Science Olympiad Students' Nature of Science Understandings

Cindy Johnson Philpot

ACCEPTANCE

This dissertation, SCIENCE OLYMPIAD STUDENTS' NATURE OF SCIENCE UNDERSTANDINGS, by CINDY JOHNSON PHILPOT, was prepared under the direction of the candidate's Dissertation Advisory Committee. It was accepted by the committee members in partial fulfillment of the requirements for the degree Doctor of Philosophy in the College of Education, Georgia State University.

The Dissertation Advisory Committee and the student's Department Chair, as representatives of the faculty, certify that this dissertation has met all standards of excellence and scholarship determined by the faculty. The dean of the College of Education concurs.

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ABSTRACT

SCIENCE OLYMPIAD STUDENTS' NATURE OF SCIENCE UNDERSTANDINGS
by
Cindy J. Philpot

Recent reform efforts in science education focus on scientific literacy for all citizens. In order to be scientifically literate, an individual must have informed understandings of nature of science (NOS), scientific inquiry, and science content matter. This study specifically focused on Science Olympiad students' understanding of NOS as one piece of scientific literacy. Research consistently shows that science students do not have informed understandings of NOS (Abd-El-Khalick, 2002; Bell, Blair, Crawford, and Lederman, 2002; Kilcrease and Lucy, 2002; Schwartz, Lederman, and Thompson, 2001). However, McGhee-Brown, Martin, Monsaas and Stombler (2003) found that Science Olympiad students had in-depth understandings of science concepts, principles, processes, and techniques. Science Olympiad teams compete nationally and are found in rural, urban, and suburban schools. In an effort to learn from students who are generally considered high achieving students and who enjoy science, as opposed to the typical science student, the purpose of this study was to investigate Science Olympiad students' understandings of NOS and the experiences that formed their understandings.

An interpretive, qualitative, case study method was used to address the research questions. The participants were purposefully and conveniently selected from the Science Olympiad team at a suburban high school. Data collection consisted of the Views of

Nature of Science – High School Questionnaire (VNOS-HS) (Schwartz, Lederman, & Thompson, 2001), semi-structured individual interviews, and a focus group.

The main findings of this study were similar to much of the previous research in that the participants had informed understandings of the tentative nature of science and the role of inferences in science, but they did not have informed understandings of the role of human imagination and creativity, the empirical nature of science, or theories and laws. High level science classes and participation in Science Olympiad did not translate into informed understandings of NOS. There were implications that labs with a set procedure and given data tables did not contribute to informed NOS understandings, while explicit instruction may have contributed to more informed understandings. Exploring these high achieving, Science Olympiad students' understandings of NOS was a crucial step to understanding what experiences formed these students' understandings so that teachers may better their practices and help more students succeed in becoming scientifically literate citizens.

SCIENCE OLYMPIAD STUDENTS'
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by

Cindy J. Philpot

A Dissertation

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In loving memory of Grandma Marge, Grandpa Red, Grandpa Cletus and Yogi.

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CHAPTER 1

INTRODUCTION

Background of the Study

Science education reform movements call for scientifically literate students, with one aspect of scientific literacy being informed understandings of nature of science (NOS). This study investigated high achieving science students' understandings of NOS, as well as experiences that may have influenced their NOS understandings. The following research questions were addressed in this study:

1. How do Science Olympiad students understand different nature of science aspects?
2. How do experiences in and out of the classroom contribute to Science Olympiad students' understandings of nature of science?

As we enter the twenty-first century, it is evident that our country and many other countries have entered a "new era" of existence. Knowledge is at the tips of our fingers, global communication is as simple as talking to a next-door neighbor, and at the same time natural resources are being used at alarming rates. These developments change how people live, learn, and work, and bring demands on schools to make science instruction in harmony with the changes taking place in our society and in nature of science (Hurd, 1997). Science educators often view the achievement of scientific literacy as the needed educational response to the many economic, social, and environmental challenges of the twenty first century (Eisenhart, Finkle, & Marion, 1996). Scientific literacy was defined in the National Science Education Standards (National Research Council, 1996) as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (p. 22).

Numerous aspects of the definition for scientific literacy exist, as discussed in Chapter 2, and can be summarized in three components. For the remainder of this dissertation, scientific literacy encompasses the following components: understanding nature of science, scientific inquiry, and science content matter (American Association for the Advancement of Science, 1990; American Association for the Advancement of Science, 1993; NRC, 1996). Refer to Figure 1.

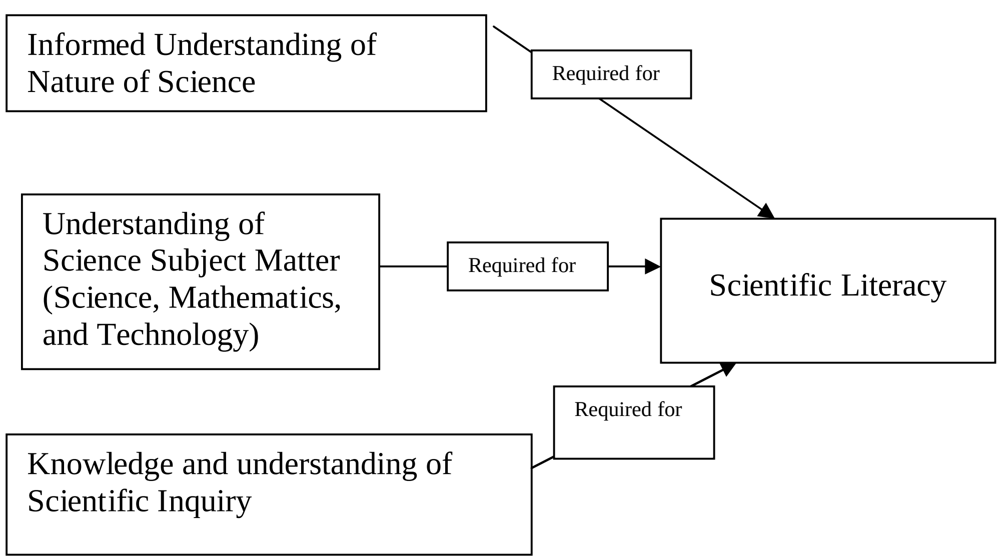

Figure 1. A Compilation of Components for Scientific Literacy. A representation of three understandings required for an individual to be considered scientifically literate (AAAS, 1990; AAAS, 1993; NRC, 1996)

