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The Influence of an Advanced Agriculture & Life Science Course on Students' Views of the Nature of Science

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THE INFLUENCE OF AN ADVANCED AGRICULTURE & LIFE SCIENCE COURSE ON STUDENTS' VIEWS OF THE NATURE OF SCIENCE

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I would like to dedicate my work to my parents and grandparents. Without their love and support throughout the years, I would not be the person I am today.

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There have been influential individuals that have helped and supported me throughout this process. The first would be my mom. Thank you mom for always being supportive and listening even when the issue was little. Thank you for always supporting me no matter the situation, positive or challenging. You continue to be the first person I call on good days and bad and I cannot express how fortunate I am to have you as my mom.

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ABSTRACT

Anderson, Megan N. M.S., Purdue University, May 2014. The Influence of an Advanced Agriculture & Life Science Course on Students' Views of the Nature of Science. Major Professor: Levon Esters

One of the goals in today's society is to ensure that students exiting school have the ability to understand, develop, and comprehend scientific information. For students to be able to meet these goals, it is imperative that they become scientifically literate and understand the concept of the Nature of Science (NOS). The discipline of Agricultural Education has strong connections with science and today many students are earning science credit and developing science understanding through Agricultural Education courses. If students are continuing to gain science mastery through their Agricultural Education courses, they should also be gaining adequate conceptions of science and the NOS. Overall, many studies have indicated that students exiting the K-12 education system lack these vital skills and understanding.

The purpose of this study was to explore the conceptions of the NOS of advanced agriculture students in Indiana. This study explored the conceptions of agricultural science students before and after taking a semester of an advanced life science course (*N*=48). Conceptions were explored through a qualitative case study utilizing the VNOS-C questionnaire. Responses were coded into one of three categories: Naïve, Emerging, or

Informed. Demographic data were also collected and analyzed. Overall, results of this study indicate that students in advanced agricultural science courses lack NOS understanding. The study's conclusions are discussed along with implications for theory, research and practice in addition to future directions for research.

CHAPTER 1. INTRODUCTION

1.1 Introduction

One of the goals in today's society is to ensure that high school students exiting school have the ability to understand, develop, and comprehend scientific information. For students to be able to meet these societal requirements, it is imperative that students become scientifically literate and understand the concept of Nature of Science (NOS). One way to achieve this goal is to help students begin making scientific connections within other disciplines, such as Agricultural Education. For many years science integration has been a priority in the field of Agricultural Education to further prepare students for an ever-changing society. With this expectation the level of science rigor within Agricultural Education courses has continued to increase throughout the years. Along with the increasing rigor in agricultural education courses, it has become apparent that scientific literacy and NOS components need to be included if integration of science is to occur. This chapter addresses science education and the reforms that have occurred within the realm of Agricultural Education. Additionally, the significance, purpose and research questions of the study will be presented.

1.1.1 Science Education

One of the key components of contemporary science education reform is the idea of students being scientifically literate (Dogan & Ozcan, 2010; National Research Council [NRC], 2012). Scientific literacy is defined as "the ability to make informed decisions on science and technology-based issues and is linked to deep understandings of scientific concepts, the processes of scientific inquiry, and the nature of science" (Bell, Blair, Crawford, & Lederman, 2003, p. 488). One of the fundamental components of science literacy is an adequate understanding of the Nature of Science (NOS) (Lederman & Zeidler, 1987). An adequate view of the NOS includes how science works and progresses. The nature of science has been defined by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) "as the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (as cited in Lederman, 1992). There are many tenets that are considered to be important constructs for NOS understanding, however, seven have been deemed important for K-12 education: 1) the empirical nature of science, 2) creativity and imagination, 3) social and cultural embeddedness, 4) laws and theories, 5) subjectivity in science, 6) tentative nature of science, and 7) observations and inferences (Young, 2011; Melville, 2011; Abd-El-Khalick, Bell, & Lederman, 1997).

If students do not have an adequate understanding of the NOS, they will lack the skills and understanding that are necessary to make informed decisions and contributions with regard to issues that affect lives in a rapidly changing society (Meichtry, 1992). For example, once students graduate from high school, they should have the ability to "engage in public discussions on science-related issues, to be critical consumers of scientific information related to their everyday lives, and to continue to learn about science throughout their lives" (NRC, 2012, p. 9). Unfortunately, decades of research have shown that many students do not have an adequate understanding of the NOS (Bektas & Geban, 2010; Khishfe, 2008; Abd-El-Khalick & Lederman, 2000; Ryan & Aikenhead, 1992). To facilitate students' development of an accurate understanding of NOS, recommendations have been made including having students work on science investigations (Bell et al., 2003). It is important to show students how different scientific discoveries come about and how there is not one process in which to meet goals, leading students to believe that science is a series of facts that need to be memorized (NRC, 2012).

As the need for increasing students' science understanding has become a priority, so has the idea of integrating more science into the Agricultural Education curriculum. Grady, Dolan, and Glasson (2010) indicated that, "In addition to understanding and applying science concepts, formal and informal Agricultural Education emphasizes learning about the processes and nature of science" (p. 10). It has also been found that agriculture teachers support teaching integrated agriculture courses as well as offering the courses for science credit for graduation (Cherry, 2011; Chiasson & Burnett, 2001; Johnson, 1996).

1.1.2 Science Integration into Agricultural Education Curricula

In the early 1900s, formal Agricultural Education began to emerge in secondary schools, giving students the opportunity to learn agriculture in a hands-on environment.

Agricultural Education aimed to teach students the importance of agriculture while training them for a vocation. During this time period, Agricultural Education classes were considered vocational. However, in 1988 in a national reform of Agricultural Education, recommendations have been made that more science needs be integrated into the Agricultural Education classroom (Balschweid, Thompson, & Cole, 1998). The purpose of integrating science was to make Agricultural Education courses more relevant and applicable towards new high school graduation requirements as well as post-secondary institutions' admission requirements (Balschweid, Thompson, & Cole, 1998). It was discovered that by utilizing agriculture as a context to teach science topics, students show equal, if not higher academic achievement compared to traditional students (Chiasson & Burnett, 2001). Today, the focus of Agricultural Education has shifted to a more science-based view of agriculture with students being awarded science credit towards graduation.

In 2004, in Indiana, the integration of a stronger science component into secondary Agricultural Education was met head on with the development of the Advanced Life Science (ALS) Program (Anderson & Esters, 2012). This program consists of three courses that were designed to teach advanced science concepts utilizing the contexts of animals, plants, and foods (Anderson, Esters, Brady, & Orvis, 2011). With the addition of these three courses, high school students in agriculture are able to earn science credit toward their high school diploma. The ALS courses are rich with rigor to further prepare students for post-secondary education in Science, Technology, Engineering, and Mathematics (STEM) disciplines. The ALS program is currently a dual credit program, utilized by schools throughout the state of Indiana. The program is considered a dual credit program because students now have the ability to earn science credit for high school graduation as well as transcripted credit for college.

Agricultural education is a contextual, hands-on model, utilizing the connection agriculture has to science. This can prove beneficial for students and their understanding of complex science concepts while demonstrating the relevancy and applicability of the science concepts that, otherwise, may seem irrelevant. By teaching students the relevancy of science to the everyday world, scientific literacy should be an outcome of Agricultural Education. By adding to the scientific literacy of students, they should also be acquiring key NOS understanding.

1.2 Problem Statement

In recent years, due to advances in science and technology, it is important that there is a greater amount and higher quality of science education to be facilitated in schools (Wilson & Curry, 2011). The National Academy of Science (2012) stated that “some knowledge of science and engineering is required to engage with the major public policy issues of today as well as to make informed everyday decisions” (p. 7). One of the key components for creating scientifically literate citizens is to encourage students to gain an understanding of the Nature of Science (NOS) (Lederman & Zeidler, 1987). However, over time it has been determined that students do not have an adequate understanding of NOS (Abd-El-Khalick & Lederman, 2000). Many students have naïve views and understanding of the role of science in their lives. Students identify science as a subject in school rather than an area to further society’s understanding of the world around them. For this purpose, programs such as Agricultural Education are being examined more closely to identify and increase the academic integration of science within their curriculum (Wilson & Curry, 2011) to meet the demand for post-secondary STEM education and careers. It has been stated that, "the use of an agricultural curriculum as a contextual frame for supporting knowledge acquisition in science would increase student learning and the meaning to which students can apply their learning" (Wilson & Curry, 2011, p. 27).

1.3 Need for the Study

McComas (2007) determined that "increasingly widespread agreement exists that the NOS must be an integral element of the K-12 science curriculum" (p. 249). In the area of NOS, several studies have examined teachers' knowledge and use of NOS in education, as well as the views and knowledge of students from elementary to post-secondary school (e.g., Akerson & Hanuscin, 2007; Akerson, Abd-El-Khalick, & Lederman, 2000; Lederman & Zeidler, 1987). However, it has been determined that students are not gaining a complete understanding of how science actually functions and works. In a recent study, Grady, Dolan, and Glasson (2010) analyzed students' views in an agricultural science context. Overall they found that students do not have an accurate understanding of how science functions. To date, there has been no indication that an enacted agriscience curriculum has been studied. Additionally, there have not been any advanced agriscience courses studied leaving a need for this area of education to be examined.

1.4 Significance of the Study

This study is significant for four reasons: 1) creating scientifically literate students who are capable of making informed decisions, 2) improving science understanding through agricultural science curriculum, 3) enhancing student learning that will lead to better preparation for STEM education and careers, and 4) enhancing NOS understanding through Agricultural Education.

With science understanding being so crucial in today's changing world, it is imperative to look at all curricula. Over the years, science integration into Agricultural Education curricula has been at the forefront of research agenda (NRC 1998; 2009). Balschweid and Huerta (2008) found that "teaching biology using animal agriculture as the context was effective for helping students appreciate and understand science better than traditional methods of teaching biology" (p. 18), indicating that using contextualized learning helps students to better comprehend science.

Another goal in science education reform is the idea of preparing students for careers in the areas of Science, Technology, Engineering, & Mathematics (STEM). It has been stated by the U.S. President's Council of Advisors (2010) that "In the 21st century, the country's need for a world-leading STEM workforce and a scientifically, mathematically, and technologically literate populace has become even greater, and it will continue to grow" (p. 2). However, currently only high-scoring or high-achieving students are being encouraged to pursue STEM fields. Thus, the STEM workforce pool is limited due to students from lower-achieving categories not receiving encouragement to study in STEM fields (Lowell et. al., 2009). The limitation in the workforce pool is in turn leaving a need for professionals proficient in STEM areas of work. By increasing the number of high school graduates who are proficient in STEM, we are further preparing individuals to become leaders and active, scientifically literate, citizens.

1.5 Purpose of the Study

The purpose of this study was to explore NOS views of students who are currently enrolled in a science-intensive agriculture course and the extent to which their views change of NOS during the course of a spring academic semester.

1.6 Research Questions

The research questions for this study are as follows:

1. What are agricultural science students' initial views of before taking an advanced life science agriculture course?
2. What are changes, if any, of agricultural science students' views of the NOS after taking an advanced life science agriculture course?

1.7 Limitations of the Study

There are two limitations of this study. First, only one school and ALS program were studied. Additionally, the same instructor taught all three ALS courses (ALS: Animals, ALS: Plants, and ALS: Foods), within the agriculture program. Because of this limitation, this study cannot be generalized to other situations and programs. However, the findings may be transferable.

Second, the students enrolled within the ALS courses are a self-selected group. To enroll within an ALS course, it is required that a student be a Junior or Senior in high school, as well as have already taken Biology and Chemistry or Biology and Integrated Chemistry and Physics. The requirements to enroll in an ALS or Anatomy course could indicate that many of the students may be higher academically achieving, as well as having a greater understanding of science as compared to the general population of students within the school.

1.8 Definitions of Terms

The following is a list of terminology that relates to this study.

- **Advanced Life Science (ALS) Program** – This program consists of three courses, ALS: Animals, ALS: Plants & Soils, and ALS: Foods, which focus on advanced science concepts utilizing the context of agriculture (Esters, Anderson, Brady, & Orvis, 2011).
- **Block Scheduling** – A daily schedule that has been organized to allow for more time for each class (Bennett, n.d.).
- **Contextualized Learning** – Teaching and learning in students' diverse life contexts that prepares students for learning in the complex environments they will encounter in their future careers (Glynn & Winter, 2004).

- **Creativity/Imagination** – Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world (Schwartz, Lederman, & Crawford, 2004).
- **Empirical Nature of Science Knowledge** – The empirical nature of science can be described as information based on observations of the natural world that are influenced by the researchers perspective and instrument inadequacies (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Discovery of new information and the interpretation of the data is impacted by the researcher's own ideas.
- **Inquiry Based Learning (IBL)** – An instructional method by which students use a variation of the scientific method of inquiry as a means to study a problem in depth (Knobloch & Ball, 2006).
- **Integrated Chemistry Physics (ICP)** – A State of Indiana accepted course that combines basics concepts of chemistry and physics (IDOE, 2014).
- **Law** - Laws describe relationships, observed or perceived, of phenomena in nature (Schwartz, Lederman, and Crawford, 2004).
- **National FFA** – An organization designed to help students meet the challenges of a changing world by helping students develop their own talents (National FFA, 2013).
- **Nature of Science (NOS)** – The epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development (Lederman, Abd-El-Khalick, Bell, and Schwartz, 2002).

- **Observations and Inferences** – Observations are gathered through human senses or extensions of those senses. Inferences are interpretations of those observations (Schwartz, Lederman, & Crawford, 2004).
- **SAE** (Supervised Agricultural Experience) – A program in which students apply classroom learned skills through job placements and entrepreneur enterprises. (FFA Manual, 2013).
- **Science Integration** – Integration of science into career and technical education (Warnick & Thompson, 2007).
- **Scientific Inquiry (SI)** – The characteristics of the scientific enterprise and processes through which scientific knowledge is acquired, included in conventions and ethics involved in the development, acceptance, and utility of scientific knowledge (Schwartz, Lederman, & Crawford, 2004).
- **Scientific Literacy** – The ability to make informed decisions on science and technology-based issues and is linked to deep understandings of scientific concepts, the processes of scientific inquiry, and the nature of science (Bell, Blair, Crawford, & Lederman, 2003).
- **Social and Cultural Embeddedness –** Science is a human endeavor and is influenced by the society and culture in which it is practiced. The values of the culture determine what and how science is conducted, interpreted accepted, and utilized (Schwartz, Lederman, & Crawford, 2004).
- **STEM** – Science, Technology, Engineering, and Mathematics
- **Subjectivity of Science** – Science is influenced and driven by currently accepted scientific theories and laws. The development of questions, investigations, and

interpretations of data is filtered through the lens of current theory (Schwakrtz, Lederman, & Crawford, 2004).

- **Tentative Nature of Science** – Scientific knowledge is subject to change with new observations and with the reinterpretations of existing observations (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002).
- **Theory** – Inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena (Schwartz, Lederman, & Crawford, 2004).
- **VNOS Questionnaire** (Views of the Nature of Science) – A questionnaire used to determine the views of the NOS with respect to the following aspects of the NOS: tentativeness, empirical basis, subjectivity, creativity, social and cultural embeddedness, observations and inferences, and theories and laws.

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CHAPTER 2. REVIEW OF LITERATURE

2.1 Introduction

The following chapter is composed of six sections. The first section will highlight the Nature of Science (NOS) and scientific literacy. Next, the technique of explicit vs. implicit teaching of the NOS to students will be discussed. The third section will review the methodology that has been utilized by researchers to determine student conceptions of NOS. Next, the connection between science integration and Agricultural Education will be discussed. Finally, the role of agricultural and scientific literacy will be highlighted.

2.2 Purpose of the Study

The purpose of this study was to explore NOS views of students who are currently enrolled in a science-intensive agriculture course and the extent to which their views change of NOS during the course of a spring academic semester.

