considerable body of evidence, which supports evolutionary theory.
6. Most scientists accept evolutionary theory to be a scientifically valid theory.
7. The theory of evolution is incapable of being scientifically tested.
8. The theory of evolution cannot be correct since it disagrees with the Biblical account of creation.
9. With few exceptions organisms on earth came in to existence at about the same time.
10. The age of the earth is less than 20,000 years.
11. The theory of evolution brings meaning to the diverse characteristics and behaviors observed in living things.
12. Evolutionary theory generates testable predictions with respect to the characteristics of life.
13. Organisms exist today in essentially the same form in which they always have.

14. Evolution is not a scientifically valid theory.

15. Much of the scientific community doubts if evolution occurs.

16. Current evolutionary theory is the result of sound scientific research and methodology.

17. Evolutionary theory is supported by factual, historical, and laboratory data.

18. Humans exist today in the same form in which they always have.

19. The age of the earth is approximately 4-5 billion years.

20. The available evidence is ambiguous as to whether evolution actually occurs.

Appendix D

Demographic Questions

1. What is your age?

2. What gender do you identify as?
   a. Male
   b. Female
   c. Other (Describe)

3. Which race/ethnicity best describes you? (Please choose only one)
   a. American Indian or Alaskan Native
   b. Asian/ Pacific Islander
   c. Black or African American
   d. Hispanic American
   e. White/ Caucasian
   f. Multiple Ethnicity/Other (Please describe)

4. What is the highest level of education you have completed/or are currently enrolled that is related to an education/teaching program such as Curriculum and Instruction, Science Education, Elementary Education, General Education etc?
   a. Never completed or been enrolled in an education/ teaching program at a university or college
   b. Associate's degree
   c. Bachelor's degree
   d. Master's degree
   e. Doctorate degree (Ph.D. or Ed.D)

5. Have you completed a Nature of Science, History of Science, or Philosophy of Science course at a college or university?
   a. Yes (please provide the name of the course)
   b. No

6. What is the highest level of education you have completed/or are currently enrolled in a science program such as biology, chemistry, environmental science, physics, or earth and space sciences?
   a. Never completed or enrolled in a science degree program at a university or college
   b. Associate's degree
   c. Bachelor's degree
   d. Master's degree
   e. Doctorate degree (Ph. D or Ed. D)

7. What area(s) of science are you currently enrolled or have earned a degree in science? Select all that apply.
    a. Biology
    b. Chemistry
    c. Physics
    d. Environmental Science
    e. Earth & Space Sciences
    f. Psychology
    g. Other - Please describe

8. What level of science have you taught? Select all that apply
    a. Do not teach science
    b. Elementary (K-5)
    c. Middle School (6th -8th grade)
    d. High School (9th-12 grade)
    e. Undergraduate Level
    f. Graduate Level

9. How many years have you taught science courses?

10. Have you ever taught a life science class or biology related course in a formal setting (K-12 or college/university level)?
    a. Yes
    b. No

11. What level of life science or biology related course have you taught? Select all that apply.
    a. Elementary School (K-5)
    b. Middle School (6th-8th grade)
    c. High School (9th-12th grade)
    d. Community College or other 2 year program
    e. Undergraduate Level
    f. Graduate Level

12. How many years have you taught life science or biology related courses?

Appendix E

Instrument Measuring Teachers' Attitude of Evolution Theory Modified from Rutledge and Warden (2000)

	Disagree (1)	Agree (2)
1. Evolution is a scientifically valid theory. (1)	○	○
2. The theory of evolution is based on speculation and not valid scientific observation and testing. (2)	○	○
3. Organisms existing today are the result of evolutionary processes that have occurred over millions of years. (3)	○	○
4. Modern humans are the product of evolutionary process, which have occurred over millions of years. (4)	○	○
5. There is a considerable body of evidence, which supports evolutionary theory. (5)	○	○
6. Most scientists accept evolutionary theory to be a scientifically valid theory. (6)	○	○
7. The theory of evolution is incapable of being scientifically tested. (7)	○	○
8. The theory of evolution cannot be correct since it disagrees with the Biblical account of creation. (8)	○	○
9. With few exceptions organisms on earth came in to existence at about the same time. (9)	○	○

10. The age of the earth is less than 20,000 years. (10)	○	○
11. Organisms exist today in essentially the same form in which they always have. (11)	○	○
12. The theory of evolution brings meaning to the diverse characteristics and behaviors observed in living things. (12)	○	○
13. Evolutionary theory generates testable predictions with respect to the characteristics of life. (13)	○	○
14. Evolution is not a scientifically valid theory. (14)	○	○
15. Much of the scientific community doubts if evolution occurs. (15)	○	○
16. Current evolutionary theory is the result of sound scientific research and methodology. (16)	○	○
17. Evolutionary theory is supported by factual, historical, and laboratory data. (17)	○	○
18. Humans exist today in the same form in which they always have. (18)	○	○
19. The age of the earth is approximately 4-5 billion years. (19)	○	○