It has been argued that students' understandings of NOS are important dimensions in the development of scientifically literate citizens (DeBoer, 1991). Students' understandings of nature of science, knowledge and understanding of scientific concepts, and the ability to conduct complete inquiries have been emphasized in current reform efforts in science education (AAAS, 1990; AAAS, 1993; NRC, 1996). Students' understanding of the content is the only aspect of scientific literacy systematically measured in schools. Classroom teachers give unit tests and finals, the school district may have a required test, and the state may give an end of course test and /or graduation test. Inquiry, as a set of skills students should know (DeBoer, 1991) as they develop understandings about scientific ideas, may be measured during laboratory investigations or classroom discussions, but is a small percentage of the grade in relation to the content understandings in most science teachers' classrooms. However, there is no protocol to measure students' understandings of NOS in the classroom. The *National Science Education* Standards (NRC, 1996) open with the following statement:

> In a world filled with the products of scientific inquiry, scientific literacy has become a necessity for everyone. Everyone needs to use scientific information to make choices that arise everyday. Everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology. And everyone deserves to share in the excitement and personal fulfillment that can come from understanding and learning about the natural world. (p.1)

Thus, scientific literacy, and its NOS component are essential to equipping citizens to function thoughtfully in a world so strongly influenced by science and technology.

The *Benchmarks for Science Literacy* (AAAS, 1993) advocates an in-depth understanding of scientific inquiry and the assumptions inherent to the processes. The National Standards (NRC, 1996) state that students should be able to understand and conduct a scientific investigation. In addition, both documents consistently support the importance of students possessing adequate understandings of NOS. Nature of Science does not refer to the activities related to the collection and interpretation of data, and forming a conclusion, but "is concerned with the values and epistemological assumptions underlying these activities" (Abd-El-Khalick et al., 1998, as cited in Khishfe & Abd-El-Khalick, 2002, p. 557). Students complete lab procedures, record data, and interpret those data on a regular basis in most high school science classrooms. Nature of science is concerned with what students understand and believe about those processes, and how that understanding was formed. In this study, NOS was taken to broadly encompass understandings or ideas about the nature of scientific knowledge, the nature of scientific inquiry, and the nature of the scientific enterprise. Scientific knowledge is the knowledge of scientific facts, concepts, principles, theories and models (NRC, 1996) and will be measured in this study by students' understandings of the tentative, empirical, and inference-based nature of science, as well as their understanding of theories and laws. Scientific inquiry is the way in which scientists study the natural world, and may also be described as the process for proposing explanations based on the evidence derived from research (NRC, 1996).

Students' understandings of scientific inquiry were assessed in this study by their understandings of the role of human imagination and creativity in science, the empirical and inference based nature of science, and theories and laws. Moss (2001) defined the scientific enterprise as developing researchable questions, collecting and analyzing data, and communicating results. Again, students' understandings of the empirical and inference based nature of science, theories and laws, and the role of human imagination and creativity in science were used to assess students' understandings of the scientific enterprise. See Figure 2 for a summary of the aspects of NOS that were used in defining students' NOS understandings, based on the National Research Council (1996) and Moss. The use of the phrase "NOS," rather than "the NOS," reflects the view that there is not a singular definition for NOS, nor is there agreement on what the phrase specifically means (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002), as I will discussed more detail in Chapter 2.

In investigating students' understandings of NOS, it was first important to think about where and from whom students would most likely learn NOS. They will most likely learn about NOS in the classroom from their teachers. It is therefore important to briefly consider research on teachers' understandings of NOS and what is happening in the classroom. In an ethnographic study, Duschl and Wright (1989) posed the following question, "One implication for teaching is that if decisions concerning what to teach and how to teach are made outside the actual instructional setting, then what expectation can we have that teachers should consider that nature of the subject matter in planning instruction and in the implementation of instruction" (p. 496)? They found teachers often make instructional decisions based on considerations for student development, curriculum guide objectives, and the appeasement and pressures of accountability, which left little room for intentionally planning NOS instruction. Lantz and Kass (1987) found that teachers teaching the same subject taught different lessons about NOS as a result of differences in their understanding of NOS. Teachers' understandings of NOS, subject matter knowledge, and the perceived relationship between nature of science and science subject matter affect the teaching of NOS (Schwartz & Lederman, 2002). How can we