2.3 Research Questions

The research questions for this study are as follows:

1. What are agricultural science students' initial views of the NOS before taking an advanced life science agriculture course?
2. What are changes, if any, of agricultural science students' views of the NOS after taking an advanced life science agriculture course?

2.4 The Nature of Science and Scientific Literacy

Scientific literacy has been defined by the American Association for the Advancement of Science (1993) as a core component of science education in today's increasingly technological society. Scientific literacy "is commonly portrayed as the ability to make informed decisions on science and technology-based issues and is linked to deep understandings of scientific concepts, the processes of scientific inquiry, and the nature of science" (Bell, Blair, Crawford, & Lederman, 2003, p. 488). Scientific literacy is a critical component in today's career industry requiring employees to exhibit skills of creativity, ability to learn, sound decision-making, and problem solving (Meyers & Dyer, 2006) and serves as a vital skill needed to be a citizen in a technologically advanced society (Jones, 2010). Further, McComas, Almazroa, and Clough (1998) stated that "at the foundation of many illogical decisions and unreasonable positions are misunderstandings of the character of science" (p. 511).

A key component to scientific literacy is the Nature of Science. Nature of Science should be included throughout the educational system as stated by the *Benchmarks for Scientific Literacy* and *National Science Education Standards* (Bell, Matkins, & Gansneder, 2011). The definition of NOS has been under debate for many years and can be difficult to define (Forhad & Buaraphan, 2013; Talbot, 2010), however NOS has been described by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) "as the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (as cited in Lederman, 1992). Students should have an adequate understanding of NOS to aid in their ability to make "informed decisions about science-based issues in their daily lives" (Ibrahim, Buffler, & Lubben, 2009, p. 248), yet many high school graduates have inadequate views of NOS (Lederman, 2002; Meichtry, 1993; Khishfe, 2008) and maintain non-normative about how science actually works and functions. Some of the inadequacy can be attributed to students seeing science as simply a body of facts and knowledge in need of memorizing, instead of as a way of acquiring knowledge and answering questions about the natural world around them. For example, McComas (1998; 1996) identified common myths held within science, some of which include: 1) The relationship between laws and theories is hierarchical, 2) The scientific method is a set of steps utilized by all researching scientists (Ibrahim, Buffler, & Lubben, 2009), 3) A gathering of evidence will lead to well-known knowledge, 4) Using science to search for understanding will give absolute truth (Ibrahim, Buffler, & Lubben, 2009), 5) There is no creativity in scientific endeavors, 6) Scientific endeavors are completely objective, and 7) Laws never change. The inadequacy in NOS understanding can further be compounded by the fact that in science education courses many of "the ideas put forth in textbooks and school science concerning the nature of science are almost universally incorrect, simplistic, or incomplete" (McComas, Clough, & Almazroa, 1998, p. 9). By textbooks being organized with very little mention, or simplistic concepts of the NOS, this can lead to minimal NOS instruction and add to further student misconceptions.

To determine how students understand NOS, researchers have analyzed student views of NOS based upon the recognized tenets, or constructs. Many different tenets of NOS have been noted as important to the understanding of NOS, however, not all of the tenets of NOS have been agreed upon by researchers. For K-12 students there are seven tenets of NOS that have gained general consensus among researchers: 1) The empirical nature of science, 2) Creativity and imagination in science, 3) Laws and theories, 4) Observations and inferences, 5) Social and cultural embeddedness, 6) Subjectivity in science, and 7) The tentative nature of science (Young, 2011; Melville, 2011; Khishfe, 2008; Akerson & Abd-El-Khalick, 2005; Schwartz & Lederman, 2002; Akerson, Abd-El-Khalick, & Lederman, 2000; Lederman, 1999; Abd-El-Khalick, Bell, & Lederman, 1997). These seven tenets, which are widely considered important for K-12 education, were the focus of this study.

Tenet One: Empirical Nature of Science

The empirical nature of science can be described as "information based on observations of the natural world that are influenced by the researcher's perspective and instrument inadequacies" (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002, p. 499). When scientists discover new information, the manner in which the data are interpreted is directly impacted by the researchers' own conceptions. The researcher's own perspective being used for data interpretation indicates that another researcher could possibly report different results based upon the same information.

Tenet Two: Creativity and Imagination

In science classrooms, the scientific method is a common way in which students learn how to design scientific investigations. This method, however, if overemphasized can lead to the misunderstanding that all science endeavors are pre-planned and will guarantee a "correct" answer (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Students need to understand that discoveries are made through the creativity exhibited by the researchers and scientists performing an experiment. Schwartz, Lederman, and Crawford (2004) noted that, "scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world" (p. 613).

Tenet Three: Theories and Laws

According to Schwartz, Lederman, & Crawford (2004) laws can be described as phenomena that are observed or perceived in nature. Additionally, theories can be described as "inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena" (Schwartz, Lederman, & Crawford, 2004, p. 613). Many students with misconceptions about Laws and Theories typically see a hierarchy between the two concepts (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Having a hierarchical relationship as a misconception could then lead to students believing that theories must become laws (McComas, Almazroa, & Clough, 1998) and laws are the highest level of knowing and can never change. However, laws and theories can change depending on new observations, research, and interpretations.

Tenet Four: Observations and Inferences

Observations and inferences are components of NOS that are included in any type of scientific endeavor. Observations result from the researcher viewing what is happening by utilizing all of the senses, while inferences are the researcher's interpretation of what he or she observed (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002).

Tenet Five: Social and Cultural Embeddedness

Schwartz, Lederman, and Crawford (2004) described the social and cultural embeddedness of NOS: "science is a human endeavor and is influenced by the society and culture in which it is practiced. The values of the culture determine what and how science is conducted, interpreted accepted, and utilized" (p. 613). Ultimately, science will be affected by the society and culture in which the individual resides.

Tenet Six: Subjectivity of Science

Researchers adhere to different paradigms, which may lead to different viewpoints about science and research. The differing viewpoints of the researchers will ultimately reflect their own ideas based upon their own work and experiences. This leads the researcher to add personal understanding and ideas into the work. Overall, it is difficult to remain completely objective (Khishfe & Lederman, 2006) when pursuing scientific endeavors.

Tenet Seven: Tentative Nature of Science

As scientific discoveries are made, the findings are considered accurate knowledge for a period of time until new information is discovered. This indicates that even scientific theories and laws can change when new discoveries are made (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Overall, this suggests that science is ever changing and not composed of concrete facts that are unalterable by new discoveries and findings.

Overall, the NOS is a component of scientific literacy (AAAS, 2013; Lederman, 1992) that has been identified as important for K-12 education. The NOS contains seven tenets that have been agreed upon by researchers as important for students to comprehend and be able to understand science and scientific processes (Young, 2011; Abd-El-Khalick, Bell, & Lederman, 1997). Without the skills gained through understanding the NOS, students lack the skills needed to make informed decisions in relation to science (Meichtry, 1992).

2.5 Implicit vs. Explicit Teaching of the Nature of Science

Two pedagogical approaches of teaching have been examined to increase student conceptions of the NOS: implicit and explicit with reflection approaches (Burgin & Sadler, 2010; Kim, Ko, Lederman, & Lederman, 2005). These two approaches will be discussed in relation to NOS understanding.

Teaching through implicit methods indicates that students will gain an understanding of how science works by actually taking part in science (Bell, 2001; Lawson, 1982) through different lab and inquiry-based activities (Kucuk, 2008; Clough, 2006; Khishfe & Abd-El-Khalick, 2002). This method carries that students will gain NOS understanding without specifically discussing NOS or the many tenets (Jones, 2010), but rather students will understand the tenets implicitly through their representation in "doing science".

Explicit teaching and reflection of NOS occurs when students are taught, precisely and intentionally, the many aspects of NOS in addition to being involved in reflection and questioning (Melville, 2011; McDonald, 2010; Lederman, 2006; Kim, Ko, Lederman, & Lederman, 2005; Schwartz & Lederman, 2002). Melville (2011) states that students need to participate in activities supporting NOS components and that students need to have ample time in which to reflect upon what they learn (Burgin & Sadler, 2010). The teacher should not just be "telling" the students about NOS (Young, 2011), however, "as part of the lesson the teacher guides students into thinking explicitly about specific aspects of the nature of science" (Bell, 2001, n.p.).

Khishfe and Abd-El-Khalick (2002) indicate that some researchers still support the concept of implicit teaching and its effects on learning. However, research supports the explicit approach, indicating greater student gains in NOS understanding (Khishfe, 2008; Akerson & Abd-El-Khalick, 2005; Khishfe & Abd-El-Khalick, 2002).

There has been extensive research conducted to determine which approach is more effective in teaching the NOS. For example, Yalcinoglu and Anagun (2012) completed a study examining 29 pre-service elementary science teachers' views of the NOS by utilizing the VNOS-C and interviews of six participants. Participants experienced an intervention that focused on specific aspects of NOS. Although gains were not made in all areas of NOS understanding, results indicated that explicit instruction of NOS was the more effective approach.

Brooks (2011) examined 134 high school students in 10 separate classes for their views of NOS. Three groups were created to determine if participation in the Partnership for Research and Education in Plants (PREP) program being taught through explicit or implicit methods would have an impact on student views of NOS. One group participated in PREP and received explicit teaching of NOS, the second group participated in PREP and received implicit teaching of NOS, and the third group was used as a comparison. Students were given a modified form of the VNOS-C questionnaire with semi-structured interviews to determine their NOS views. All three groups showed equal improvement in their NOS understanding. Additionally, no significant difference was found between the implicit and explicit group due to “equal gains” in NOS understanding.

Schwartz et al. (2010) examined the impact of a full immersion scientific research program on secondary teachers’ views of NOS. Two groups of teachers participated in the study with one group receiving explicit NOS instruction and the other receiving standard laboratory and lesson plan instruction. Pre and posttest data were collected using the VNOS-C. Focus group interviews were also conducted to obtain an in-depth understanding of teachers’ views of NOS. Overall, teachers who received explicit NOS instruction showed greater gains in NOS conceptions than did the group not receiving explicit instruction.

Palmquist and Finley (1997) surveyed and interviewed pre-service science teachers participating in a teaching methods course to determine their NOS understanding. The students were divided into two groups, with one receiving explicit NOS instruction and the other group experiencing implicit NOS instruction. Results indicated that when cooperative learning, students working together, and conceptual change are utilized, implicit instruction could have an impact on student understanding of NOS.

Moss (2001) conducted a study examining five students in the 11th and 12th grades taking an environmental science class. Students collected scientific data and were involved in a project-based curriculum. Researchers collected student data through six separate interviews. Findings from this study indicated that students held common misconceptions about some of the major aspects of NOS and that explicit instructional approaches should be utilized in classrooms.

Overall, research indicates that providing students with the proper pedagogical approach to learning NOS is crucial for adequate understanding of the various constructs. Also, based on the findings from empirical studies, it was also revealed that the explicit pedagogical approach to NOS instruction appears to be the most effective method. However, there is also empirical evidence offering some support for the use of implicit teaching methods. In this study the ALS curriculum had been implicitly taught to gain understanding of advanced agricultural science students and advanced agricultural science curricula in relation to NOS.

2.6 Secondary School Students' Views of the Nature of Science

Although several studies have been conducted to determine NOS conceptions for teachers and scientists there have also been a number of studies conducted with students across all grade levels. The following section will focus specifically on high school students and their conceptions of NOS.

Bektas and Geban (2010) examined 162 Turkish high school students to determine their views and understanding of NOS. Researchers utilized the Views of the Nature of Science-C (VNOS-C) questionnaire and conducted interviews of a random sample of participants. Findings indicated that students held misconceptions and deficiencies in NOS understanding.

Fishwild (2005) examined the impact of explicit instruction on 65 high school students to determine student views of NOS. Students were given the VNOS-C questionnaire to determine pre- and post- NOS views. Students were divided into two groups. Each group of students received modeling instruction in their physics class to assist in Newtonian Mechanics understanding. One group received explicit laboratory-based NOS instruction while the other group was used as the control. Students who received explicit NOS instruction made greater significant gains in their overall concept of the NOS than the students who received only implicit NOS instruction.

Bell, Blair, Crawford, and Lederman (2003) analyzed high school students who participated in an internship experience that focused on placing students in science laboratories. The Views of the Nature of Science (VNOS-B) questionnaire (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) was utilized in conjunction with interviews. Results indicated that students did not hold informed views of NOS and did not improve in their NOS understanding by participating within the internship experience.

Millwood and Sandoval (2004) examined the impact of a protein synthesis modeling activity on high school student NOS understanding. The study included 12 students enrolled in a high school integrated science course. Researchers used the VNOS questionnaire followed by interviews before and after the protein synthesis modeling activity. Overall, students held common misconceptions about NOS, which could be linked to how activities in school classrooms are portrayed.

Several studies have been conducted analyzing high school students' understanding of NOS in various contexts. However, most research points to students lacking knowledge and understanding as to how science functions. With evidence of student misconception still occurring in U.S. high schools, there still remains a need for research to determine the best way in which to increase student NOS conceptions.

2.6.1 Agricultural Education and NOS Understanding

In light of NOS research having been conducted on secondary students in various science courses, to date only two studies have been conducted in Agricultural Education on the topic of NOS. For example, Grady, Dolan, and Glasson (2010) conducted a study on a secondary agriscience teacher and her students. The activities that students were engaged in throughout the course were a part of a program called Partnership for Research and Education in Plants (PREP), which utilizes Scientific Inquiry (SI) during lab experiences. Data were collected through teacher and student interviews, classroom observations, student work, and informal discussions with the teacher. Through this study, only three tenets of NOS were examined: empirical nature of science, theory-ladenness nature of science, and science knowledge is socially and culturally embedded. Findings indicated that students' "reinforced a combination of accepted, underdeveloped, and incorrect assumptions of NOS" (p. 14).

Recently, Nortrup (2013) conducted a study to determine the conceptions of the NOS held by Agricultural Science & Business (ASB) teachers. Nortrup (2013) examined ASB teachers through a mixed-methods survey approach. The questionnaire was emailed to teachers to complete. Nortrup found that "many [teachers] lacked a fundamental understanding of the science enterprise, the relationship between theories and laws, the social and cultural embeddedness of science knowledge, how science is practiced and how knowledge is constructed" (p. xiv).

Overall, students continue to be studied to determine the methods and courses through which a student can best learn NOS. However, research continues to indicate that students lack an understanding of the important components of NOS (Grady, Dolan, & Glasson, 2010; Parker, Krockover, Lasher-Trapp, & Eichinger, 2008). Additionally, only two studies have been conducted in Agricultural Education to determine teacher and student understanding of NOS. The purpose of this study was to expand the research in Agricultural Education to gain a better understanding of high school agriscience students' perceptions of NOS.

2.7 Science Integration and Agricultural Education

This section will review the integration of science into the Agricultural Education curriculum and the impact of science integration on student learning.

2.7.1 Relationship Between Science and Agricultural Education

For over two decades the concept of integrating science into Agricultural Education has been at the forefront of research and discussion (Thompson & Warnick, 2004; Thompson, 1988; NRC, 1988). The acknowledgement of decreasing science scores has prompted a cause for alarm about the future of the U.S. workforce and educational process. Now, more than ever, there has been a realization of the need to increase and improve K-12 science education (Wilson & Curry, 2011).

To address the insufficiency of science education in the U.S., reform was called into action indicating a need to integrate science into Agricultural Education curricula (Balschweid, Thompson, & Cole, 1998). The benefit of Agricultural Education in teaching science is through utilizing a contextual model to educate students about the world around them. In turn, students are acquiring the skills they need to be successful after leaving the K-12 education system. Nortrup (2013) stated that, "In its truest form, agricultural practices inherently teach science principles, through real world data collection, research, experimentation, observation and analysis that lead to the construction of theories" (p. 22). Additionally, Agricultural Education offers a unique inquiry-based opportunity for students to learn academic concepts, especially science, in a contextual manner. Above all, the potential for science learning is due to the fact that agriculture is a science (Thoron & Rubenstein, 2013; Thoron & Myers, 2010). Research has shown that students who are taught science through the context of agriculture demonstrate performance levels in science above or equivalent to students taught in more traditional educational settings (Duncan, Ricketts, & Shultz, 2011; Ricketts, Duncan, & Peake, 2006; Chiasson & Burnett, 2001; Enderlin & Osborne, 1992; Roegge & Russell, 1990; Whent & Leising, 1988). Thompson and Warnick (2004) add that, "integrating science helps students understand the science of agriculture through a love of discovery, scientific inquiry, problem solving, and learning with experiments" (p. 13). Further, Balschweid and Huerta (2008) found that "by teaching biology using animal agriculture as the context was effective for helping students appreciate and understand science better than the traditional methods of teaching biology" (p. 18). Overall, agriculture can be a pathway to assist in the quest for greater science understanding among students (Thompson & Warnick, 2004).