20. The available evidence is ambiguous as to whether evolution actually occurs. (20)	○	○

Appendix F

Instrument Measuring Teachers' Understanding of Evolution Theory Modified from Rutledge and Warden (2000)

1. The evolutionary theory proposed by Charles Darwin was:
   A. Change in populations through time as a result of mutations
   B. The spontaneous generation of new organisms
   C. The passing on of genes from one generation to the next
   D. Change in populations through time as a response to environment change
   E. The development of characteristics by organisms in response to need

2. The wing of the bat and the forelimb of the dog are said to be homologous structures. This indicates that:
   A. They have the same function.
   B. Bats evolved from a lineage of dogs.
   C. They are structures, which are similar due to common ancestry.
   D. The leg bones of each are anatomically identical.
   E. They have a different ancestry but a common function.

3. Using radioactive dating techniques, the first life seems to have appeared on the earth about:
   A. 10 thousand years ago
   B. 270 million years ago
   C. 3.3 billion years ago
   D. 4.5 million years ago
   E. 10 billion years ago

4. Which of the following phrases best describes the process of evolution?
   A. The development of man from monkey-life ancestors
   B. The change of simple to complex organisms
   C. The development of characteristics in response to need
   D. Change of populations through time
   E. The change of populations solely in response to natural selection

5. Marine mammals have many structural characteristics in common with fishes. The explanation that evolutionary theory would give for this similarity is:

   A. Fish and mammals are closely related.
   B. Fish evolved structures similar to those already existing in mammals.
   C. Marine mammals evolved directly from the fishes.
   D. Marine mammals never developed use of limbs.
   E. Marine mammals adapted to an environment similar to that of the fishes.

6. When first proposed, Darwin's theory of natural selection did not fully explain how evolution could occur. This was due to:

A. Darwin's failure to recognize the tendency of organisms to over-reproduce

B. Darwin's initial overemphasis of the significance of genetic drift

C. The fact that accurate mechanisms explaining genetic inheritance were not widely known

D. The absence of accurate descriptions of the embryological development of most plants and animals

E. The absence of biochemical techniques to determine the genetic similarities between species

7. Radiometric dating techniques rely on the fact that:

A. The bony portions of organisms decompose at a known rate

B. Organisms which lived earlier in time will tend to be found in sediment below organisms which lived more recently

C. The magnetic field of the earth has reveres its polarity at known time intervals in geological time

D. The earth contains elements which change into other elements at a constant known rate

E. During the decomposition process organic matter is converted into radioactive elements at a known rate

8. The population of Florida panthers has been drastically reduced by the actions of man. Which of the following most likely threaten their ability to continue to evolve in response to the pressures of their environment:

A. There is no longer the prospect of over-reproduction.

B. There is no longer the prospect of a struggle for limited resources.

C. There is a lack of genetic variation for selection to act upon.

D. There is no longer the prospect of a trait conferring a reproductive advantage.

E. There is no longer the prospect of genetic drift occurring.

9. Two islands are found in the middle of the Pacific Ocean, isolated from an other landmass. These two islands were at one time connected by a land bridge and are of recent origin. They have identical plant and animal life and are separated by 50 miles of ocean. Assuming different selection pressures, which of these island populations would be most likely to be reproductively isolated, possibly allowing for species divergence?

A. Dandelions, with airborne seeds
B. Coconuts with floating seeds
C. Birds
D. Butterflies
E. Mice

10. The extinct species, *Archaeopteryx,* had characteristics of both birds and reptiles. This is an example of a(n):

A. Convergent species
B. Trace fossil
C. Archetype
D. Intermediate form
E. Polymorphic species

11. The most compelling evidence for large-scale evolutionary change or macroevolution is:

A. Kettlewell's release-recapture experiment with peppered moths
B. The fossil record
C. The occurrence of mass extinctions
D. Domestication of plants and animals
E. The observed increase of mutation rates across all species

12. Which of the following is NOT a part of Darwin's theory of natural selection?

A. Individuals of a population vary
B. Organisms tend to over-reproduce themselves
C. There are limited resources for which individuals compete
D. Modifications an organism acquires during its lifetime can be passed to its offspring
E. Variations possessed by individuals of a population are heritable