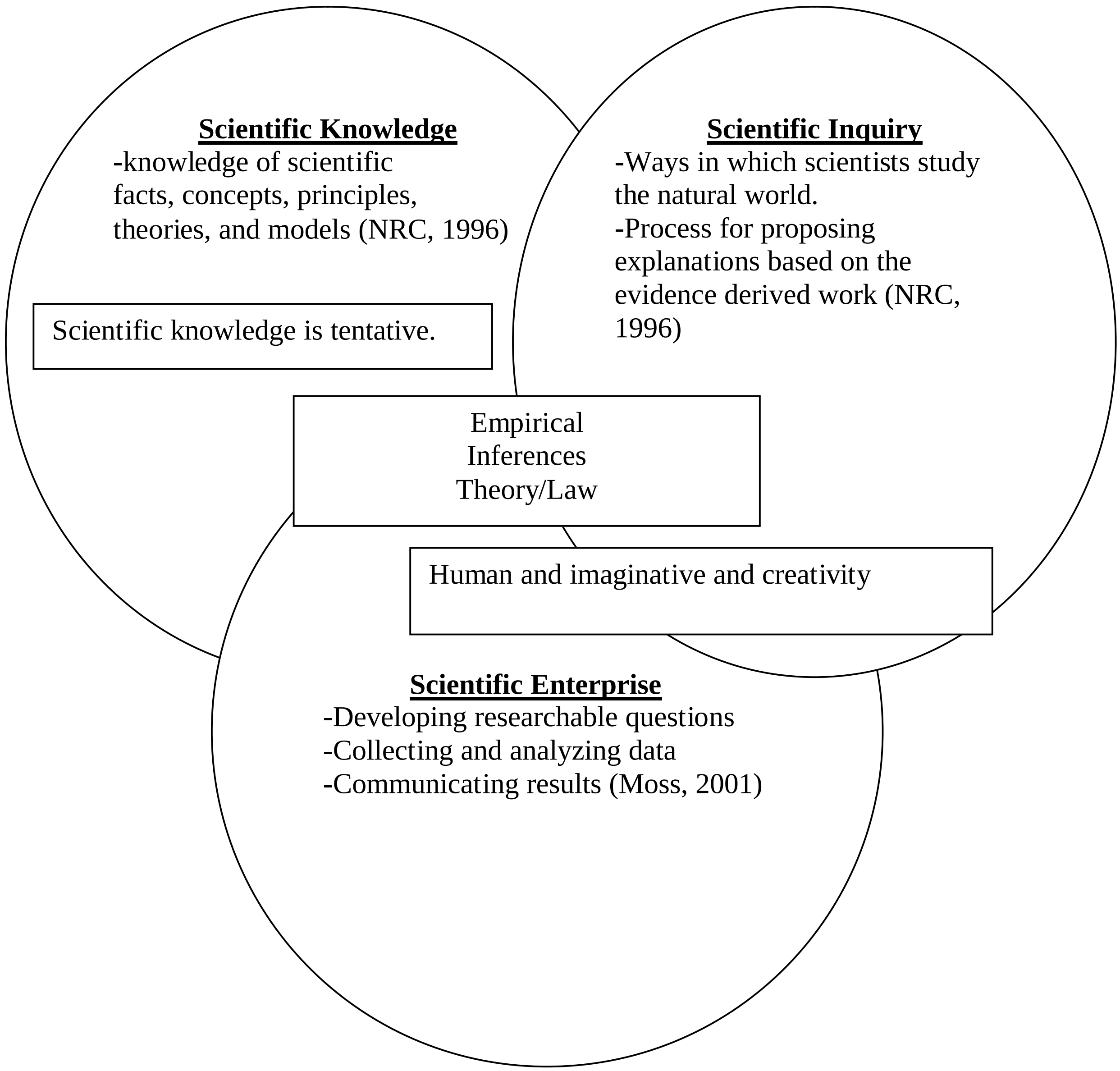

Figure 2. A Conceptual Representation of NOS. This is my interpretation of how Scientific Knowledge, Scientific Inquiry, and Scientific Enterprise are defined, as well as showing how the specific aspects of NOS in this study fit in the broader definition of NOS (NRC, 1996; Moss, 2001).

expect students to possess adequate understandings of NOS if their teachers do not have consistent and adequate understandings of NOS (Aghadiuno, 1995; Brickhouse, 1990; Lederman, 1999; Schwartz & Lederman, 2002), and feel constrained in what they can teach? Research is consistently showing that students' understandings of NOS are inadequate (Abd-El-Khalick, 2002a; Bell, Blair, Crawford, & Lederman, 2003; Clough, 1997; Dawkins & Dickerson, 2003; Griffiths & Barman, 1993, 1995; Kilcrease & Lucy, 2002; Mackay, 1971; Meichtry, 1995; Schwartz, Lederman, & Thompson, 2001;).

Understandings of NOS are generally described as naïve/inadequate, or informed/ adequate. Naïve or inadequate understandings of NOS are evident in participants who reflect an "absolutist view of scientific knowledge" (Abd-El-Khalick, 2002b, p. 68), meaning that scientific knowledge is certain and true, and does not change. In addition, naïve or inadequate understandings mean that there is not a distinction between inferences and observations, and that inference and imagination are not viewed as playing a role in scientific claims. For example, students who fail to "appreciate the role of scientists' ideas in guiding scientific investigations" (Khishfe & Abd-El-Khalick, 2002, p. 552), and believe that investigations follow a prescribed method, with no imagination and creativity have naïve understandings of NOS. Those ideas stem from the understanding that you have to see it to be true. Students with naïve understandings also believe that theories can be proven and eventually become scientific laws, and that scientific knowledge can only be obtained through precise experiments (Lederman et al., 2002). On the other hand, students with informed or adequate understandings of NOS believe that scientific knowledge can change with new evidence and that scientists use inferences to determine things, such as atomic structure and knowledge about dinosaurs because neither can be directly observed by students in a classroom (Khishfe & Abd-El-Khalick, 2002). In addition, students who view an experiment as a way to manipulate objects of interest, but as not always crucial to scientific knowledge are considered to have informed understandings of NOS (Lederman et al., 2002).

McComas (1993) and Moss (2001) each conducted NOS studies that had outcomes similar to each other. McComas looked at high ability students involved in summer internships who were considered to have strong science backgrounds. During the internship, each student had daily contact with researchers at a university laboratory as they worked on some aspect of an on-going project. Students operated mainly as lab technicians, where contact with lab assistants was frequent, but there was little work actually done with the principal investigator. Moss studied 11th and 12th grade students taking environmental science. Moss's 11th and 12th grade students were part of a project-based Conservation Biology classroom in which they could "readily learn nature of science because students were engaged in various aspects of the process of doing science throughout the year in a partnership with scientists" (p. 774). The students were actively engaged in data collection activities as part of a network of schools investigating authentic science questions. The project allowed students to experience research as well as various facets of science within a hands-on, engaging atmosphere.

Both studies showed high pretest scores with no significant change in post test scores for students' understanding of NOS. Both groups of students were considered high achieving students and scored well in their understandings of NOS. Are the science backgrounds and science experiences of upperclassmen, and the interest to apply for and participate in a science internship related to students' understanding of nature of science?

Are these particular students better informed of NOS? If so, what experiences contributed to this understanding? An investigation into this matter promises to extend efforts to promote NOS.

The students in this study were high achieving science students who were interested in and excited about science. High achieving students are those who participate in gifted programs (Farenga & Joyce, 1998), take high level science courses (McHale, 1994; Farenga & Joyce, 1998), have high perceptions of involvement and affiliation with their school (Huang & Waxman, 1996), and move at a fast pace and require more demanding lessons (Mills, 1998).

Research shows that inquiry-based instruction is a starting point for personal construction of meaning and can lead to higher achievement of students (Freedman, 1997; von Glasserfeld, 1984). The idea that students will come to understand NOS by doing science, contrary to Schwartz el al.'s (2001) definition of the explicit approach described below, is the basis of the implicit approach to teaching. Research has consistently shown that the implicit approach was not effective in helping students develop informed understandings of NOS (Khishfe & Abd-El-Khalick, 2002). Several studies reported that for students to have informed views of NOS, inquiry and explicit instruction were necessary (Khishfe & Abd-El-Khalick, 2002; Larson, 2000; Lederman et al., 2003; MacDonald, 1996; Schwartz et al., 2001; Stein & McRobbie, 1997). "Explicit instruction refers to questions, guided reflection, and instruction to draw learners' attention to relevant aspects of NOS" (Schwartz et al., 2001, p. 5). As application of science in the laboratory, McComas (1993) suggested that the longer one works as a laboratory intern the more likely it is that growth in understanding will occur in the domain of knowledge regarding the scientific enterprise, and he suggested further research in this area. “If time-on-task is a factor in the increase in knowledge about any aspect of the essential character of scientific research, the logical recommendation would be to increase the length of time that students spend in this area” (p. 14). Do years of experience and exposure to science courses have an effect on students’ understanding of nature of science? What about those students who are more interested in science and seek extracurricular science activities? How well do students who participate in extracurricular science related activities understand NOS? Huler (1991) found students who participated in science-related activities outside of the school curriculum generally had positive views of science and even chose to pursue careers in science.