2.7.1.1 Agricultural Education and Scientific Literacy

The shift from Agricultural Education to agriscience education through the integration of science subject matter can enhance curricula and aid in scientific literacy and agricultural literacy (Nolin & Parr, 2013). Myers, Washburn and Dyer (2004) also argued that scientific literacy is an important skill for people entering into careers within the agricultural industry. Without question, schools need to be enhancing scientific thinking among students while boosting scientific literacy (Schmidt, Burroughs, & Cogan, 2013) to better prepare students for the demands and decisions required of them from society. Students need to be able to see the application outside of the traditional classroom setting and given the chance to think scientifically (Balschweid, 2002). Further, Shoulders and Myers (2013) indicate that "the link between the goals of laboratory instruction, scientific literacy, and agriscience education suggest that well designed experiences in agricultural laboratories can be designed to enhance students' scientific literacy" (p. 101).

Moreover, the goals of Agricultural Education and scientific literacy are closely aligned in purpose (as cited in Shoulders & Myers, 2013). For example, the National Research Council (1996), in its report of the National Science Standards, explained that citizens need to be scientifically literate so they can make informed decisions as it relates to important agriculturally related topics such as how natural resources (i.e., wind, water, etc.) should be managed. With agriculture having been labeled as one of the oldest forms of science (Ricketts, Duncan, & Peake, 2006) scientific literacy maintains strong connections with Agricultural Education and should be considered and further evaluated as to the benefits Agricultural Education can have on student science understanding.

2.8 Summary

This chapter addressed NOS and the constructs important for K-12 education. Next, the pedagogical approaches, explicit and implicit, of NOS were highlighted, along with their impact on student learning. Additionally, a summary of empirical studies was presented which analyzed and described high school students' understanding of NOS. Only recently has NOS been explored in the discipline of Agricultural Education with these studies focusing on student and teacher conceptions of NOS. Lastly, scientific literacy and its connection to Agricultural Education was discussed.

Although student conceptions of NOS have been explored in many content areas, Agricultural Education has not been explored with regards to the seven commonly accepted K-12 NOS tenets. Having an adequate understanding of NOS has been described as a vital skill for students to have when leaving the K-12 education system. However, research indicates that students are leaving without adequate conceptions of NOS. Because agriculture is a science-related discipline, further research should be conducted to determine the role agriculture can play in developing student conceptions and understanding of NOS.

CHAPTER 3. METHODOLOGY

3.1 Introduction

This chapter will serve as a guide to discuss and explain the methodology and procedures for this qualitative case study. Specifically, this chapter will discuss the research design and the rationale behind the decisions made during study implementation. Additionally, participant selection, data collection and analysis procedures will be reviewed. Finally, the instrument used in this study will be described.

3.2 Purpose of the Study

The purpose of this study was to explore NOS views of students who are currently enrolled in a science-intensive agriculture course and the extent to which their views change of NOS during the course of a spring academic semester.

3.3 Research Questions

The research questions for this study are as follows:

1. What are agricultural science students' initial views of the NOS before taking an advanced life science agriculture course?
2. What are changes, if any, of agricultural science students' views of the NOS after taking an advanced life science agriculture course?

3.4 Research Design

The approach utilized for this study was a qualitative research design. The focus was a single case study of an advanced agriscience high school course. Creswell (2007) describes a case study as "research [that] involves the study of an issue explored through one or more cases within a bounded system (i.e., a setting, or context)" (p. 73). Case study methodology was utilized because there is one bounded system being analyzed: the ALS program.

The ALS curriculum is being analyzed to determine if students' views of NOS changed during the course of a semester as a result of completing the curriculum. The control group for this study were students enrolled in an Anatomy course. The Anatomy course used in this study was a randomly selected advanced science course. The Anatomy course was utilized as a way to ensure that the ALS students were not beginning with a greater NOS understanding than students in a comparable advanced science course.

3.5 Institutional Review Board Approval

The first step to gain permission to complete the study was for the researcher to complete the Collaborative Institutional Training Initiative (CITI) course in the Protection of Human Research Subjects training. After the CITI training was completed, all information and forms for the study were submitted to the Purdue University Institutional Review Board (IRB) on the Use of Human Research Subjects for approval. Approval (IRB protocol: 1110011349) was granted on November 15^{th}, 2011.

3.6 Participant Assent and Consent

Before participants could take part in the study, the participants, and parents or guardians of minors, had to provide assent and consent. The IRB-approved forms were attached with a cover letter outlining the purpose and goal of the study. All information related to the study was contained on the approved assent and consent forms so that participants understood the study and how they would be participating. All of the forms (with cover letter attached) were given to the students by the ALS teacher. Due to the nature of the study, it was important that both adults and minors be able to participate so that all students in the ALS course, no matter the age, could participate. For this to occur, all minors (under the age of 18) in the ALS and Anatomy class were asked to complete and sign an assent form. Additionally, the minors were required to gain permission from their parent or legal guardian by taking the consent forms home to be signed. This was accomplished by having the parent or guardian complete and sign the IRB-approved consent form for their son/daughter who is under the age of 18. Students who were over the age of 18 were only required to complete a consent form if they were willing to participate in the study per the requirements set forth by IRB.

After the assent and consent forms were distributed to the students, they were instructed to complete the forms and return them to school within two weeks. Students were asked to submit their forms in a sealed box placed in the office of the ALS teacher and the Anatomy teacher. The students had specific instructions to seal all of their paperwork in a Purdue University envelope, write the name of their class on the outside of the envelope, and then place the envelope in one of the two designated "drop" boxes. The researcher picked up the forms within two weeks to determine which students had the proper consent and assent to participate in the study.

3.7 Participant Selection

This case study focused on one school and two different types of classes, an Advanced Life Science (ALS) agricultural science course and an Anatomy course. For this study, three different ALS courses utilized: ALS: Animals, ALS: Plants, and ALS: Foods. The Anatomy course was used as a comparison for students' science understanding at this school in a science intensive course. Below is a description of the school selection process, courses, instructors, and participants.

3.7.1 School Selection

The selection of the school was based upon several criteria with the first being the size of the ALS program. For example, the high school in this study had the largest number of students enrolled in ALS in Indiana. Second, the school was selected based on the number of years the agriculture program has been in the school. Specifically, the agriculture program within the school was not newly developed. Additionally, the teachers within the department have five or more years of teaching experience.

The school selected for this study is located in a more rural town in Indiana. The median household income is $44,000/year with 95% of the population being Caucasian U.S. Census Bureau, 2014). The entire school corporation (K-12) consists of 3,557 students, whom are primarily (90%) Caucasian. Within the corporation, over half of the students completely pay for their meals, meaning that the majority are not part of the free and reduced lunch program (IDOE, 2014).

3.7.2 Courses and Instructors

The instructor of the ALS courses in the selected school won the *Teacher of the Year Award* in Indiana for excellence in education. Additionally, this instructor taught the ALS curriculum utilizing pedagogical methods that are recommended and discussed extensively in the ALS training workshop that all ALS teachers are required to attend. During the ALS training workshop, teachers are encouraged to teach the ALS curriculum utilizing inquiry-based learning methods, as well as many different hands-on learning techniques. Finally, the school also has high academic standards and offers a wide array of coursework to students. The high academic standards are reflected in the school's rating as an "A" and "4-star" school within Indiana by the Indiana Department of Education.

An Anatomy course, and its students, were selected as the control for this study because the requirements to take the course and the advanced level of material being taught is comparable to the ALS courses. Students in the Anatomy course were chosen for the sole purpose of ensuring that the students in the ALS course were not beginning with a greater understanding of NOS than students not enrolled in an ALS course.

3.7.3 Course Selection

The individual courses chosen were determined based upon the course schedule at the high school. For example, because the school was on block scheduling, it was important to have all of the courses, ALS (ALS: Animals, ALS: Plants, and ALS: Foods) and Anatomy, in one day so that data from all of the courses in this study could be collected the same day. The ALS instructor selected the day during the week that data collection would occur.

The ALS curriculum overall contains some reference to NOS for teachers to follow. However, not all seven accepted tenets for K-12 education are present. Further, the ALS curriculum does not include explicit teaching of NOS. Rather, NOS that is present is in an implicit format. When the ALS: Plants curriculum was analyzed for NOS it was found that there was only moderate representation of the empirical NOS, subjective nature of NOS, and the social context of science (Anderson & Esters, 2012). To gain a baseline understanding of NOS present in the ALS curricula and the NOS being taught within the ALS classroom, implicit teaching was utilized for this study.

3.7.4 Student Selection

Students for this study were selected based upon several criteria. First, students were selected based on their course enrollment. Specifically, a student had to be enrolled in one of the three ALS courses (ALS: Animals, ALS: Plants, or ALS: Foods) or in the Anatomy course. The following were the course-specific qualifications for a student to be included in the study:

3.7.4.1 ALS Students

Before students are allowed to register for an ALS course, they must meet certain requirements to ensure they will be successful in the course. The first requirement is that a student must be a high school junior or senior. Second, each student must have taken one year of Biology and Chemistry, or one year of Biology and Integrated Chemistry and Physics (ICP). Further, the student must not have taken an ALS course prior to the 2011-2012 academic school year. This requirement was included because many students take multiple ALS courses to enhance their science understanding and college preparedness. Additionally, if a student had already taken an ALS course, it was possible they have more informed views of NOS, making it difficult to determine if their NOS understanding had been influenced by taking an ALS course.

3.7.4.2 Anatomy Students

Before students can enroll in an Anatomy course they must have first taken Biology I and Chemistry I or Integrated Chemistry and Physics (ICP). Additionally, for this study it is important that the Anatomy students not have previously taken or be currently enrolled in an ALS course. If a student had previously taken an ALS course they were removed from the study.

3.8 Instrumentation

The primary questionnaire used for this study was the Views of the Nature of Science-Form C (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). This questionnaire was selected due to the open-response format, which allowed for the most freedom in obtaining student responses. Specifically, the student can write as much as they would like about a single question. The VNOS-C contains 10 open-ended questions that address seven different aspects of NOS.

3.8.1 Instrument Validity

The VNOS was created to address the need for an open-response format questionnaire in which to analyze student understanding of the NOS. When using the VNOS, the responses are open-ended which require interviews to clarify student responses. The VNOS-C questionnaire began as the VNOS-B, which was validated through several iterations. The VNOS-B was later modified to include additional questions (Jones, 2010). The questions on the VNOS-C were validated through a panel of experts. The VNOS-C questionnaire has been used in several studies, further ensuring the validity of the instrument (Abd-El-Khalick, 2005; Schwartz, Lederman, & Crawford, 2004).

3.9 Biases Held by the Researcher

The primary researcher is familiar with the ALS program through work experiences and completion of college courses that focused on the ALS content. The researcher is also a licensed Agricultural Science and Business teacher, has taught an ALS course during her student teaching experience, and is currently teaching an ALS: Animals course. Additionally, the researcher was previously employed as the ALS Program Assistant. Due to the researcher working so closely with the ALS courses, bias exists in the fact that the researcher recognizes the importance and need of the ALS courses, and wants to see the Agricultural Education programs, and students, in Indiana be successful in science and science comprehension.

3.10 Data Collection

For this study, three sources of data were collected: (a) student responses on the VNOS-C; (b) interviews based upon the student's answers to the VNOS-C; and (c) student demographic information.

3.10.1 Student Responses on VNOS-C

Data were collected from students who completed the VNOS-C questionnaire. Prior to administration each student who turned in an IRB approved assent and consent form was assigned a code to ensure the questionnaire would be anonymous during coding. Additionally, using a code allowed for identification of specific students for follow-up interviews. The code was a letter and number that corresponded to the student's class (i.e., Animals, Plants, or Foods). For example, code P12 indicated the ALS: Plants course and student number 12. The procedure used to administer the VNOS-C was designed by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002). Each item of the questionnaire was printed on only the front side of a single sheet of paper to allow for enough room for the student's open-responses. Additionally, students were given the VNOS-C in an environment that was free from distractions (e.g., talking, loud noises, etc.) outside of normal classroom activity during a test.

On the day of the VNOS-C administration, the ALS teacher assisted in distributing all of the VNOS-C questionnaires to the ALS classes as well as the Anatomy class. The researcher gave the students instructions to answer every question as best they could, and give examples of their understanding and what they were trying to say whenever possible. Students were asked not to use any notes or resources in which to aid in answering the questions. Additionally, students were informed that they had as much time as they needed to complete the questionnaire. Students were informed not to write his or her name on the questionnaire in order to avoid identification by the researcher during the actual coding of answers.

After students completed the VNOS-C, they returned the questionnaire to the researcher who was present in the classroom. Students took an average of 45-60 minutes to complete the VNOS-C and demographic section. The second administration of the VNOS-C was given using the same methods as the first administration of the VNOS-C. The second administration of the VNOS-C took students, on average, 25-40 minutes to complete.

3.10.2 Interviews

To determine participation for the interviews, all of the VNOS-C questionnaires were coded for the seven tenets of NOS found within the questionnaire. The VNOS-C questionnaires were coded into three different categories based upon the student's VNOS-C responses, which included: 1) Naïve, 2) Emerging, or 3) Informed. A stratified random sampling technique resulted in six students being selected from the ALS course: two in the Naïve category, two in the Emerging category, and two in the Informed category. Additionally, three students were selected from the Anatomy course: one each from the Naïve, Emerging, and Informed categories.

The interviews were a component of the design of this study because they were used to help triangulate and understand the data being collected from the students (Creswell, 2007). The interviews were semi-formal, individual, and were audio recorded so that they could be transcribed accurately. Prior to the interview, the student's VNOS-C questionnaire was returned to remind the student of their written response to the questions on the VNOS-C. During the interviews the researcher read one question to the student and then asked the student to read their response for the question. After the student read their response, the researcher would ask the student to elaborate on parts of their response that needed clarity. This process was used for all 10 questions on the VNOS-C. Each interview took approximately 25-45 minutes. The interviews were transcribed verbatim for coding purposes.

3.10.3 Demographic Information

Demographic information was collected from both the ALS and Anatomy students to better understand the student population. Specifically, data were collected regarding students' ethnicity, age, gender, previous science classes taken (e.g., Integrated Chemistry Physics, Biology, Chemistry, etc.), as well as students' general interest in science. Student demographic information was collected during the first administration of the VNOS-C.

3.11 Data Analysis

The first data analyzed were the pre- and post- VNOS-C questionnaires. Each VNOS-C questionnaire was analyzed by evaluating each question individually for NOS understanding based upon the tenet(s) represented within the question. The level of understanding was determined by the researcher based upon what the student wrote in response to each question. Each question was evaluated individually to determine the category the response should fall within (i.e., Naïve, Emerging, or Informed). The responses were evaluated based upon the examples given by the developers of the VNOS (see Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) (see Appendix J) and were evaluated by the researcher of this study. Each question for all students was evaluated three times to ensure coding accuracy. Once the level of understanding for each question was determined, the question was placed in a category (Naïve, Emerging, or Informed) and recorded into an Excel spreadsheet. Once each question had been evaluated, the number of questions in each category for a student was added to determine the overall NOS understanding for that student. After an overall level of understanding was determined based upon the student's responses to the VNOS-C items, students were selected to be interviewed by the researcher. Overall, nine students were selected to be interviewed, 6 from the ALS courses and 3 from the Anatomy course. Once the interviews were completed, the researcher transcribed the interviews into a word processing document. The transcribed interviews were then printed and coded by the researcher. The researcher worked through each interview and coded for specific words and phrases utilized by the students that indicated the presence or absence of NOS understanding for each tenet being analyzed.