Appendix G

Instrument Measuring Teachers' Understanding of NOS Modified from Rutledge and Warden (2000)

	Disagree (1)	Agree (2)
1. The goal of science is the improvement of man's quality of life. (1)	○	○
2. Scientists must limit their investigation to the natural world. (2)	○	○
3. The scientist is limited to the investigation of phenomena, which are directly observable by the senses. (3)	○	○
4. A theory has been corroborated by many scientific facts. (4)	○	○
5. Scientists must be accepting of all findings of their fellow researchers. (5)	○	○
6. If an experiment yields results, which are contradictory to one's hypothesis, one should find other ways to corroborate the hypothesis. (6)	○	○
7. A fact in science is a truth, which can never be changed. (7)	○	○
8. A hypothesis is a guess based on a premonition. (8)	○	○
9. Scientific experiment must be repeatedly performed to be considered valid. (9)	○	○

10. A hypothesis, which has been validated by an experiment, is elevated to the level of theory. (10)	○	○
11. A hypothesis must be capable of being tested in order for it to be in the realm of science. (11)	○	○
12. To make any scientific determinations about historic occurrences in nature, there must be direct human observation. (12)	○	○
13. As a result of scientific methods, definite conclusions can be made to the absolute and ultimate cause behind an event. (13)	○	○
14. Science can never reach absolute truth about a particular phenomenon in nature. (14)	○	○
15. A scientific theory may be elevated to the status of scientific law with enough evidence. (15)	○	○
16. The theory of evolution must deny the existence of a creator-God (16)	○	○
17. Any scientific finding that contradicts religious doctrine should be discarded. (17)	○	○
18. A scientific theory may be elevated to the status of scientific law with enough evidence. (18)	○	○

Appendix H

VNOS – C Developed by Lederman et al. 2002

VNOS–Form C

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. What is an experiment?

3. Does the development of scientific knowledge **require** experiments?
   - If yes, explain why. Give an example to defend your position.
   - If no, explain why. Give an example to defend your position.

4. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
   - If you believe that scientific theories do not change, explain why. Defend your answer with examples.
   - If you believe that scientific theories do change: (a) Explain why theories change? (b) Explain why we bother to learn scientific theories? Defend your answer with examples.

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence **do you think** scientists used to determine what an atom looks like?

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence **do you think** scientists used to determine what a species is?

8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these **different conclusions** possible if scientists in both groups have access to and use the **same set of data** to derive their conclusions?

9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.
   - If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.
   - If you believe that science is universal, explain why. Defend your answer with examples.

10. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
    - If yes, then at which stages of the investigations you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
    - If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

Appendix I

IRB Approval Letter

APPROVAL OF SUBMISSION

February 11, 2018

Stephanie Toro

sptoro@uh.edu

Dear Stephanie Toro:

On February 9, 2018, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title of Study:	The relationship between the understanding of the Nature of Science and the understanding and acceptance of evolution
Investigator:	Stephanie Toro
IRB ID:	STUDY00000780
Funding/ Proposed Funding:	Name: Unfunded
Award ID:	
Award Title:	
IND, IDE, or HDE:	None
Documents Reviewed:	• Survey Email Letter, Category: Recruitment Materials; • HRP-502e.pdf, Category: Consent Form; • HRP-503.pdf, Category: IRB Protocol; • Dissertation_Survey.pdf, Category: Study tools (ex: surveys, interview/focus group questions, data collection forms, etc.);
Review Category:	Exempt
Committee Name:	Not Applicable
IRB Coordinator:	Sandra Arntz

The IRB approved the study from February 11, 2018 to February 10, 2023, inclusive.

To ensure continuous approval for studies with a review category of "Committee Review" in the above table, you must submit a continuing review with required explanations by the deadline for the January 2019 meeting. These deadlines may be found on the compliance website (http://www.uh.edu/research/compliance/). You can submit a continuing review by navigating to the active study and clicking "Create Modification/CR."

UNIVERSITY of HOUSTON
DIVISION OF RESEARCH
Institutional Review Boards

For expedited and exempt studies, a continuing review should be submitted no later than 30 days prior to study closure.

If continuing review approval is not granted on or before February 10, 2023, approval of this study expires and all research (including but not limited to recruitment, consent, study procedures, and analysis of identifiable data) must stop. If the study expires and you believe the welfare of the subjects to be at risk if research procedures are discontinued, please contact the IRB office immediately.

Unless a waiver has been granted by the IRB, use the stamped consent form approved by the IRB to document consent. The approved version may be downloaded from the documents tab.Attached are stamped approved consent documents. Use copies of these documents to document consent.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system.

Sincerely,

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