Science Olympiad is an example of a voluntary, extracurricular science activity in elementary, middle and high schools, which attracts students who enjoy science and are generally considered high achieving students. High school Science Olympiad students were the focus of this study, not because Science Olympiad necessarily promotes NOS, but because students who participate in Science Olympiad enjoy science and may even be described as passionate about science, which is one of Huang and Waxman’s (1996) descriptors of high achieving students. Science Olympiad is an international organization with rigorous tournaments that consist of a series of individual and team events, which students prepare for during the year. Events range from study events, to laboratory investigations, to building and engineering events. Preparation for the competition depends on the event. For example, the genetics event is a study event and the students prepare for the competition by taking practice tests found in textbooks and on the Science Olympiad website. Some events require practice in the lab for identifying an unknown compound, and other events require design and construction. There are over 20 events, with a team of 15 students, so each student generally participates in three events.

Former "Science Olympians," now in college, often return to work with their high school team. They return to participate in the preparation for Science Olympiad and offer support to less experienced students. Bernard (2005) had similar findings in that students who had experience participating in science fairs were more successful and felt comfortable offering advice to other participating students. The students went so far as to suggest that science fair projects be assigned earlier in their high school careers with the hopes that they will be interested enough to pursue research for more than one year. In an effort to learn from students who enjoy science and are considered high achieving students, this study examined Science Olympiad students' understandings of NOS and attempts to explain how the students came to understand NOS.

Statement of the Problem

Abd-El-Khalick, Bell, and Lederman (1998) defined a scientifically literate individual as one who makes informed decisions within a science/technology context by drawing upon his/her rich scientific knowledge and understanding of the concepts, principles, theories, and processes of science. Current reform efforts in science education call for scientifically literate students. One aspect of being scientifically literate is having informed understandings of nature of science. Students' understandings of NOS and its processes beyond knowledge of scientific concepts have been emphasized in current reform efforts in science education (AAAS, 1990; AAAS, 1993; NRC, 1996). McComas, Almazroa, and Clough (1998) urged science teachers and their students to gain an understanding of the nature of science. The logical place to start on the track to students having informed understandings of NOS is with science teachers having informed understandings of NOS. Research shows that not all teachers possess informed understandings of NOS (Duschl & Wright, 1989; Lantz & Kass, 1987; Schwartz & Lederman, 2002), and that teacher views of NOS have an impact on the way they present science to their students (Allchin, 1999; Bright & Yore, 2002; Mueller & Wavering, 1999). If teachers do not have informed understandings of NOS, which is transferred to students by the way they present science in their classes then how can the typical student be expected to have informed understandings of NOS? Research shows that typical science students do not possess informed understandings of NOS (Abd-El-Khalick, 2002a; Bell et al., 2002; Clough, 1997; Dawkins &Dickerson, 2003; Griffiths & Barman, 1993; Kilcrease & Lucy, 2002; Mackay, 1971; Meichtry, 1995; Schwartz et al., 2001). Based on that information, a NOS investigation using a population other than the typical student may be needed. A group of students engaged in learning science beyond that required in the typical classroom may be more productive in studying high school students' NOS understandings.

If schools are to produce scientifically literate students, meaning students with informed understandings of NOS, it might help to look at students who participate in extracurricular science activities. First, it can be assumed they have a positive attitude toward science because they are looking for more involvement in the sciences. In addition, they spend more time working on science, which McComas (1993) found to have a positive correlation with NOS understandings. As previously discussed, students who participated in a science internship were high achieving students and their pre-internship NOS evaluation reflected informed understanding of NOS (Bell et al., 2003;

McComas, 1993). This leads to the population who participated in this study. Science Olympiad is an extracurricular science activity, which generally attracts high achieving students who enjoy science.

High achieving science students participate in gifted programs and take multiple high level courses (Farenga & Joyce, 1998; McHale, 1994), have high perceptions of involvement and affiliation (Huang & Waxman, 1996), and move at a faster pace, requiring more demanding lessons (Mills, 1998). In an evaluative study, McGee-Brown, Martin, Monsaas and Stombler (2003) found that Science Olympiad students had an in-depth understanding of science concepts, principles, processes, and techniques. If this group of students is exposed to higher level classes and seek additional involvement in science through Science Olympiad, we can learn from them. Why did they choose to participate in Science Olympiad? What previous science experiences led to their interest in science? Do students who participate in Science Olympiad have informed NOS understandings?

In addition to national reform efforts calling for scientifically literate students, with informed understandings of NOS as one piece of scientific literacy, we need students to enter the science fields, bringing creative, innovative ideas to medicine, technology, national defense, consumer products, refining the use of natural resources, and science education for future generations. It is essential to investigate and learn from a group of students who enjoy science, seek more involvement in science by participating in Science Olympiad, and are generally considered high achieving students. The aim of this study was to assess students’ understandings of NOS and experiences contributing to those understandings.

Significance of the Problem

Science education reforms have focused on NOS and inquiry in an effort to develop scientifically literate and informed communities. Science classes are considered of central importance, required for graduation, and are allocated considerable resources. However, the current literature tells us that the typical science classrooms are producing students with naïve understandings of NOS, which could be considered a crisis given Driver, Learch, Millar, and Scott's (1996) explanation of why understanding NOS is important: "The impact of scientific and technological developments on our everyday lives is so great that no one can afford to be ignorant of these developments" (p. 10). Science is part of a general education and preparation for life. On a national level, there is a perceived need to maintain a pool of qualified people from whom scientists, technologists, and technicians of the future may be drawn. And, understanding NOS is important if the wider public is to be able to exercise appropriate democratic control over the purposes and directions of scientific and technological advances. The debates over stem cell research and weapons of mass destruction (as in the Manhattan Project) are just two examples.