Students were also given a demographics questionnaire during the first administration of the VNOS-C. Demographic data were entered into the Statistical Package for the Social Sciences (SPSS statistical software) Version 20. All quantitative data were analyzed using SPSS.

CHAPTER 4. RESULTS

4.1 Introduction

The results and findings for this study will be presented throughout this chapter. First, a demographic profile of the participants will be presented which includes a summary of their interests in science, as well as science courses taken. Data will be presented having been analyzed using SPSS version 20 for Windows. Finally, findings will be presented for the two research questions guiding this study.

4.2 Purpose of the Study

The purpose of this study was to explore NOS views of students who are currently enrolled in a science-intensive agriculture course and the extent to which their views change of NOS during the course of a spring academic semester.

4.3 Research Questions

The research questions for this study are as follows:

1. What are agricultural science students' initial views of the NOS before taking an advanced life science agriculture course?

2. What are changes, if any, of agricultural science students' views of the NOS after taking an advanced life science agriculture course?

4.4 Study Participants

The participants for this study were separated into two groups: the ALS course group and the Anatomy course group. Fifty percent of ALS students reported their age as being 18 (*SD*=.74). The students in ALS courses were 46% male and 54% female. All ALS: Animals, ALS: Plants, and ALS: Foods students identified themselves as Caucasian/White. Demographic information for ALS students is summarized in Table 4.1. The Anatomy students were 67% female and 33% male, with 83% identifying themselves as being White/Caucasian. The average Anatomy student was 17 (SD=.67) years of age. Demographic information for Anatomy students is summarized in Table 4.2.

Table 4.1 *Demographic Characteristics of ALS Students*

Category	Response	*f*	%	*M(SD)*
Age				17*(.74)*
	16	6	13%	
	17	17	35%	
	18	24	50%	
	19	1	2%	
Gender				
	Male	22	46%	
	Female	26	54%	
Race[a]				
	White/Caucasian	48	100%	

Note. Total number of responses (*N*=48)
[a]Race categories not reported are not included.

Table 4.2 *Demographic Characteristics of Anatomy Students*

Category	Response	*f*	%	*M(SD)*
Age[a]				17*(.67)*
(*N*=12)				
	16	3	25%	
	17	7	59%	
	18	2	17%	
Gender[a]				
(*N*=12)				
	Male	4	33%	
	Female	8	67%	
Race[b]				
(*N*=12)				
	White/Caucasian	10	83%	
	Asian American	1	8%	
	Other	1	8%	

[a]Race and age totals are less than 100% due to rounding.
[b]Race categories not reported are not included in the analysis.

Next, students were asked to indicate if they have an overall interest in science. Sixty-seven percent of Anatomy students indicated an interest in science whereas 73% of ALS: Plants students, 52% of ALS: Animals, and 50% of ALS: Foods students indicated an overall interest in science (Table 4.3).

Table 4.3 *General Science Interest Among ALS and Anatomy Students*

Category	Response	*f*	%
ALS: Animals Science Interest			
(*N*=23)	Yes	12	52%
	No	11	48%
	No Response	0	0%
ALS: Plants Science Interest			
(*N*=11)	Yes	8	73%
	No	2	18%
	No Response	1	9%
ALS: Foods Science Interest			
(*N*=14)	Yes	7	50%
	No	6	43%
	No Response	1	7%
Anatomy Science Interest			
(*N*=12)	Yes	8	67%
	No	3	25%
	No Response	1	8%

Note. Total ALS respondents: *N*=48.

Students were also asked to list any and all science courses taken prior to their current ALS or Anatomy class. All ALS and Anatomy students reported having taken Biology I. Additionally, 100% of the students in ALS and Anatomy reported having taken either Integrated Chemistry & Physics (ICP) or Chemistry I. Table 4.4 reports courses completed by ALS students and Table 4.5 reports courses completed by Anatomy students.

Table 4.4 *Science Courses Reported Being Taken by ALS Students*

Category	Response	*F*	%
Science Course Taken			
(*N*=48)	Biology I	48	100%
	Chemistry I	21	44%
	Integrated Chemistry and Physics	32	67%
	Biology II	14	29%
	Earth and Space Science	10	21%
	Anatomy & Physiology	7	15%
	Health Careers	5	10%
	Horticulture	3	6%
	AP Environmental Science	2	4%
	Animal Science	2	4%
	Plant & Soil Science	2	4%
	Natural Resource Management	2	4%
	Physics	1	2%
	Introduction to Agriculture	1	2%

Note. Totals are greater than 100% because students took multiple courses.

Table 4.5 *Science Courses Reported Being Taken by Anatomy Students*

Category	Response	*f*	%
Science Course Taken			
(*N*=12)	Biology I	12	100%
	Chemistry I	12	100%
	Integrated Chemistry and Physics	3	25%
	AP Environmental Science	1	8%
	Biology II	1	8%
	Physics	1	8%

Note. Totals are greater than 100% because students have taken multiple courses.

4.5 Research Question #1: What are Agricultural Science Students' Initial Views of the NOS Before Taking an Advanced Life Science Agriculture Course.

The questionnaire utilized for this study was the Views of the Nature of Science-Form C (VNOS-C). The VNOS-C contains 10 open-ended questions that address seven tenets of the NOS. Respondent answers were coded as Naïve, Emerging, or Informed. Results were coded by the researcher based upon examples given in Ledermen, Abd-El-Khalick, Bell, and Schwartz (2002). Results for participant responses will be broken down by question on the VNOS-C. Please note that all responses are unedited student responses.

Question #1 to which students responded to was: *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)?* Table 4.6 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.7 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.6 *ALS Student Understanding of NOS related to VNOS-C Question #1*

Category	*f*	%	Example Responses
Naïve Views	46	96%	*P7:* Science is the idea of knowing all that there is to know about the way the universe works. Science is different from religion or philosophy because it is centered on true, unchanging facts, where as religion/philosophy is based more on beliefs and opinions.
Emerging Views	2	4%	*A22:* Science is things that have to do with the body and plants. It explains how things work. Science is different from religion is considered your opinion even though I don't agree with that. *F13:* I think that science is just a way of explaining and finding answers in the physical environment around us; even thoughts can be scientific if you ask me. Religion and philosophy are just other ways of explaining things, in terms of where we came from with religion and possibilities with philosophy.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.7 *Anatomy Student Understanding of NOS related to VNOS-C Question #1*

Category	*f*	%	Example Responses
Naïve Views	12	100%	*B14:* Science is a study of facts and things you can define. Science is different because it only real or possible if proven and inquiry is belief and faith in one person. *B11:* Science is different from disciplines such as religion and philosophy because there are concrete, provable facts involved in science. A philosopher can't declare his theories as absolute truth, but scientific concepts such as Boyle's law can be backed up with evidence and proven fact.
Emerging Views	0	0%	No students gave emerging responses.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=12).

For Question #1, the majority of students in ALS (98%) and Anatomy (100%) indicate Naïve understanding of NOS. Students gave responses that indicate that there is a distinct difference between science and other disciplines of inquiry, such as philosophy and religion. Many responses indicated that there is a difference between science and other areas of inquiry because science contains "provable" facts indicating a Naïve understanding of science.

Question #2 and Question #3 were coded as one question and "used in combination to assess respondents' views of investigative processes in science" (Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001; Abd-El-Khalick, F., 1998, p. 3).

Question #2 to which students responded to was: *What is an experiment?* Question #3 that students responded to was: *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.* Table 4.8 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.9 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.8 *ALS Student Understanding of NOS related to VNOS-C Question #2 & #3*

Category	*f*	%	Example Responses
Naïve Views	37	77%	*A10:* An experiment is something that is used to prove or disprove something through science. Yes, everything in science that we know and use today was found through experiments in earlier times. To keep expanding our knowledge, we need to keep experimenting. *F3:* An experiment is something you try. It can be anything. There are also a ton of reasons why people want to experiment. Maybe they want to see what happens when they do a certain thing. Along after the experiment and during, I suppose, the experimenter is trying to figure something out. Yes, you can't just assume that something works a certain way without experimenting the theory.
Emerging Views	11	23%	*P7:* An experiment is any type of action made with the intention of a result to occur. Though experimenting is common in scientific research, it is not required. For example, learning about the tendencies of erosion could be done by simply observing it first hand, without an experimental process. *F9:* A way to get an answer to a question. Or a way to gather information about an unknown. No, serendipity is accidental discovery and there have been multiple serendipitous off products like peanut butter cups.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Food

Table 4.9 *Anatomy Student Understanding of NOS related to VNOS-C Question #2 & #3*

Category	*f*	%	Example Responses
Naïve Views	10	83%	*B4:* Something done to prove a hypothesis. Experiments make up the base of science. Because something needs to be proven before it can become a concrete scientific idea, experiments are essential to perform. Yes, scientific knowledge does require experiments. Scientific knowledge must be proven to be concrete. For example, one can't simply say, "the kidneys have no essential function in the human body" and then expects everyone to believe them and for it to be "scientific knowledge". Nothing, then, would develop; everything would crumble because there is no base. Thus, all ideas must be proven by experimentation. *B11:* An experiment is a procedure performed in order to prove or disprove a theory. First, a person comes up with a hypothesis, then he conducts a test or series of tests. The result of these tests determine whether or not the hypothesis is valid. Yes- there is no way to be completely positive that an observation is 100% fact until one validates it through scientific studies. For example, humans would never be aware of the intricate and complex workings of their circulatory systems if scientists had not researched and investigated it. They would see blood when they got a paper cut, and they could feel their pulse, but they could never understand what causes the effects.

Note. Total number of responses (*N*=12).

(Table 4.9 continues)

Table 4.9 continued

Category	*f*	%	Example Responses
Emerging Views	2	17%	*B7:* An experiment is a system of variables and controls that is used to test a postulation. Experiments do not have to yield in favor of the hypothesis to be a success. Yes; observation is essential. Science could progress with only a system of mathematic proofs to justify its claims, but without observations of subjects claims will not always be rational or able to be expanded upon. *B15:* In a statistical sense, an experiment is taking a subject and altering something from the norm and monitoring the change if any. Sort of like a more engaged observational study. Yes, if we seek to look into how things work and how we could stimulate, enhance, or alter it experimentation would be a necessity.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=12).

Question #2 & 3 indicates that overall ALS and Anatomy students hold Naïve understanding of NOS regarding scientific experimentation and how investigations should be conducted. Students continue to indicate that science can be “proven” and that experiments are important to be able to “prove” concepts in science. Being able to “prove” science was consistent in both classes, Anatomy and ALS.

Question #4 to which students responded to was: *Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, do you think scientists used to determine what an atom looks like?* Table 4.10 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.11 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.10 *ALS Student Understanding of NOS related to VNOS-C Question #4*

Category	*f*	%	Example Responses
Naïve Views	42	88%	*A4:* I think that scientists are pretty sure about the structure of an atom, yet due to it being so small, they may have missed something. I think that scientists probably used a lot of advanced technology and powerful microscopes, tests, and experiments to determine what an atom looks like. *P3:* They spent lots of time with their microscopes, experimenting, and creating theories. After long periods of time, they proved themselves right.
Emerging Views	6	13%	*A24:* I think scientists may have an idea what an atom looks like, but I don't think they know exactly what it looks like. I think the evidence they have is from knowledge from other scientists and pictures they've seen. *F18:* In my opinion scientists are using educated guesses to predict what an atom looks like. Parts of science (dieting and food science for example) are changing constantly because scientists haven't proved what works or what is good for the body for certain. White or yellow part of the egg?
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.11 *Anatomy Student Understanding of NOS related to VNOS-C Question #4*

Category	*f*	%	Example Responses
Naïve Views	9	75%	*B7:* They must have used experiments involving the behavior of particles with certain charges in certain conditions. Evidence was observable and/or computable. *B17:* I would say that scientists are fairly certain about the structure of atoms. They can hypothesize their generally shape based on bonding characteristics and using microscopic viewing technology.
Emerging Views	1	8%	*B3:* Scientists are not positively certain about the structure because you cannot see an atom using the naked eye. They used experiments and theories to test what they think it might look like.

Note. Total number of responses (*N*=12)

(Table 4.11 continues)

(Table 4.11 continued)

Category	*f*	%	Example Responses
Informed Views	2	17%	*B4:* I remember when I was younger, the atom representation looked different than what it does today. An a hundred years ago, it looked vastly different. I think scientists create an educated idea, then test it to the best of their ability. When the first model of the atom was created, it was the best that they could produce given the time. Then, as new scientists experimented, the base (atom model, in this case) began to crumble and didn't' make sense, so they began creating new ideas and models. Even today, who knows if the model we have is correct, but we will continue to improve it, as we have always done. *B11:* I don't think that scientists are anywhere near sure of the appearance of the atom. Atoms are constantly moving and changing due to reactions with other atoms, and I don't believe scientists have the technology to view a real atom. Throughout history, scientists have just taken what they know bout atoms and made inferences based on their characteristics. As they gained more information on atoms, they updated the model, starting all the way back with the simple Billiard Ball model to the current one. Science's image of the atom has changed so much over the centuries, and there's more than likely many changes to come.

Note. Total number of responses (*N*=12)

For both ALS and Anatomy students, Question #4 further indicated Naïve views of NOS. Students indicated that scientists are able to "prove" or come very close to understanding because scientists have advanced technology and powerful microscopes. The majority of students, who held Naïve views, were not able to point out that scientists have to draw conclusions using their own interpretations and creativity and imagination.

Question #5 to which students responded to was: *Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example*. Table 4.12

reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.13 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.12 *ALS Student Understanding of NOS related to VNOS-C Question #5*

Category	*f*	%	Example Responses
Naïve Views	41	85%	*P4:* Yes, theories are possible ways things happen (how they happen) while laws tell what happens. *P11:* A theory is something that is not 100% sure of and known about completely. A law is something, like gravity, that has to exist for the function of other things. Scientific theory-atomic theory.
Emerging Views	6	13%	*F13:* Scientific theories, in my mind, are just characteristics that scientists find that they think will occur again. For example, scientists think that if a ball falls from a cliff, that it will hit the ground because of gravity. Can a scientist actually prove this however? In my mind, there are very few, if any scientific laws that are absolutely true and set in stone. I can't think of any at any rate.. *P12:* A scientific theory is just what someone thinks might happen, where a scientific law is what will actually happen. Someone might believe that if an apple fell from a tree, it might fall up. The scientific law shows that it will actually fall down.
Informed Views	1	2%	*F1:* Yes. Theory can't be proven true every time. Scientific law would state that it has to happen. In my opinion, law doesn't exist in science. It only exists with math, 2+2=4 everyday, forever and ever. Newton doesn't know if gravity will exist when we wake up tomorrow.

Note. Total number of responses (N=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.13 *Anatomy Student Understanding of NOS related to VNOS-C Question #5*

Category	*f*	%	Example Responses
Naïve Views	9	75%	*B3:* Scientific theory is kind of not all the way proven and scientific law is concrete and unchangeable. For example, Darwin's theory was not completely proven and has changed over the past years with the use of more experiments. *B16:* Yes, a scientific theory is a thought or prediction of what they think it might be. A law is the actual truth. A law may prove a theory correct which in that case, they are the same.
Emerging Views	2	17%	*B15:* A theory wouldn't be proven with factual evidence but a commonly accepted rule or understanding. A law would bound the information as fact and truth and have no other method or solution. Use temperature as a theory. 0 Kelvin is the point where everything freezes. When has man ever experienced 0 Kelvin? Or a temperature in Kelvin when everything burns. *B17:* There is no such thing as a scientific law-everything is based on theory. The law of gravity isn't a "law", it's a prediction based on millions upon millions of "experiments". We predict that an apple dropped will fall to the ground because every time an apple has been dropped since the beginning of tome it has fallen, but there is no 100% guarantee that it will happen the next time you drop it. You can't prove it without actually doing it.
Informed Views	1	8%	*B11:* Scientific theories are educated hypotheses made by scientists and have some evidence and support, but haven't been tested yet. Las have been tested and have nearly indisputable support. However, there is no way to completely prove a law, so they can't be accepted as total fact.