The Royal Society (1985) said understanding science, its accomplishments and limitations, is a vital investment in the future well-being of their society, and the AAAS (1989) said without a scientifically literate population, the outlook for a better world is not promising. Thomas and Durrant (1987) gave an overview of arguments in the literature for promoting public understanding of science. With email as a key means of communication and the internet as a vast means of information, there is a need for the public to know how to use the technology they encounter on a day to day basis. Being part of a democracy, the public must be informed about science to participate in the decision making related to science and technology topics. And with those decisions, there is a moral commitment to use science and technology with care and to be cautious of overstepping boundaries, as in stem cell research, cloning, and even nuclear weapons. In addition, it is important to have an appreciation for the comforts, advances, and explanations for a wide variety of phenomena scientists' work has provided.

As previously noted, study after study is showing that most students do not have informed understandings of nature of science. Why? The research already shows that teachers' understandings of NOS impact classroom practice and that not all teachers have informed understandings of NOS (Aghadiuno, 1995; Lederman, 1999). In addition to the "teacher" factor, James and Smith (1985) reported that there is a large decline in student attitudes toward science during the middle school years. They said the abstract and counter-intuitive content puts stress on newly developing cognitive skills and often poorly developed study habits. What experiences encourage some students to have positive attitudes toward science? This study adds to the growing body of research that explores students' understandings of nature of science, particularly students who participate in Science Olympiad.

Rationale for the Problem

There are numerous demands on science teachers during each and every class – demands set locally, system wide, state wide, and nationally. And, of course there are the differing needs of the individual students. As teachers design units and decide what to teach, there are guidelines to help choose the content. The guidelines come from the needs of the students, and are set by the school, the county, the state, and the national standards. The national standards in science education have one main goal, scientific literacy for all students, and equal access to achieve that goal (NRC, 1996). A scientifically literate student must have knowledge of the science content, have knowledge and understanding of scientific inquiry, and have informed understandings of NOS. Teachers generally measure content knowledge with summative assessments and incorporate varying levels of scientific inquiry into the classroom through required lab time, but there is little measurement of students' understandings of NOS. The NOS research tends to focus on students in various inquiry settings and usually shows that students do not have informed understandings of NOS. If an informed understanding of NOS is a necessary component of scientifically literate citizens, which is the central idea behind the National Standards, then it seems logical to start trying to identify experiences that lead to informed understandings of NOS.

Theoretical Framework

Students often find science harder to learn than any other subject. In part, this is because science typically requires students to learn a great many new concepts very quickly (Ramos, 1999). For example, in a high school biology course taught in one semester on a block schedule, students learn details of molecular and cell biology, genetics, evolutionary biology, and taxonomy. With that plethora of information crammed into one semester, with little connections to science from elementary and middle school, it would be easy for students to become overwhelmed by the scope of the content and resort to mere memorization of information and with little connection made between what they are learning and what they already know. The meaning a student makes of any learning situation depends not only on characteristics of that situation but on the knowledge and attitudes the student brings to the situation (Driver, 1990). "Learning something new, or attempting to understand something familiar in greater depth is not a linear process. In trying to make sense of things we use both our prior experience and the first-hand knowledge gained from new explorations" (Miami, 2001, p. 1). The philosophy about learning that proposes learners' need to build their own understanding of new ideas is called constructivism. Constructivists view learning as a process not just of acquiring information, but of creating a personally meaningful understanding.

The American Association for the Advancement of Science published book on constructivism in science education and claims that there is widespread acceptance of constructivism and that constructivism has become increasingly popular in science education (Matthews, 1998). "Science educators suggest that concepts students hold are constructed; they are neither discovered nor received directly from another person" (Hassard, 1992, p. 22). Constructivists believe that the learner constructs knowledge and is actively seeking meaning; therefore, interacting with the physical world is crucial. Learners' constructs and reasoning affect science learning (Hassard, 1992), and must therefore affect students' understandings of NOS. Figure 3 illustrates the idea that for new meaning to occur, new information must be relevant to prior experiences. The experiences students have at home, and in science classes contribute to their understanding of NOS.

Constructivist perspectives on learning and teaching are foundations of many preservice education programs (Dias, 2000). The perspectives are grounded in the cognitive and developmental perspectives of Piaget, the interactional and cultural emphasis of Vygotsky, as well as the educational philosophy of John Dewey, as shown in Figure 3. Piaget's fundamental idea was that knowledge is merely another stage in the adaptation of an organism to its environment (Nola, 1998), and that knowledge was essentially constructed (Piaget, 1971). Piaget's view of cognitive development was based on allowing children to build concepts actively rather than providing those concepts through direct teaching. This is the belief that each individual personally constructs knowledge and meaning, but always included is social interaction with other cognizing subjects (Glassman, 2001). In a science class, hands-on, cooperative learning groups, and inquiry learning would be a key to Piaget's ideas.

Vygotsky (1978) was also a proponent of group learning. In addition to Piaget's active learning, Vygotsky suggested that students need a stimulating environment in which they are active participants. He thought educators should promote discovery by modeling, explaining, and providing suggestions to suit each child (Gallimore & Tharp, 1990). Vygotsky's major questions concerning education were: "How and why does natural human activity [as opposed to being passive] serve as the major impetus for learning? And how, through understanding that activity, can we promote and guide human learning?" (Glassman, 2001, p. 1). Vygotsky believed the educational processes work from the outside in. He thought human inquiry to be imbedded within culture, which is embedded within social history. According to Vygotsky's social cognition theory (Vygotsky, 1978) every aspect of a child's development occurs in the context of

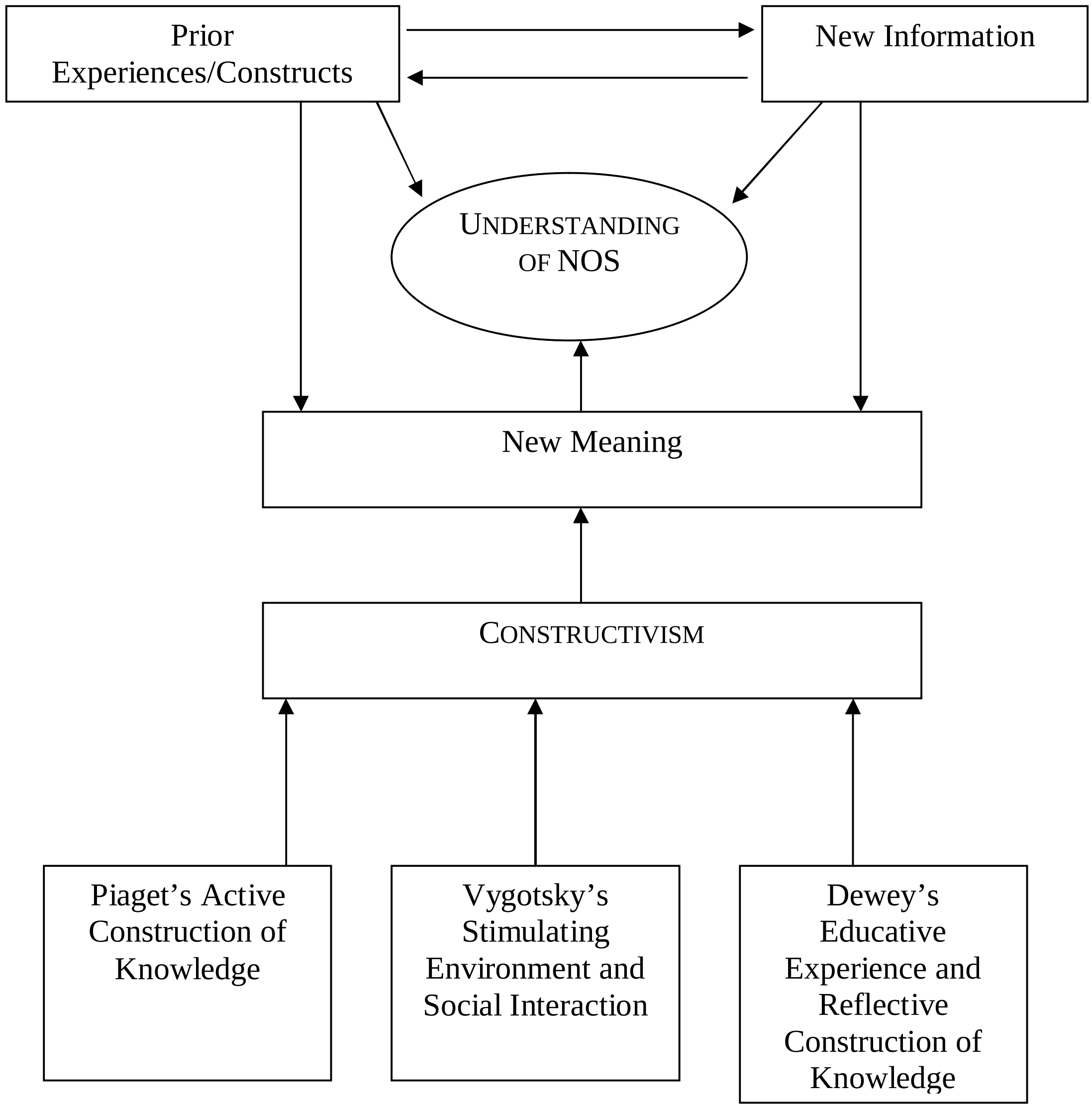

Figure 3. Foundations of Constructivist Learning Theory in Relation to NOS. Constructivists' ideas on how new meaning are created and therefore form understandings of NOS (Driver, 1990; Gallimore & Tharp, 1990; Glassman, 2001; Hassard, 1992; and Ramos, 1999).

culture, including the family environment. In light of Vygotsky's ideas on social cognition and the role of culture in terms of family, it was important to note how students perceive their parents' value of education and more specifically science education. In addition, classroom culture and team culture in Science Olympiad may be valuable pieces to the puzzle of students' understandings of NOS. Schwab (1974) points out that more than just what happens inside one particular classroom affects students' learning.

> For the effectiveness of any means of teaching any body of knowledge is in part a function of what else is happening to the students, what they are taught in other areas and other classrooms. They carry with them from room to room and teacher to teacher, the expectations, the habits, and the attractions and repulsions generated in all the classrooms. These expectations, habits, and attitudes affect their reaction to the teaching in any classroom. (p. 316)

Many of Vygotsky's ideas that have the greatest imprint for education bear a resemblance to John Dewey. Both men were strong proponents of bringing everyday activities into the classroom and focusing on the importance of social context in learning (Glassman, 2001). Dewey's philosophies were based on the belief that learning is the result of experience and that the only way students learn is by tying new information to existing knowledge. It is the individual's processing of stimuli from the environment and the resulting cognitive structures that produce adaptive behavior rather than the stimuli themselves (Dewey, 1933). He thought teachers should teach students to become problem solvers rather than simply learning large amounts of information (Ramos, 1999). Dewey believed in long-term projects to encourage students to become independent thinkers.

> In long term projects children are immersed in everyday activities. It is expected that the activities of the children will eventually coalesce around a topic that is of interest to them. The topic need not be of any relevance to the demands of the larger social community, or even have meaning of interest for the teachers. As a matter of fact, the teacher should step back from the process once children display a relevant interest and act as facilitator rather than mentor. It is the students who must drive the inquiry

> based on their own goals. The children learn that they control and are responsible for inquiry in their lives, and they determine what goals are important and the ways in which they can be met.
>
> Dewey's essay (as cited in Glassman, 2001, p. 4)

Dewey's ideas were published in the early 1900's. As public education emerged, standardized tests, accountability, more emphasis on grades for scholarships, colleges, and parents, and less emphasis on student responsibility become more prevalent. There is very little encouragement for students to pursue their own ideas unless the projects directly impact learning within a specific content area or mandated standard.

Bruner (1973) said learning is an active process in which learners construct new ideas or concepts based upon their current and/or past knowledge. He thought instruction should be concerned with the experiences and contexts that make the student willing and able to learn, and structured so that the student may easily grasp information. In addition, Bruner said instruction should be designed to facilitate exploration and/or fill in the gaps so students could go beyond the information given. Bruner (1966) thought good methods for structuring knowledge should result in simplifying, generating new explanations, and increasing the manipulation of information.

The way teachers understand constructivism has major implications in the classroom. Clements (1997) identified five myths that surround constructivism and are views held by many teachers: (a) Students do not have to always be actively engaged to construct new knowledge. Manipulation can occur in the students' minds. (b) Students are not always actively learning when they use manipulatives. They may use the manipulatives in a futile attempt to reproduce the teacher's actions, thereby using manipulatives in a prescribed fashion. (c) The students do not lead themselves towards conceptual ideas; teachers must guide them in that direction. If students are left to their own devices to construct meaning, they may never gain an understanding of the material they are "learning." (d) Teachers believe that if the students are working in groups or in Cooperative-Learning groups, that constructivism is taking place. (e) Teachers must still discriminate student's answers; not all answers are correct, they must make sense. Clements went on to further say that students can construct their learning from lectures. If they are active listeners and think about the information at the same time, they are constructing their knowledge. However, it is important to keep in mind that the average high school student my not choose to think about the information being presented as they have a different idea about what is important in their day to day lives.