Note. Total number of responses (*N*=12).

Regarding question #5, students indicated Naïve understanding as to how scientific laws and theories function. Students with Naïve conceptions of laws and theories discuss the distinction in the fact that laws are proven and theories can change based upon new discoveries. Further, once theories have been extensively tested the theory can become a law.

Question #6 to which students responded to was: *After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?* Table 4.14 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.15 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.14 *ALS Student Understanding of NOS related to VNOS-C Question #6*

Category	*f*	%	Example Responses
Naïve Views	45	94%	*A22:* Yes theories can change because you can gain knowledge which may effect the theory. We learn theories because it helps you learn and understand other things in science. *A21:* Theories change as scientists learn more about the subject. We learn about the theories so that we can understand what may be happening in the world. For example, evolution is not a proven topic but we learn about it to learn what may have brought us to where we are today.
Emerging Views	3	6%	*P12:* I think theories change as you go farther into an experiment because you gain more knowledge. *P9:* Yes, tests reveal new information that adds to or even changes the theory. Newton's Law of Gravity is a theory, but several other theories are based on this. If humans didn't have theories, we would have nothing to test.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.15 *Anatomy Student Understanding of NOS related to VNOS-C Question #6*

Category	*f*	%	Example Responses
Naïve Views	9	75%	*B14:* I believe they change because a theory is a possibility that hasn't been proven or proven wrong. To see the different possibilities that we think can happened what actually does. Like in physics. When we drop a ball from high up it will fall. It is possible to kill someone from 1000s ft. up. *B16:* I don't think the specific theory changes. It us used to form a law which is the "right" theory. A theory on how electricity is formed may say it is only formed from lightening, which is not true so someone takes that theory to create their own or a law. That specific theory is not changing.
Emerging Views	3	25%	*B7:* Theories change everyday almost constantly. New information becomes available through technology or a special opportunity (such as the viewing of a lunar eclipse). Scientific theories are worth learning so that people may challenge and revise the theories if the people believe the theories to be incomplete. *B15:* Of course they change. New thins are discovered everyday. New numbers even. Back when 1+1=2 and nothing else was needed, no one ever knew that $i = \sqrt{-1}$. Atoms never existed in our minds until they were discovered, even longer, it took for electrons. We learn what we can as we can, accept that there may be more to it and until it is found learn as much as we can about [what] we think we know.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=12).

For Question #6 the majority of students continue to define theories as something that change based upon new discoveries. Further, students indicated that these theories have been tested extensively and can be proven, they can then progress on to be considered a law. Additionally, students indicated that these proven laws are absolute and never changing which indicates Naïve NOS understanding.

Question #7 to which students responded to was: *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?* Table 4.16 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.17 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.16 *ALS Student Understanding of NOS related to VNOS-C Question #7*

Category	*f*	%	Example Responses
Naïve Views	45	94%	*A22:* I think that scientists are pretty certain about their characterization of specie. Scientists use physical characteristics, habitat, and genetics to determine the species. *F19:* I believe scientists are positive with their characterization of a species. Its basically just a definition so evidence isn't really required. Studying animals is evidence enough.
Emerging Views	3	6%	*P9:* Fairly certain but not 100% certain. Past is used to determine a definition, but there is no set way how the future may play out, so things may change. *A8:* Scientists are almost positive because they've observed them. They believe a species is a group of living things that share more than less characteristics. Horses vs. zebras. 4 legs. Muscular body build. Same bone structure. Different height.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.17 *Anatomy Student Understanding of NOS related to VNOS-C Question #7*

Category	*f*	%	Example Responses
Naïve Views	12	100%	*B9:* I think scientist are certain but yet some species will breed with a different species type. I think scientist that study species categorize them into their characteristics and they learn about them that way. I think scientist could always learn more about their characterization but I believe they are certain on it. *B16:* I have no idea on how certain scientists are, but I hope they are right, because that is what everyone is learning. Scientists use the species characteristics like colors, shape, sizes, sounds, food they eat, where they come from etc. to determine species.
Emerging Views	0	0%	No students gave emerging responses.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=12).

Question #7 indicates Naïve NOS understanding in both ALS and Anatomy courses. Students gave responses stating that scientists understand different species categorizations because of extensive research due to visible characteristics of an organism. Further, students indicated that scientists are certain of their species classification indicating Naïve understanding of NOS.

Question #8 to which students responded to was: *Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imaginations during their investigations?* Table 4.18

reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.19 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.18 *ALS Student Understanding of NOS related to VNOS-C Question #8*

Category	*f*	%	Example Responses
Naïve Views	14	29%	*P5:* They do not use creativity because they must follow standardized tests and methods. They cannot prove anything with their imagination. *A4:* I don’t think that scientists use their creativity. Scientists usually stick to the facts and data they receive to determine their questions.
Emerging Views	33	69%	*A13:* Yes, they have to use imagination and creativity. I think they use it most with planning and design because they have to come up with an experiment that they think will work. They also have to be open-minded and prepared for other findings. *F12:* Yes, I think scientists use their creativity/imagination before and after an experiment. Using their imagination may help make things easier.
Informed Views	1	2%	*A12:* Yes, I think some scientists do. At all stages they could I think. They might use their imagination to find out other things.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.19 *Anatomy Student Understanding of NOS related to VNOS-C Question #8*

Category	*f*	%	Example Responses
Naïve Views	1	8%	*B3:* No because science is based purely on facts and what is there, not what someone imagines.
Emerging Views	11	92%	*B18:* Yes, scientists use imagination and creativity mostly when planning and designing the experiment. They have to be creative in this stage to compose an experiment that will yield the most informative results possible in regards to their question. *B16:* Yes, they use their creativity and imagination during investigations. I feel they use this in the planning and designing stage. If they used it elsewhere, it would alter the experiment. They us it to produce a way for others to learn and make it interesting.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=12).

For Question #8 the majority of both ALS and Anatomy students gave emerging responses with regards to the use of creativity and imagination in science. Typical responses indicated that creativity and imagination does occur, however, only in the planning and design phases. Overall, students lacked the understanding that creativity and imagination occurs throughout the scientific process indicating that students did not have a completely informed understanding of the use of creativity and imagination in science..

Question #9 to which students responded to was: *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?*

Table 4.20 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.21 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.20 *ALS Student Understanding of NOS related to VNOS-C Question #9*

Category	*f*	%	Example Responses
Naïve Views	24	50%	*A11:* They have found both volcanic ash and meteorites in the earth that dated back 65 million years ago. *F12:* Both a meteorite and a volcano would have close to the same effect so I could see why the conclusions were made.
Emerging Views	24	50%	*P14:* I think it is possible because they are both being creative in different way to get their conclusion. *A21:* Both theories have similar results-something not hit the ground and prompted a reaction. So the scientists reached different conclusions based on the data at hand.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.21 *Anatomy Student Understanding of NOS related to VNOS-C Question #9*

Category	*f*	%	Example Responses
Naïve Views	5	42%	*B6:* The meteorite could have set off a volcanic reaction which caused them to erupt and the dinosaurs to become extinct. *B18:* I'm assuming that the data is derived from a visible piece of evidence indicating that there must have been temperature changes and some sort of trauma to the landscape as well as changes in the atmosphere. All of these could be caused by either a huge meteor or a volcano. The different conclusions are possible when the data could apply to either scenario.
Emerging Views	7	58%	*B16:* They have evidence as to show that there was some devastating event that wiped out the dinosaurs, but there is not enough evidence as to what caused the catastrophe. They must create their own opinions. *B17:* It all depends on what a particular scientists buys into. 65 million years ago is far to long ago to be able to know exactly what happened. Both a cataclysmic volcano eruption and a giant meteor strike would have similar affect on the planet, so the same set of data could yield both conclusions.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=12).

For Question #9, 50% of ALS students gave Naïve responses and 50% gave emerging responses. Anatomy students were split 42% Naïve and 58% Emerging. Students that gave Naïve responses typically gave responses that discussed meteors causing volcanic eruptions. Students that gave more Emerging responses began to discuss that scientists can come to different conclusions based upon creativity and imagination or personal perspective. However, overall, students were not able to fully express the subjectivity, inferences and observations, and creativity and imagination used by scientists.

Question #10 to which students responded to was: *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 and how. Defend your answer with examples*. Table 4.22 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.23 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.22 *ALS Student Understanding of NOS related to VNOS-C Question #10*

Category	*f*	%	Example Responses
Naïve Views	29	60%	*A16:* Science is universal because it is all about testing theories and proving them with evidence and facts. *P9:* Universal. Laws of physics and chemistry do not change over borders, just the knowledge known about them.
Emerging Views	18	38%	*F6:* I believe that science reflects social and cultural values. Most people are going to go with what they believe and the people around them believe more than what everyone believes. *A4:* I believe that science reflects social and cultural values. The way you grew up and what your parents believe in effect how you view science. Religion vs. Philosophy.
Informed Views	1	2%	*P11:* I think the way that science is practiced is affected by culture. Cultures do things in completely different ways. Going to the moon is an example. Not every culture has tried that yet.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.23 *Anatomy Student Understanding of NOS related to VNOS-C Question #10*

Category	*f*	%	Example Responses
Naïve Views	5	42%	*B9:* I think its universal because we don't tend to use religion, and political beliefs when were trying to do science. Science is its own thing and doesn't usually get affected by a persons beliefs and values because science isn't having to do with values. *B18:* I believe that science is universal People may choose not to believe some things because of their own philosophical assumptions (evolution) but scientific evidence is typically straightforward and as accurate as possible.
Emerging Views	5	42%	*B7:* Science is supposed to be universal, but unpopular theories maintaining their right to exist often have their feet cut out from them, such as those explaining the origins of the universe as we know it. The Big Bang and natural selection are the only widely preached theories. *B16:* Science does reflect social and cultural values. They tell everyone what they want to hear. A great example is evolution, how we got here. Some scientists tell us we formed from apes. Some say God created us.

Note. Total number of responses (*N*=12)
Note. Totals do not equal 100% due to rounding.

(Table 4.23 continues)

(Table 4.23 continued)

Category	*f*	%	Example Responses
Informed Views	2	17%	*B11:* I think science reflects social and cultural values. While the world has access to one universal database of scientific discoveries, many cultures interpret the information differently. Religion, philosophies, and value systems each have their own way of explaining the same science that applies to the whole world. *B17:* Science is affected by social and cultural examples. It's these that decide what gets studied and what doesn't. Morals and ethics are the reasons we don't experiment on humans, and why stem cell research is so controversial. Also, the needs of humans propel scientific research, especially on the medical field.

Note. Total number of responses (*N*=12)
Note. Totals do not equal 100% due to rounding.

Students in ALS primarily held Naïve views of the Social and Cultural Embeddedness of Science. Students indicated that science is universal because it should not change based upon location. Additionally, students indicated that science is factual and cannot change, lending to the concept that science has no connection to religion or culture. Anatomy students gave primarily Naïve and Emerging responses. Naïve responses given by Anatomy students were similar to the students in ALS. However, students who provided Emerging responses indicated that the people you are around influence the science that will be performed and researched.

4.6 Research Question #2: What are changes, if any, of agricultural science students' views of the NOS after taking an advanced life science agriculture course

The questionnaire utilized for this study was the Views of the Nature of Science-Form C (VNOS-C). The VNOS-C contains 10 open-ended questions that address the seven tenets of the NOS. After responding, the answers were coded as being Naïve, Emerging, or Informed. Results were coded by the researcher based upon examples given in Ledermen, Abd-El-Khalick, Bell, and Schwartz (2002). Results for participant responses will be broken down by question on the VNOS-C. Please note that all responses are unedited student responses.

Question #1 to which students responded to was: *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)?* Table 4.24 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.25 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.24 *ALS Student Understanding of NOS related to post VNOS-C Question #1*

Category	*f*	%	Example Responses
Naïve Views	44	92%	*P4:* Science is a way to try and prove how things work. In religion and philosophy, beliefs and guessing are used to explain things. In science, they try to find more logical answers. *P7:* Science is the study of how the world works. Science differs from other disciplines of inquiry because it is logical and explainable, whereas religion and philosophy include some aspects that are more theoretical.
Emerging Views	4	8%	*F13:* Science is just a form, mostly a physical way, to find meaning and purposes. Religion and philosophy try to find these in the metaphysical and reasoning aspects. *A24:* I think everything pertains to science. Everyday tasks are sometimes scientific. I don't think there is a big difference between physics and philosophy besides the way you get to the answers you need.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.25 *Anatomy Student Understanding of NOS related to post VNOS-C Question #1*

Category	*f*	%	Example Responses
Naïve Views	11	92%	*B3:* Science is the collection of factual evidence to support a suggested hypothesis. Religion is not considered science because it has to do with faith alone with no factual evidence. *B4:* Science is more factual and requires proof as opposed to "other disciplines of inquiry". Everyone can have their own opinion in, say, religion but science is more concrete.
Emerging Views	1	8%	*B15:* Science by definition is definitions. Science is man's explanation for nature, the body, life forms, chemicals, basically any action or reactions. Every free radical, every variable, science is man's ambition to understand and explore the unseen. Its all based on perception.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=12).

For question #1, 92% of ALS and Anatomy students indicated Naïve views. Students noted that science and religion and philosophy are different. Further, students indicated that science is backed by evidence whereas religion and philosophy are not. The distinction between science and other areas of inquiry indicates a limited understanding of NOS.

Question #2 and Question #3 were coded as one question because the questions "used in combination to assess respondents' views of investigative processes in science"

(Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001; Abd-El-Khalick, F., 1998, p. 3). Question #2 to which students responded to was: *What is an experiment?* Question #3 that students responded to was: *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*. Table 4.26 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.27 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.26 *ALS Student Understanding of NOS related to post VNOS-C Question #2 & #3*

Category	*f*	%	Example Responses
Naïve Views	44	92%	*P11:* An experiment is a test to see how or why things work/function and to prove a hypothesis. Yes, if people move forward in science but do not perform any experiments, there would be no way to prove yourself to make discoveries. You have to go through many tests and trial. *F19:* An experiment is a group of studies, usually a trial and error based study used to prove theories or ideas. Yes, because without having proof or any statistics behind your idea it will only get you so far. For example if they never experimented with chemotherapy and just said "Hey it works" a lot of people would/could have been harmed more.

Note. Total number of responses (*N*=48).

(Table 4.26 continues)

Table 4.26 continued

Anatomy Student Understanding of NOS related to post VNOS-C Question #1

Category	*f*	%	Example Responses
Emerging Views	4	8%	*P7:* An experiment is any test that determines the effects of controllable variables and incontrollable variables. Yes. Without solid proof of information, it is merely theory that can be refuted. If no one had ever controlled an experiment to show gravitropism, it could never be certain that gravitropism is responsible for plants bending and defying gravity. *F1:* An experiment, or experimentation, is the trial and error method of discovery. In order to determine if the atom bomb would work, it required experimentation. The first test run might not work, hence the trial and error, but eventually they discovered a means to accomplish their goal through experimentation. Tricky question indeed. Some may argue no, but the key word here is development. Discovery of scientific knowledge may be a total fluke, and could be a total coincidence, but in order to further develop that previously discovered knowledge, experimentation is a necessity. When drinking tea, some prefer milo, sugar, and/or lemon. However, upon a certain happenstance, one discovered that the mixing of lemon along with milk in tea made the milk curdle. This is a discovery. But what else makes milk curdle? So then someone added coffee, or vodka, or vinegar, and eventually we developed a greater base of scientific knowledge which allows u (sp) to understand why milk curdles.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.27 *Anatomy Student Understanding of NOS related to post VNOS-C Question #2 & #3*

Category	*f*	%	Example Responses
Naïve Views	7	58%	*B4:* An experiment is conducted with intents to draw a conclusion from a set hypothesis. Experiments must be conducted to prove something as factual, they provide evidence. Yes, because otherwise science cannot develop on a factual basis. Without experiments, nothing is able to be deemed as "factual" and thus places itself in the category of "other disciplines of inquiry". *B6:* An experiment is a test conducted to prove a point you are trying to argue. Yes, the development of scientific knowledge requires experiments to prove whether or not something is true.
Emerging Views	5	42%	*B18:* An experiment is the act of testing the validity of a theory in a way that would yield the most accurate results. Yes, without experiments questioning new theories, science would be stagnant. Science cannot develop without experimentation, because experiments allow scientists to develop thoughts and draw important conclusions. *B15:* Trial and error. It's the action and reaction concept mention prior. Man's attempts at understanding uses imitation or repetition of events to try and better understand the event itself. Even myself posing the question of GOD at a lunch table for the purpose of watching people's reactions could be an experiment.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=12).