Each student brings something unique to the classroom, whether it is personality, issues in daily life, or previously held ideas and explanations relating to science. Nelson (1999) discussed misconceptions students have about concepts in their science classes prior to even learning that concept in their current class. One issue was the transfer of knowledge from teacher to student. He thought that teachers who regard the text as a repository of knowledge to be taught may present that information directly to the students. "United States' textbooks lack focus and coherence and rarely provide teachers with effective instructional strategies to help students learn specific content" (p. 56). If that is the case, the instruction provided by the teachers does not confront students' misconceptions and allows students to interpret the new input as consistent with their existing misconception. Teaching a body of knowledge involves not just teaching the concepts, but also the method and something of the methodology or theory of method (Matthews, 1998). Driver (1994) maintains that:

> Learning science involves being initiated into the culture of science. If learners are to be given access to the knowledge systems of science, the

> process of knowledge construction must go beyond personal empirical enquiry. Learners need to be given access not only to physical experiences but also to the concepts and models of conventional science. (p. 6)

These ideas suggest that students must have informed understandings of NOS concepts in order to truly understand what they are learning in their science classes. To create new meaning, students should understand the processes and scientific reasoning behind the concepts and be able to relate new information to prior experiences. Students' favorite question regarding atomic structure is "How did they ever figure that out?" Atomic structure is often the pivotal unit where students become skeptical over all ideas based on atomic structure (which is everything thereafter in a chemistry course). Atoms are abstract, removed from experience, and have no connection with prior conceptions. For students to truly understand ideas about the atom and how those ideas were formed, constructivists believe students must have a prior experience to which they can relate the new knowledge. The prior experience could be as simple as a discussion where students provide examples of things they believe to be true and why, without really seeing proof, to the use of a black box activity as described by Abd-El-Khalick (2002a).

Brooks (1990) defined constructivism as a process in which the individual is repeatedly verifying new information against prior knowledge. He wrote about teaching being dynamic in that teachers must, at the same time, continue developing content knowledge, and continue revising methods used to teach the knowledge. In a dynamic classroom, teachers must focus on each student to make learning interesting to each student. Understanding how students connect information from previous science classes, home, media, and experiences outside of school is crucial to developing a method to get at the heart of students' understandings of NOS, not only to find out if they have informed understandings of nature of science, but to also be able to paint a rich description of their science experiences during their school years.

Overview of Methodology

An interpretive, qualitative, case study method was used to explore high school science students' understandings of nature of science. More specifically, the participants were high school students at a suburban high school in Georgia, and participated in Science Olympiad. The students were selected based on purposeful and convenience sampling. Data collection consisted of the Views of Nature of Science – High School (VNOS-HS) version questionnaire (see Appendix A); semi-structured interviews, which served as follow-up interviews to the VNOS-HS questionnaire and as a basis to learn about students' science experiences; and a focus group in an attempt to allow ideas from other participants to enhance student discussions about science experiences and ultimately understandings of NOS. The interviews are transcribed and coded, and a constant comparative method was used for data analysis.

Summary

Science education is viewed as a means to develop students' abilities to reason based on observation, and to apply their science knowledge to make informed decisions regarding personal and societal problems. Current reform efforts emphasize students' understandings of NOS. However, American schooling often encourages control over creativity and tends to emphasize learning facts rather than developing understanding (Brickhouse, 1990). The purpose of this study was to investigate a group of high achieving science students' understandings of NOS and attempt to explain what experiences contributed to the students' understandings of NOS. The students were

Science Olympiad team members and took multiple high-level science courses. By examining Science Olympiad students' NOS understandings, science educators can better understand how experiences in and out of the science classroom translates into students' NOS understandings from students' perspectives.

CHAPTER 2

REVIEW OF LITERATURE

Introduction

Literature and research addressing scientific literacy, NOS, inquiry, and Science Olympiad was the focus of this chapter. This chapter defines scientific literacy, NOS and inquiry, and examines studies regarding inquiry as it relates to students' understanding of NOS. Teachers' views of NOS and how they translate into classroom practice are also investigated because the science classroom is the main avenue students have to experience science. There is a body of literature which recounts studies that neither teachers nor students have informed understandings of NOS, which should not be a surprise given the varying definitions among researchers. The research suggests that informed understandings of NOS are directly linked to inquiry and explicit nature of science instruction. Science instruction is often cyclical in that most teachers came from a lecture based science classroom, where facts were fed to them without NOS instruction, so that is in turn what these teachers do with their students.

If the typical science classroom is producing students with naïve conceptions of NOS, how do students who participate in extracurricular science activities compare? The research in this chapter focuses on teachers' and students' understandings of NOS, inquiry, and Science Olympiad. It repeatedly suggests that school science should extend beyond the classroom to be relevant to the students' world, that teachers must have informed conceptions of NOS, and that students should receive explicit NOS instruction.

What are science Olympiad students' understandings of NOS? Of interest is how this purposefully selected group of students' science experiences formed their understandings of NOS.

Scientific Literacy

The goal of the national science education standards is for all students to achieve scientific literacy (AAAS, 1990; AAAS, 1993; NRC, 1996). Scientific literacy is the ability to use scientific knowledge to make informed personal and societal decisions (Lederman, 1998). The national science education standards (NRC, 1996) define scientific literacy as greater knowledge and understanding of physical, life and earth sciences, and understanding NOS, scientific enterprise and the role of science in society and personal life constitute scientific literacy. The National Science Education Standards (NRC, 1996) qualify evidence of scientific literacy as: (a) ask, find or determine answers to questions derived from curiosity about everyday experiences; (b) describe, explain and predict natural phenomenon; and (c) express positions that are scientifically and technologically informed. Abd-El-Khalick, Bell, and Lederman (1998) describe a scientifically literate individual as one who can make informed decisions with-in a science/technology context by drawing upon his/her rich scientific knowledge and understanding the concepts, principles, theories, and processes of science.

There is no one, short, simple definition for scientific literacy. However, all aspects of scientific literacy expressed so far fit into three categories. In order to be scientifically literate, an individual (a) must have informed understandings of NOS, (b) understand the process of scientific inquiry, and (c) have science content knowledge (AAAS, 1990; AAAS, 1993; NRC, 1996). Students' understandings of science content knowledge are addressed in the classroom, and teachers are held accountable for students' understandings by means of standardized tests. Scientific inquiry is generally addressed through labs and hands-on activities, but teachers are generally not held accountable for students' specific understandings of inquiry, only for completing the required amounts of lab time as set by local systems. Students' understandings of NOS are not evaluated in the classroom and teachers are not held accountable for this third piece of a scientifically literate citizen. As the research in the next section shows, students generally do not have informed understandings of NOS.