Question #2 & #3 responses by ALS students were primarily Naïve. Students in ALS gave responses that indicated that experiments are important to help try and “prove” science. Anatomy students did make a small shift in understanding with students being split between Naïve and Emerging views. Anatomy students who gave Naïve responses indicated that experiments are trying to “prove information factual”. However, students with Emerging views indicated that experiments assist in greater understanding of an area of science and assist in scientific progress.

Question #4 to which students responded to was: *Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, do you think scientists used to determine what an atom looks like?* Table 4.28 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.29 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.28 *ALS Student Understanding of NOS related to post VNOS-C Question #4*

Category	*f*	%	Example Responses
Naïve Views	37	77%	*P5:* Scientists are certain of this structure because they have done multiple studies to prove the atom contains things such as the nucleus, protons, electrons, and neutrons. Scientists used today's technology to dissect the atom to ensure the philosophy of its being. *F19:* Today, scientist are much more certain about the structure of an atom there is much more and better technology that can make microscopic things seen by the eye.
Emerging Views	11	23%	*F13:* Scientists still have a lot to learn about atoms, particularly quarks and such, but in general, I think they are pretty sure that they know quite a bit about atoms. Things like electron microscopes and CERN helped determine these things I'm sure. *A21:* They studied the way atoms hold together to form molecules then made conclusions based on experiments. They may not be certain but it's a generally accepted idea that hasn't been disproven so the scientific community accepts it as truth.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.29 *Anatomy Student Understanding of NOS related to post VNOS-C Question #4*

Category	*f*	%	Example Responses
Naïve Views	7	58%	*B6:* Scientists are fairly certain of the structure of an atom because they can be seen and manipulated with the right equipment. *B8:* Pretty certain if their willing to put it in textbooks. Think scientists did experiments to help determine their information.
Emerging Views	4	33%	*B3:* I do not think scientists are certain about the atom because it is not visual for us to see it. We are unclear about what we cannot see and the atom structure has been changed many times throughout history. *B15:* Over time technology has been developed to create a clearer image of the atom. Many concepts of the atom have been formed and yet each new discovery adds to its depth. Right now we see a portion as did these before us. No one knows as of yet how far down or deep they go.
Informed Views	1	8%	*B11:* I don't think scientists are very certain about what an atom really looks like. Because there is no way of directly observing a single atom, scientists can only base their theories concerning atoms on their observations of its functions. These observations increase in accuracy as time goes on. When scientific technology improves, there will be more information obtained about the atom, once again changing science's view of it.

Note. Total number of responses (*N*=12).

Students in ALS primarily gave Naïve views (77%) as well as Anatomy students (58%). Students who gave Naïve responses indicate that scientists are certain of the structure of the atom because of the technology available, such as microscopes. However, students that gave Emerging views indicated that scientists may not be certain and did not reference utilizing tools such as microscopes for the discovery of the atom. Students with Naïve views of NOS may struggle with understanding science beyond the physical tools used in the laboratory, which may indicate a challenge in understanding some of the abstractness of science.

Question #5 to which students responded to was: *Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example*. Table 4.30 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.31 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.30 *ALS Student Understanding of NOS related to post VNOS-C Question #5*

Category	*f*	%	Example Responses
Naïve Views	43	90%	*P3:* A theory is a proposed idea. A law is an idea that's been proven. *F19:* A scientific law is a theory that has been proven and its stuff that we live by today. A theory is an idea that is still currently being experimented with. An example would be Newton's Laws, we refer to those daily, a theory would be evolution and how we came to life because there are so many other alternatives.
Emerging Views	4	8%	*F6:* Yes, scientific theory is what someone believes to be true and a law is what everyone believes. Kind of like in a town how tons of people believe our laws are good ones and came up with them so most people follow them. Then there are a few people who believe certain ones are not goo so they create a theory like a stop sign is just a suggestion of something like that. *F9:* Yes, theory is an educated guess, but a law is supported by data. But sometimes laws change when more stuff is discovered.
Informed Views	1	2%	*F13:* I really don't think that scientists can really prove anything, so I think there is a difference between scientific theory and scientific law. Take gravity - scientists know that it has happened time and time again, but can they absolutely prove that it will continue to happen?

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.31 *Anatomy Student Understanding of NOS related to post VNOS-C Question #5*

Category	*f*	%	Example Responses
Naïve Views	10	83%	*B3:* A scientific theory is knowledge still capable of alterations from findings of experiments but scientific law is concrete and unchanging. Ex: Law of Gravity. *B6:* A law is something that has been proven and put in place to get a desired result every time, but a theory is nothing more than an educated guess.
Emerging Views	1	8%	*B15:* Arrogance. Scientific law is created by whom? A man. Who is one man to place absolute uncontestable fact and boundaries on anything? Nothing is absolutely known. Everything is changing incessantly. All is theory because there's always more out there that is not yet understood.
Informed Views	1	8%	*B17:* There is no such thing as scientific law. The world is not absolute. Scientific "laws" are actually theories based upon experience. We know that gravity will pull a dropped apple to the ground before we drop an apple, but this is a prediction. Gravity has done so for millions of years so it is logical that it will continue doing so, but there is no way to absolutely prove it will act the next time you drop the apple.

Note. Total number of responses (*N*=12)
Note. Percentages do not add to 100% due to rounding.

The majority of students in both the ALS (90%) and Anatomy (83%) courses gave responses indicating Naïve understanding of theories and laws in science. Students that gave Naïve responses mentioned how theories become laws and that laws can be proven. This indicates that still students lack the understanding of how science is constantly changing and the fact that there is no hierarchical relationship between theories and laws.

Question #6 to which students responded to was: *After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?* Table 4.32 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.33 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.32 *ALS Student Understanding of NOS related to post VNOS-C Question #6*

Category	*f*	%	Example Responses
Naïve Views	47	98%	*P5:* Scientific theory is changing with time because scientists are narrowing down the conclusions in hopes of securing the concrete answer and it becoming a scientific law. An example is the evolution theory, scientists cannot prove it to be true but everyday they are narrowing their possibilities. *A22:* Yes theories change by what other scientists find. We learn about them because they can help explain other scientific things.
Emerging Views	1	2%	*A13:* Yes the theories change. They change because of religion, though process, and other proven theories. We learn theories to open imagination to prove what's right.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.33 *Anatomy Student Understanding of NOS related to post VNOS-C Question #6*

Category	*f*	%	Example Responses
Naïve Views	9	75%	*B4:* Theories certainly change; they must change otherwise science cannot progress. Scientific theories provide the spark wherein we desire to prove something (the theory) so that it may be considered a scientific law. If no one ever came up with any theories relating to physics, we would never have the definite laws where upon we can base our conclusions and results. *B14:* Theories do change. They can be disproven by scientist and change the theories or a new discovery can be made that will change a theory on facts. We bother with theories because we are curious people. We went to know what happens and why. We search for answers.
Emerging Views	3	25%	*B9:* Yes they change because they aren't always true since they are theories. With different people's ideas changes the theories. We learn theories because if someone says a theory that helps other people add on to that theory to expand and change it some. *B18:* Theories most definitely can develop and change. As people question the theory, and test it, or add new perspective to it, the theory will evolve.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=12).

Students in both ALS (98%) and Anatomy (75%) courses maintained Naïve views, as compared to the pre- VNOS-C of how theories in science function. Students do believe that theories can change. However, students also indicate that theories can change to become closer to being “proven”, or in some responses theories can become laws.

Question #7 to which students responded to was: *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?* Table 4.34 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.35 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.34 *ALS Student Understanding of NOS related to post VNOS-C Question #7*

Category	*f*	%	Example Responses
Naïve Views	44	92%	*P5:* Scientists are pretty certain of their characterization due to their extensive experimenting. Categorizing species is based off of similarities but hey have proven the similarities to be genetic ultimately creating a species. *A12:* Very specific. They use every tool and resource they have to come out with an accurate species
Emerging Views	4	8%	*A21:* They're not certain but once again, it's a generally accepted idea that scientists agree upon and they all characterize the same way (# of legs, wings, legs, environment, etc.) *A24:* I don't think scientists are very certain about species characterization because they can't be 100% sure about every single characteristic of every single organisms.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.35 *Anatomy Student Understanding of NOS related to post VNOS-C Question #7*

Category	*f*	%	Example Responses
Naïve Views	10	83%	*B11:* I think scientists are fairly firm in what they believe a species is. I think they categorize species by their characteristics such as habitats, diets, and physical characteristics, and if they are able to interbreed. *B14:* Scientists are very certain. If they weren't, they would not say so. They never say anything unless they are certain. They did a lot of experiments to determine this.
Emerging Views	2	17%	*B3:* Scientists were pretty accurate because they have conducted many experiments to verify their characterization but it could change in the future when additional experiments are conducted. *B15:* It seems to initially be physical appearance and attributes. Certain similarities can't go unnoticed. For instance, a beaver with a duck bill…nothing is set in stone. Creatures earn and adapt, change is constant.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=12).

Students in the ALS and Anatomy courses tend to hold Naïve views with regards to if scientists are certain of their characterization of animals. Student responses indicated Naïve understanding because their responses revealed that scientists are certain and they are certain due to genetics and testing. More Emerging NOS responses showed how there is interpretation by scientists and that characterizations of different species could change in the future.

Question #8 to which students responded to was: *Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imaginations during their investigations?* Table 4.36 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.37 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.36 *ALS Student Understanding of NOS related to post VNOS-C Question #8*

Category	*f*	%	Example Responses
Naïve Views	7	15%	*P5:* An intelligent scientist would not imagine an outcome to prevent tampering of the experiment. If a scientist wants the experiment to result a certain ay. Subconsciously they will tamper the data when estimating. *P9:* No. Scientists may use imagination in coming up with a hypothesis, but its use any farther into the experiment would deem it erroneous and inaccurate.
Emerging Views	39	81%	*P7:* Yes, scientists have to be creative when deciding how best to test the single variable they want to and get the best results. Scientists must use their imaginations because they are trying to discover things that are unheard of. *F18:* Yes during planning and design, and sometimes after data collection. Data collection is straight facts in my opinion so creativity can't be used here. Sometimes scientists see what they want to believe from the data collected.
Informed Views	2	4%	*A12:* Yes, they always want to have an open mind. All [stages of investigation]. It allows them to learn new things. *A13:* Yes, they have to. They use it throughout the investigations to help prove themselves.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.37 *Anatomy Student Understanding of NOS related to post VNOS-C Question #8*

Category	*f*	%	Example Responses
Naïve Views	1	8%	*B14:* No, because they are strictly facts and don't believe unless its done. They can come up with new experiment by only with the facts and idea behind it, not by thinking beyond whats there.
Emerging Views	10	83%	*B16:* Yes, they must use abnormal ideas in order to obtain abnormal results. I feel in the planning and design is the most creative and imaginative part. They use this to have results to catch peoples eye. *B17:* Of course scientists use creativity and imagination. These traits come in to play during the planning and design of experiments. We never thought it would be possible to send a man to the moon, but some imaginative scientists at NASA got it done.
Informed Views	1	8%	*B15:* To even be in the field f imagination and creativity is required. If you don't believe there's something else out there then why bother looking. All throughout the process imagination is used even if just prediction or anticipation.

Note. Total number of responses (*N*=12).
Note. Percentages do not add to 100% due to rounding.

Students in the ALS (81%) and Anatomy (83%) courses gave Emerging responses regarding to Questions #8. Students with Emerging conceptions were able to identify that creativity and imagination can occur in science when developing experiments, however, many students added that if any further creativity was utilized in the experiment then the results reported would be false. Students with Emerging conceptions had difficulty providing examples further indicating they did not fully understand that creativity and imagination is a vital component in science and could not be classified as an informed response. Students who gave responses indicating a Naïve conception of creativity and Imagination in science typically indicated that “facts are facts” and cannot change.

Question #9 to which students responded to was: *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?* Table 4.38 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.39 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.38 *ALS Student Understanding of NOS related to post VNOS-C Question #9*

Category	*f*	%	Example Responses
Naïve Views	27	56%	*F19:* I think both are created based on the fact that they have the same variables. Obviously both had a fiery hot substance that wiped out thousands of dinosaurs. *P9:* The data is too vague to fit only the one hypothesis. Therefore both are applicable.
Emerging Views	20	42%	*A6:* Because they both can look at the data differently, no one can know the exact way they did you just have to give it your best guess. *P7:* The data could lend evidence of both because both could have happened. It all depends on how you use the data in your explanation.
Informed Views	1	2%	*F1:* The different conclusions are possible because the same sets of data can be interpreted in different ways. Science is in no way solid. Interpretation of data relies almost solely on creativity and imagination.

Note. Total number of responses (*N*=48).
Note. *P*=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.39 *Anatomy Student Understanding of NOS related to post VNOS-C Question #9*

Category	*f*	%	Example Responses
Naïve Views	6	50%	*B14:* They both could be right. If they have back up facts. But it won't change the fact the dinosaurs are extinct. *B17:* Both a meteor strike and massive volcanic eruptions would produce similar results, which would lend scientists to conclude either could have happened.
Emerging Views	6	50%	*B8:* These 2 groups think differently. We do not all think that same and the way we go about doing things is different than one another. *B11:* The data that the scientists used could have been a result of either event; it was how the scientists interpreted it that let them form their theory.
Informed Views	0	0%	No students gave informed responses.

Note. Total number of responses (*N*=12).

Students in ALS and Anatomy were again evenly split: Naïve and Emerging. Students with Naïve responses indicated that meteors and volcanoes were related and that facts cannot change. However, students with Emerging views indicated that creativity and imagination could have been used by scientists to come up with the different theories/explanations for the disappearance of the dinosaurs. Students in the Emerging category lacked the overall understanding of subjectivity and inference.

Question #10 to which students responded to was: *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 and how. Defend your answer with examples*. Table 4.40 reports the number of students in ALS coded as Naïve, Emerging, or Informed categories as well as representative written response examples. Table 4.41 reports the number of students in the Anatomy course and the category students were coded into as well as representative written response examples corresponding to NOS understanding.

Table 4.40 *ALS Student Understanding of NOS related to post VNOS-C Question #10*

Category	*f*	%	Example Responses
Naïve Views	27	56%	*F6:* I don't believe it is influenced by social, political, and philosophical values. I believe science is science and it can't be influenced by a social life. Science is factual and it is hard to change. *A11:* Science is supposed to be universal so that the findings come out true. Peoples views should not get in the way of science.
Emerging Views	20	42%	*A4:* I think that science reflects cultural values. I think scientists study more of the things that we find culturally important. *P14:* I think science reflects social and cultural values because depending on your location in the world and culture and technology some of these theories aren't going to make sense because it has never been introduced before.
Informed Views	1	2%	*F1:* Social and cultural values determine our moral, and our upbringing. These are the things that form our beliefs as adults. These beliefs can then mold how we interpret data. Data interpretation leads to science. Therefore, science doesn't reign free throughout the world, it does know bounds. Therefore culture and social values are reflected in our findings. Just look at evolution.

Note. Total number of responses (*N*=48).
Note: P=ALS Plants, *A*=ALS Animals, *F*=ALS Foods

Table 4.41 *Anatomy Student Understanding of NOS related to post VNOS-C Question #10*

Category	*f*	%	Example Responses
Naïve Views	4	33%	*B3:* Science is universal because it is all based on facts proven through experiments. It only becomes reflective of social and cultural values when someone tries to teach it with their perspective *B6:* Science is universal because it is the same all over the world and when something major happens scientists from around the world join to help.
Emerging Views	7	58%	*B4:* I think that social and cultural values certainly have places in science and it would be near impossible to keep them out. I think that that is important, however, I think science should be universal also, so I don't really know where I stand on that. I suppose social and cultural values can be presented in scientific theories, but when it is being proven and refined to become a law, universal thought should conclude.
Informed Views	1	8%	*B14:* I believe science is reflected on every thing. Our beliefs is what makes us think a certain way. It makes us who we are. We see all of that in your work. Each scientists did something different and believed differently to get different theories and ideas.

Note. Total number of responses (*N*=12).
Note. Percentages do not add to 100% due to rounding.

For Question #10, 56% of ALS students held Naïve views, while 42% held Emerging views. Students that gave Naïve responses indicated that science in universal and transcends all borders. However, students who gave Emerging views indicated that science is studied and researched in parts of the world in which that particular area of science is accepted by the people in that particular area.

CHAPTER 5. CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

5.1 Introduction

This chapter will present the conclusions for the two research questions guiding this study. Additionally, limitations for this study will be presented. Finally, implications for research and practice will be discussed followed by recommendations for future research.

5.2 Purpose of the Study

The purpose of this study was to explore NOS views of students who are currently enrolled in a science-intensive agriculture course and the extent to which their views change of NOS during the course of a spring academic semester.

5.3 Research Questions

The research questions guiding this study were:

1. What are agricultural science students' initial views of the NOS before taking an advanced life science agriculture course?

2. What are changes, if any, of agricultural science students' views of after taking an advanced life science agriculture course?

5.4 Limitations of the Study

There are two limitations of this study. First, only one school and ALS program were studied. Additionally, the same instructor taught all three ALS courses (ALS: Animals, ALS: Plants, and ALS: Foods), within the agriculture program. Because of this limitation, this study cannot be generalized to other situations and programs.

Second, the students enrolled within the ALS courses are a self-selected group. To enroll within an ALS course, it was required that students be Juniors or Seniors in high school, as well as have already taken Biology and Chemistry or Biology and Integrated Chemistry and Physics. The requirements to enroll in an ALS or Anatomy course could indicate that many of the students may be higher academically achieving, as well as having a greater understanding of science as compared to the general population of students within the school.

5.5 Conclusions of the Study

This section will present the conclusions for each research question. Each research question will be presented and then discussed relative to each tenet covered by the VNOS-C. Table 5.1 presents a summary of responses given by students in both the ALS and Anatomy courses.

Table 5.1 *Summary of Student Responses to VNOS-C Questionnaire*

VNOS-C Question	Response Category	Pre- VNOS-C		Post- VNOS-C	
		ALS (*f*)	Anatomy (*f*)	ALS (*f*)	Anatomy (*f*)
#1	Naive	46	12	44	11
	Emerging	2	0	4	1
	Informed	0	0	0	0
#2 & #3	Naive	37	10	44	7
	Emerging	11	2	4	5
	Informed	0	0	0	0
#4	Naive	42	9	37	7
	Emerging	6	1	11	4
	Informed	0	2	0	1

Note: Total number of ALS responses (*N*=48); Total number of Anatomy responses (*N*=12)

(Table 5.1 continues)

Table 5.1 continued

Summary of Student Responses to VNOS-C Questionnaire

VNOS-C Question	Response Category	Pre- VNOS-C		Post- VNOS-C	
		ALS (*f*)	Anatomy (*f*)	ALS (*f*)	Anatomy (*f*)
#5	Naive	41	9	43	10
	Emerging	6	2	4	1
	Informed	1	1	1	1
#6	Naive	45	9	47	9
	Emerging	3	3	1	3
	Informed	0	0	0	0
#7	Naive	45	12	44	10
	Emerging	3	0	4	2
	Informed	0	0	0	0

Note: Total number of ALS responses (*N*=48); Total number of Anatomy responses (*N*=12)

(Table 5.1 continues)

Table 5.1 continued

Summary of Student Responses to VNOS-C Questionnaire

VNOS-C Question	Response Category	Pre- VNOS-C		Post- VNOS-C	
		ALS (*f*)	Anatomy (*f*)	ALS (*f*)	Anatomy (*f*)
#8	Naive	14	1	7	1
	Emerging	33	11	39	10
	Informed	1	0	2	1
#9	Naive	24	5	27	6
	Emerging	24	7	20	6
	Informed	0	0	1	0
#10	Naive	29	5	27	4
	Emerging	18	5	20	8
	Informed	1	2	1	0

Note: Total number of ALS responses (*N*=48); Total number of Anatomy responses (*N*=12)

5.5.1 Conclusions for Research Question 1: What are agricultural science students' initial views of the NOS before taking an advanced life science agriculture course?

The VNOS-C encompasses seven tenets of NOS commonly accepted for K-12 education. The results for this question are the students' initial thoughts and understandings of NOS.

Overall, students' initial responses indicated overall Naïve views and understanding of NOS for both ALS and Anatomy students. Naïve misconceptions of NOS may be enhanced by the fact that textbooks give students a series of disjointed facts and figures (McComas, Clough, & Almazroa, 1998) that continue to give the picture that science needs to be and can be "proven." Further, the manner in which science is presented in classrooms may have an impact on how students view the scientific process.

Students also indicated having Emerging views regarding to the use of creativity and imagination in science. However, in one question (Question #9) on the VNOS-C questionnaire students were asked how scientists could develop two different conclusions as to how dinosaurs disappeared based upon identical data. However, in a previous question (Question #8) the concept of creativity and imagination in science was discussed. It is possible that students were predisposed to the terms creativity and imagination in Question #8 on the VNOS-C. It is conceivable that students were inclined to use the terms creativity and imagination on Question #9 of the VNOS-C due to a test influence and not due to a more informed conception of the role of creativity and imagination in science. A similar finding by Gendall and Hoek (1990) describes that there could be an influence between these two questions.

5.5.2 Conclusions for Research Question 2: What are changes, if any, of agricultural science students' views of the NOS after taking an advanced life science agriculture course?

The VNOS-C encompasses seven tenets of NOS commonly accepted for K-12 education. The results for research question two are the views and NOS understandings of students after taking an advanced life science agriculture course.

Overall, there was no change in students' understanding of NOS for both courses, ALS and Anatomy. However, responses on the post VNOS-C questionnaire from ALS students showed some change in understanding of the social and cultural embeddedness through their written responses. Many students began to move from more Naïve views, with science being "Universal," to conceptions that would be more Emerging and developing. Advanced Life Science students cited examples in their responses of evolution as well as stem cell research. Students also mentioned how some religions and cultures do not recognize some research areas (such as stem cell research) leading to a more emerging conception of the social and cultural embeddedness of the NOS. Contextual topics such as stem cell research are commonly discussed through inquiry methods within agricultural courses. As such, the contextual and inquiry-based manner in which agricultural science courses are taught could assist in helping students take abstract concepts and gain NOS understanding.

Further, despite the fact that students still seem to lack a full understanding of NOS, a couple of students, in the ALS courses with Emerging conceptions mentioned concepts such as gravitropism and milk curdling to give examples of how some scientific discoveries were “by accident” or by “happenstance.” Examples such as these may have a connection with the overall understanding of the empirical basis of science. The examples of gravitropism and milk curdling indicate that students may be forming NOS science conceptions regarding agriculture. The context of agriculture may assist students in forming accurate conceptions of the empirical basis of science.

In this study, students believed that information in textbooks is proven because it is published. Students may lack understanding of the tentativeness of science due to a lack of contact with new revolutionary concepts in science (Nortrup, 2013). Students in Agricultural Education need to have current research and scientific discoveries included in their courses to begin making connections to how science changes.

Lastly, the question can be raised: Is it reasonable to expect that students be able to understand such abstract terms that are embedded within the VNOS-C? The NOS is an important concept that is to be taught throughout the K-12 educational system. However, students in high school courses are indicating a lack of understanding of NOS. It could be argued that the terminology may be too abstract for students be able to fully comprehend.

5.6 Implications for Research and Theory

There are several implications for research that result from this study for the area of Agricultural Education in relation to NOS understanding and science integration. To begin, NOS needs to be further explored to better understand student NOS understanding in relation to their enrollment in Agricultural Education courses. Prior to this study, only two other studies had been conducted on NOS in agricultural education leaving many facets of Agricultural Education and the impact on NOS understanding unexplored. This study can assist in laying the foundation to utilizing the context of Agricultural Education as means to determine how to enhance student NOS understanding.

A second implication for research can be extended to how science is being presented and taught in Agricultural Education courses. Agriculture is a science (Thoron & Rubenstein, 2013; Thoron & Myers, 2010), and as such, needs to be further explored as to how science concepts should be presented and taught to students. Findings from this study indicate that even in advanced science courses, students who took previous high school science courses are not gaining adequate levels of understanding of NOS.

A third implication for research would be to explore implicit vs. explicit teaching of NOS in Agricultural Education courses. Research has shown that the explicit teaching of NOS to be the most effective way to teach NOS concepts (Yalcinoglu & Anagun, 2012; Schwartz et al., 2010; Moss, 2001). Agricultural Education has a very contextually rich and hands-on curricula. Due to the manner in which Agricultural Education is taught, explicit instruction on NOS needs to be further researched and explored.

5.7 Implications for Practice

The implications for practice from this study focus on issues related to curriculum development and advancement, Agricultural Education instruction, and ASB teacher education of NOS.

The first implication is tied to ALS curriculum improvement and new Agricultural Education curriculum development. Previous research has indicated that the most effective pedagogical method for successfully teaching NOS is through an explicit NOS teaching method (Yalcinoglu & Anagun, 2012; Schwartz et al., 2010; Moss, 2001). Having explicit strategies embedded within the Agricultural Education curriculum could assist in guiding Agricultural Science and Business (ASB) teachers to better implement activities with reflection that could enhance curricula and student connections and understanding of NOS.

The second implication for practice is for ASB teacher preparation programs and how to integrate NOS instruction into the classroom. Overall, students in this study were shown to have uninformed conceptions of NOS, which suggests a need for more NOS instruction to be explicitly implemented within the classroom through reflection, discussion, and NOS explicit activities. Including NOS in teacher preparation programs would greater assist ASB teachers in furthering the understanding of NOS for their students through their in-classroom instruction. If teachers are more comfortable with and knowledgeable as to how science works, students will have a greater chance of making the connections between science, agriculture, and society.

Finally, ASB teachers in Indiana do not receive instruction on NOS during their pre-service education which indicates that pre-service ASB teachers need to acquire adequate education related to NOS to assist in their understanding of NOS. For example, Nortrup (2013) discovered that, overall, ASB teachers tend to lack understanding of many of the NOS tenets deemed important for K-12 science education. Agriculture is a science which means if ASB teachers are to properly teach the full scope of science and how science works they need to be including NOS in their curriculum. Overall, to further aid in assisting teachers in understanding NOS so that it can be taught within agricultural education classrooms, NOS-focused professional development opportunities geared toward ASB teachers should be offered.

5.8 Recommendations for Future Research

The following are recommendations for research in the area of Agricultural Education as it relates to NOS. First, future research should focus on a larger and more diverse group of Agricultural Education students who are enrolled in different agricultural education courses. The current study focused on only one course (Advanced Life Science) that is not offered in states beyond Indiana, and included a small population of Agricultural Education students (*N*=48) from one school. To gain a more comprehensive understanding of the influence of Agricultural Education on student NOS understanding, more courses and across all grade levels of students should be explored.

Previous research has shown that explicit teaching of NOS can be effective in assisting students with NOS understanding (Yalcinoglu & Anagun, 2012; Brooks, 2011; Schwartz et al., 2010). To better understand the connection agriculture has with science and how students view these connections, explicit instruction of NOS needs to be examined within agricultural education.

Further, the different methods for explicit instruction, and which method would work best for agricultural education need to be explored to find the best methods of practice for the agricultural context. Further, with the experiential learning that is utilized within Agricultural Education, it is important to explore how NOS can be integrated explicitly into these activities to assist students in their NOS understanding.

Finally, science integration research within Agricultural Education research needs to focus on elements of the NOS. Doing so would help to make a greater connection between science and agriculture. Additionally, by including NOS in Agricultural Education research, the opportunity for improving agricultural and scientific literacy will be enhanced by giving teachers and students a more complete understanding of how the realm of science actually works.

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APPENDICES

Appendix A: IRB Approval

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	LEVON ESTERS AGAD
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	11/21/2011
Committee Action:	**Approval**
IRB Action Date	11/15/2011
IRB Protocol #	1110011349
Study Title	Do students have a better understanding of the Nature of Science after taking a life science intensive agriculture course?
Expiration Date	11/14/2012

Following review by the Institutional Review Board (IRB), the above-referenced protocol has been approved. This approval permits you to recruit subjects up to the number indicated on the application form and to conduct the research as it is approved. The IRB-stamped and dated consent, assent, and/or information form(s) approved for this protocol are enclosed. Please make copies from these document(s) both for subjects to sign should they choose to enroll in your study and for subjects to keep for their records. Information forms should not be signed. Researchers should keep all consent/assent forms for a period no less than three (3) years following closure of the protocol.

Revisions/Amendments: If you wish to change any aspect of this study, please submit the requested changes to the IRB using the appropriate form. IRB approval must be obtained before implementing any changes unless the change is to remove an immediate hazard to subjects in which case the IRB should be immediately informed following the change.

Continuing Review: It is the Principal Investigator's responsibility to obtain continuing review and approval for this protocol prior to the expiration date noted above. Please allow sufficient time for continued review and approval. No research activity of any sort may continue beyond the expiration date. Failure to receive approval for continuation before the expiration date will result in the approval's expiration on the expiration date. Data collected following the expiration date is unapproved research and cannot be used for research purposes including reporting or publishing as research data.

Unanticipated Problems/Adverse Events: Researchers must report unanticipated problems and/or adverse events to the IRB. If the problem/adverse event is serious, or is expected but occurs with unexpected severity or frequency, or the problem/even is unanticipated, it must be reported to the IRB within 48 hours of learning of the event and a written report submitted within five (5) business days. All other problems/events should be reported at the time of Continuing Review.

We wish you good luck with your work. Please retain copy of this letter for your records.

Ernest C. Young Hall, 10th Floor - 155 S. Grant St. - West Lafayette, IN 47907-2114 - (765) 494-5942 - Fax: (765) 494-9911

Appendix B: Informational Letter to Parents

Purdue University

Youth Development and Agricultural Education

Agricultural Administration

Phone: 494-48423

Fax: 7656-496-1152

DATE: October 31, 2011

TO: Parent and/or Guardian of High School Student

FROM: Levon Esters

RE: Request for Study Assistance

The purpose of this memo is to request permission for your child to participate in a study titled, "Student understanding of the Nature of Science (NOS) when enrolled in a science-intensive agriculture course." Your child was selected as a possible participant because he/she is enrolled in a course, which we are interested in studying. Attached is a Parental Consent Form, Subject Consent Form, and Assent Form outlining the purpose of the study as well as information regarding the study's procedures, participant rights, confidentiality, etc. We ask that you read the attached form before agreeing to have your child participate in this study. If your child is under the age of 18 and you allow your child to participate in this study, you will need to sign the attached "Research Parent Consent Form" and your child will then need to sign the "Student Assent Form". Your child will then need to return the forms in three days to the drop box located in your child's Biology or Agriculture teacher's office. If your child is over the age of 18 your child will need to sign the "Research Participant Consent Form" and then return the form in three days to the drop box located in your child's Biology or Agriculture teacher's office. If your child does not return the form(s) with the proper signatures, your child will not be able participate in this study. If you have any other questions or concerns, please contact me.

Appendix C: Student Assent Form

Student Assent Form

Project Title: Do students have a better understanding of the Nature of Science taking a life science intensive agriculture course?

Investigator(s): Megan Anderson, Graduate Student, Purdue University, B.S. in Youth Development and Agricultural Education

We are doing a research study. A research study is a special way to find out about something. We want to find out if your view of the Nature of Science changes after taking an Advanced Life Science class.

You can be in this study if you want to. If you want to be in this study, you will be asked to take a short test at the beginning and end of your Advanced Life Science class. Also, during the study there will be a student from Purdue that may visit the classroom to watch the activities that occur on a daily basis. In addition, you may be asked for an interview by the researcher just to ask you about the test.

There is no possibility of harm coming to you for participating in this study.

By participating in this study you will be helping to inform the researcher about the Advanced Life Science course that you are participating in. This could help improve the course over time.

When we are done with the study, we will write a report about what we found out. We won't use your name in the report.

You don't have to be in this study. You can say "no" and nothing bad will happen. If you say "yes" now, but you want to stop later, that's okay too. No one will hurt you, or punish you if you want to stop. All you have to do is tell us you want to stop.

If you want to be in this study, please sign your name.

I, ______________________________________, want to be in this research study.
(write your name here)

_______________________________________ ________________
Investigator signature (Date)

Appendix D: Consent Form

For IRB Office Use Only

APPROVED
NOV 1 5 2011
EXPIRES 11/14/12
PURDUE UNIVERSITY
INSTITUTIONAL REVIEW BOARD

Research Project Number __________

RESEARCH PARENT CONSENT FORM
Do students have a better understanding of the Nature of Science after taking a life science Intensive Agriculture course?
Principal Investigator: Levon Esters, Ph. D.
Purdue University
Youth Development and Agricultural Education

Purpose of the Study: The purpose of this study is to determine if students' views of the Nature of Science (NOS change during the course of a science-intensive agriculture course known as the Advanced Life Science Program (ALS).

Procedure to be followed during the study: Your child will be asked to fill out a short pre-test about their views of the Nature of Science in which your child will be given as much time as needed to complete the test. Your child will also be asked some demographic information so that the researcher understands the student population. During the course of the semester the co-investigator will be in the classroom 6-10 days observing classroom activities that are occurring during everyday lessons, labs, and activities. The observations will last the duration of the class period. In addition, your child may be selected for an interview, which will involve asking your child about their thoughts about the Nature of Science. The interview will last no more than 45 minutes and will be audio recorded to ensure accuracy of coding of your child's answers. At the end of the course your child will again be asked to fill out a post-test about their views of the Nature of Science in which your child will be given as much time as needed to complete the test. In addition, your child may be asked for a short interview, simply to ask them about the test and their thoughts. The interview will last no more than 45 minutes. During the interview your child's answers will be audio recorded to ensure that the answers given are completely understood by the researcher. Your child will only be identified by name to determine which test your child took. This information will only be seen by the primary or co-investigator and will be locked in a cabinet in the office of the co-investigator. If your child is randomly selected at the beginning of the study for an interview, your child will be selected again for an interview at the end of the study. You have the right to review all of the questions on the test as well as the interview questions prior to allowing your child to participate in this study.

Duration of this Study
The duration of this study is for the academic school year of 2011-2012. All data collected (i.e., observation notes, tests, consent forms, assent forms, audio recording and transcriptions) will be destroyed within 2 years of this study. None of the raw data will be used in the future. For the test (pre-test and post-test), your child will be given as much time as needed to complete the test. The interview will not last more than 45 minutes if your child is selected. The researcher observing the classroom will only be in the classroom 6-10 times for the duration of the class period.

Risks
There are no risks to the participants beyond everyday activity at school and a possibility of a breach in confidentiality. Although this risk is a possibility, safeguards are in place to prevent this from happening. All research carries risk. The standard for minimal risk is that which is found in everyday life.

Initials: _______

Date: ______

Research Project Number __________

Benefits
There are no direct benefits to the participants. However, the results of this study could improve the ALS program for future students. There are some indirect benefits that may occur to your child which include increasing a student's thinking about and interest in science.

Confidentiality
Any data collected (i.e., tests, audio recordings, classroom observations) will be stored in a locked desk drawer with access available only to the primary and co-investigator. For this study your child's GPA will be accessed. However, the researcher will not have your child's name or be able to link a GPA with your child. The project's research records may be reviewed by departments at Purdue University responsible for regulatory and research oversight.

Voluntary Nature of Participation
You do not have to give permission for your child to participate in this research project. If you do allow your child to participate you can withdraw your child's participation at any time without penalty.

Contact Information:
If you have any questions about this research project, you can contact Megan Anderson at (618) 978-6703 or Dr. Levon Esters at (765) 494-8423. If you have concerns about the treatment of research participants, you can contact the Institutional Review Board at Purdue University, Ernest C. Young Hall, Room 1032, 155 S. Grant St., West Lafayette, IN 47907-2114. The phone number for the Board is (765) 494-5942. The email address is irb@purdue.edu.

Documentation of Informed Consent
I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research project and my questions have been answered. I am prepared to grant permission for my child to participate in the research project described above. I will receive a copy of this consent form after I sign it. If your child is under the age of 18, a parent or guardian must sign this consent form. In addition your child must also sign the "Student Assent" form (attached).

____
Parent or Guardian (please print)

______________________________ __________
Parent or Guardian Signature Date

____
Child's Name (please print)

______________________________ __________
Researcher's Signature Date

Initials: _______

Date: ______

Appendix E: School Principal Permission to Complete the Study

September 21, 2011

Community High School

In my role as principal of I High School in I IN, I have discussed with Megan Anderson the project entitled "Students Understanding of the Nature of Science Within a Life Science-Intensive Agriculture Course?" I have considered the components and goals of this project and am happy to collaborate with Purdue University in this endeavor. The Advanced Life Science (ALS) program is an integral part of our agricultural department and I would like to help in making the program even better. In addition, meeting state standards and increasing the level of Nature of Science understanding in our classrooms is very important. Collaborating with Purdue University for this project is a great way to continue to make our program great. Finally, this project will allow participating teachers and students the opportunity to develop further understanding of the Nature of Science through the ALS program.

Upon approval of this project, Mr. , on behalf of I High School, will assist in identifying participants enrolled in the ALS courses as well as a comparable advanced level Biology course. We understand that the students' views of the Nature of Science will be examined in both the Biology and the ALS courses with no intent to alter how the curricula are normally taught. Furthermore we understand that the study will last for one year and Megan Anderson will:

- Submit a research protocol for approval to Purdue University's Institutional Review Board for the Protection of Human Rights.
- Coordinate the collection of informed consent from the project participants.
- Coordinate and carry out the data collection procedures throughout the project period.
- Share findings of the study throughout the project period.
- Coordinate with High School mechanisms for communicating information based on project data.

Resonant with I High School's vision to ensure a quality educational program for all students in a challenging and secure environment, I believe that the proposed project will have important implications for enhancing our science instruction. We look forward to contributing to the knowledge base about how to best educate and serve our students. I High School is happy to support this effort.

Sincerely,

[illegible]
Principal
High School

Appendix F: VNOS-C Questionnaire

VNOS (C)

Name:________________________________

Date: / /

Please answer each of the following questions. Include relevant examples whenever possible. You can use the back of a page if you need more space.

- **There are no "right" or "wrong" answers to the following questions. We are only interested in your opinion on a number of issues about science.**

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. 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, or types of evidence, **do you think** scientists used to determine what an atom looks like?

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

6. 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.

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. 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 do you believe that 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.

9. 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?

10. 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 and how. Defend your answer with examples.
- If you believe that science is universal, explain why and how. Defend your answer with examples.

Appendix G: VNOS Interview Protocol

Participants are provided with their VNOS responses to read and review.

1. Could you read your response to question # 1 (2-10) and explain and elaborate on your response?

2. What did you mean by [response, written or verbal]?

3. Could you give an example of what you meant by [response, written or verbal]?

4. How does your response on # X relate to what you said on # Y?

5. Have your views changed since you wrote your response? If so, how?

Appendix H: Demographic Questionnaire for ALS Students

Demographics

Advanced Life Science

1. How old are you? __________

2. Please indicate your gender. Male Female

3. How would you identify yourself?

   a. Caucasian _____
   b. African American _____
   c. Asian American _____
   d. Pacific Islander______
   e. Native American______
   f. Hispanic ______
   g. Other ______

4. Are you interested in Science? Yes No

5. What science courses have you taken before enrolling in an Advanced Life Science course?

____
____
____
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____

Appendix I: Demographic Questionnaire for Anatomy Students

Demographics

Biology

1. How old are you? _________

2. Please indicate your gender. Male Female

3. How would you identify yourself?

    a. Caucasian _____
    b. African American _____
    c. Asian American_____
    d. Pacific Islander______
    e. Native American______
    f. Hispanic ______
    g. Other ______

4. Are you interested in Science? Yes No

5. What science courses have you taken before enrolling in your current Biology course?

____
____
____
____
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____
____

Appendix J: VNOS-C Coding Schematic

Table 2
Illustrative examples of responses to VNOS Items

NOS Aspect	More Naive Views	More Informed Views
Empirical NOS	Science is something that is straightforward and isn't a field of study that allows a lot of opinions, personal bias, or individual views—it is fact based. (Form C: Item 1) Science is concerned with facts. We use observed facts to prove that theories are true. (Form B: Item 6)	Much of the development of scientific knowledge depends on observation. . . . [But] I think what we observe is a function of convention. I don't believe that the goal of science is (or should be) the accumulation of observable facts. Rather . . . science involves abstraction, one step of abstraction after another. (Interview follow-up on Form C: Item 1)
The scientific method	Science deals with using an exact method. . . . That way we know we have the right answer. (Form B: Item 4) Science has a particular method of going about things, the scientific method. (Form C: Item 1)	When you are in sixth grade you learn that here is the scientific method and the first thing you do this, and the second thing you do that and so on . . . That's how we may say we do science, but [it is different from] . . . the way that we actually do science. (Interview follow-up on Form C: Item 1)
General structure and aim of experiments	An experiment is a sequence of steps performed to prove a proposed theory. (Form C: Item 2) Experiment is everything that involves the act of collecting data and not necessarily manipulation. (Interview follow-up on Form C: Item 2)	An experiment cannot prove a theory or a hypothesis. It just discredits or adds validity to them. (Form C: Item 2) An experiment is a controlled way to test and manipulate the objects of interest while keeping all other factors the same. (Form C: Item 2)
Role of prior expectations in experiments	You usually have some sort of idea about the outcome. But I think that to have a scientific and valid experiment you should not have any bias or ideas in advance. (Interview follow-up on Form C: Item 2)	To organize an experiment you need to know what is going to come out of it or it wouldn't really be a test method. I don't know how you would organize a test . . . if you don't have a general idea about what you are looking for. (Interview, follow-up on Form C: Item 2)
Validity of observationally based theories and disciplines	Science would not exist without scientific procedure which is solely based on experiments. . . . The development of knowledge can only be attained through precise experiments. (Form C: Item 3)	Experiments are not always crucial . . . Darwin's theory of evolution . . . cannot be directly tested experimentally. Yet, because of observed data . . . it has become virtually the lynchpin of modern biology. (Form C: Item 3)

Table 2
(*Continued*)

NOS Aspect	More Naive Views	More Informed Views
Inference and theoretical entities	Scientists can see atoms with high-powered microscopes. They are very certain of the structure of atoms. You have to see something to be sure of it. (Form B: Item 2)	Evidence is indirect and relates to things that we don't see directly. You can't answer . . . whether scientists know what the atom looks like, because it is more of a construct. (Form B: Item 2)
	There is . . . scientific certainty [about the concept of species]. While in the early days it was probably a matter of trial-and-error . . . nowadays genetic testing makes it possible to define a species precisely. (Form C: Item 7)	Species is . . . a human creation. It is a convenient framework for categorizing things. . . . It is a good system but I think the more they learn the more they realize that . . . we cannot draw the line between species or subspecies. (Interview follow-up on Form C: Item 7)
Theory-laden NOS	[Scientists reach different conclusions] because the scientists were not around when the dinosaurs became extinct, so no one witnessed what happened. . . . I think the only way to give a satisfactory answer to the extinction of the dinosaurs is to go back in time to witness what happened. (Form C: Item 8)	Both conclusions are possible because there may be different interpretations of the same data. Different scientists may come up with different explanations based on their own education and background or what they feel are inconsistencies in others ideas. (Form C: Item 8)
	Scientists are very objective because they have a set of procedures they use to solve their problems. Artists are more subjective, putting themselves into their work. (Form B: Item 4)	Scientists are human. They learn and think differently, just like all people do. They interpret the same data sets differently because of the way they learn and think, and because of their prior knowledge. (Form B: Item 7)
Social and cultural embeddedness of science	Science is about the facts and could not be influenced by cultures and society. Atoms are atoms here in the U.S. and are still atoms in Russia. (Form C: Item 9)	Of course culture influence the ideas in science. It was more than a 100 years after Copernicus that his ideas were considered because religious beliefs of the church sort of favored the geocentric model. (Form C: Item 9)
	Well, the society can sometimes not fund some scientific research. So, in that sense it influences science. But scientific knowledge is universal and does not change from one place to another. (Interview follow-up on Form C: Item 9)	All factors in society and the culture influence the acceptance of scientific ideas. . . . Like the theory of evolution was not accepted in France and totally endorsed in Germany for basically national, social, and also cultural elements. (Form C: Item 9)

Table 2
(*Continued*)

NOS Aspect	More Naive Views	More Informed Views
Tentative NOS	If you get the same result over and over and over, then you become sure that your theory is a proven law, a fact. (Form B: Item 3) Compared to philosophy and religion . . . science demands definitive . . . right and wrong answers. (Form C: Item 1)	Everything in science is subject to change with new evidence and interpretation of that evidence. We are never 100% sure about anything because . . . negative evidence will call a theory or law into question, and possibly cause a modification. (Form B: Item 1)
Difference and relationship between theories and laws	Laws started as theories and eventually became laws after repeated and proven demonstration. (Form B: Item 3) A scientific law is somewhat set in stone, proven to be true . . . A scientific theory is apt to change and be proven false at any time. (Form C: Item 5)	A scientific law describes quantitative relationships between phenomena such as universal attraction between objects. Scientific theories are made of concepts that are in accordance with common observation or go beyond and propose new explanatory models for the world. (Form C: Item 5)
Scientific theories		
Nature of	A theory is an untested idea, or an idea that is undergoing additional tests, Generally it hasn't been proved to the satisfaction of the scientific community. (Form C: Item 4)	In the vocabulary of a scientist the word theory is used differently than in the general population. It does not mean someone's idea that can't be proven. It is a concept that has considerable evidence behind it and has endured the attempts to disprove it. (Form B: Item 3)
Functions of	We learn scientific theories just so that scientists don't start all over from the beginning . . . they just can add to the old ideas. (Form C: Item 4)	Theories set a framework of general explanation upon which specific hypotheses are developed. Theories . . . also advance the pool of knowledge by stimulating hypotheses and research. (Form C: Item 4)
Logic of testing	Many theories can't be completely tested, e.g., the theory of evolution can't be tested unless you create your own world and then live for millions of years. (Form C: Item 5)	Most theories have things we cannot observe. So, we deduce consequences from them that could be tested. This indirect evidence allows us to see if the theory is valid. (Interview follow-up on Form C: Item 5)
Creative and imaginative NOS	A scientist only uses imagination in collecting data. . . . But there is no creativity after data collection because the scientist has to be objective. (Form B: Item 5)	Logic plays a large role in the scientific process, but imagination and creativity are essential for the formulation of novel ideas . . . to explain why the results were observed. (Form C: Item 10)