Nature of Science

There have been major shifts in the way the science community has conceptualized NOS (Abd-El-Khalick & Lederman, 2000). In the 1960s, NOS was equated to science process skills and shifted to characterize scientific knowledge as tentative, replicable, humanistic, and empirical in the 1970s. The NOS trend in the 1980s was the inclusion of psychological factors, such as the theory-driven nature of observation and the role of human creativity in developing scientific explanations (Tao, 2003). "Currently there is much debate among science educators regarding a specific definition of the nature of science" (Bell et al., 2003, p. 490). Lederman (1992) felt that the disagreement should be expected given the multifaceted nature of the scientific enterprise and given the way understandings of the scientific enterprise have evolved over time. *Science for all Americans* (AAAS, 1990) and *Benchmarks for Science Literacy* (AAAS, 1993) each devoted their first chapters to nature of science. They focused on the scientific world view, scientific methods of inquiry, and the nature of the scientific enterprise.

The scientific world view has “to do with the nature of the world and what can be learned about it” (AAAS, 1990, p.2), and is based on the following premises: the world is understandable; scientific knowledge is durable, yet subject to change; and scientists cannot provide complete answers to all questions. The scientific enterprise, which was least understood by students in Moss’s (2001) study, “has both individual and social dimensions. Developing researchable questions, collecting and analyzing data, and ultimately communicating results are all components of the scientific enterprise” (Moss, 2001, p.772). *Science for All Americans* (AAAS, 1990) referred to science as a complex social activity regarding communication of results, and the ethical principles most scientists use to conduct their work.

The most widely used definition in the recent literature (Lederman et al., 2002; Lederman et al., 2003; Moss, 2001; Schwartz et al., 2001; Tao, 2003) is that NOS refers to the epistemology of science, or how we come to know the values and beliefs inherent to developing scientific knowledge (Lederman, 1992). Lederman argues that scientific knowledge, including theories and laws, is tentative, i.e., it is never absolute or certain because it can never be absolutely proven, only disproven (Lederman, 1998). In order to prove a law or theory, it should account for every instance of the phenomena it implies, however, a future instance may behave in a manner contrary to what the theory or law states. Lederman (1998) defines seven tenets of NOS: scientific knowledge is tentative, empirically based, subjective, involves human inference, imagination and creativity, and is socially and culturally embedded. Alters (1997) reviewed 39 popular tenets explicitly and implicitly stated in science education literature. After reading various researchers’ views on science (nature of science was not the term used by all of the researchers), it was clear that there was not a consensus of the definition. The main idea that linked all of the researchers' views was the tentative nature of science.

McComas (1998) described 15 myths commonly held by science teachers and science students and these myths were often the source for inadequate views of NOS in the studies discussed in this section. The myths were important to recognize as the data collected in this study was analyzed. The following is a list of the myths (a) hypothesis become theories that turn into laws; (b) scientific laws and other such ideas are absolute; (c) a hypothesis is an educated guess; (d) a general and universal scientific method exists; (e) evidence accumulated carefully will result in sure knowledge; (f) science and its methods provide absolute proof; (g) science is procedural more than creative; (h) science and its methods can answer all questions; (i) scientists are particularly objective; (j) experiments are the principal route to scientific knowledge; (k) acceptance of new scientific knowledge is straightforward; (l) science models represent reality; (m) science and technology are identical; and (n) science is a solitary pursuit. What leads students to uphold these myths- movies, school science, teachers' views, or making partial or not fully informed connections of scientific ideas?

Assessing Nature of Science

With such a broad and loosely defined construct of science education, finding accurate and precise ways to measure an individual's understanding of NOS has been quite difficult. Lederman, Wade, and Bell (1998) identified 25 questionnaires developed since 1954 that intended to assess ideas and attitudes on science. Munby (1983) gave detailed descriptions and critiques on 56 instruments designed to assess ideas and attitudes on science. The instruments were "composed of forced-choice items, such as agree/disagree, Likert-type, or multiple choice" (Lederman et al., 2002, p. 502). The development and testing of three questionnaires will be discussed- the Test of Understanding Science (TOUS), Ideas on Nature of Science, and Views of the Nature of Science (VNOS).

The TOUS was developed by Cooley and Klopfer in 1961 (as cited in McComas, 1993). It was considered "the best single measure of a student's understanding of the philosophy of science" (McComas, 1993, p. 7). The instrument was a 60 item multiple choice test that targeted knowledge of the scientific enterprise, the scientist, and the methods and aims of science. It was the most commonly used instrument from the time of its inception, but it was also criticized for items relating to national goals and politics and also for gender bias (McComas, 1993). "During the height of its popularity, the TOUS instrument was applied in a number of studies primarily to examine the extent to which one teaching technique or another best communicated aspects of the philosophy of science to students" (p. 8). McComas suggested that a new nature of science assessment instrument be developed for students working in laboratory and field environments because several studies (Mackay, 1971; McComas, 1993; and Williamson, 1971) found no significant gain between pre and post tests for laboratory experiences. Scores on the TOUS were high in the pretest and left little room for growth in the post test. McComas (1993) described it as the "low discriminatory ability of the test" (p. 15).

Good, Cummins, and Lyon (1999) were interested in assessing understanding about science using the description of the nature of science set out in Benchmarks (AAAS, 1993) and the National Science Standards (NRC, 1996). Before the publication of those documents, the researchers felt there was no general consensus on the definition of nature of science, which was supported by Alters (1997). The goal of the instrument they developed was not to assess science attitude, it was meant only to assess understanding of science. The assessment was a 28-item questionnaire called the Ideas on Natural Science (INS). The instructions called for the subjects to agree or disagree with each item and then explain why they believed their position was correct. Most of the items were taken from the first chapter of *Science For All Americans* (AAAS, 1990), which makes the following claims: (a) the world is understandable, (b) scientific ideas are subject to change, (c) scientific knowledge is durable, (d) science cannot provide complete answers to all questions, (e) science demands evidence, science is a blend of logic and imagination, (f) science explains and predicts, (g) scientists try to identify and avoid bias, (h) science is not authoritarian, (i) science is a complex social activity, (j) science is organized into content disciplines and is conducted in various institutions, (k) there are generally accepted ethical principles in the conduct of science, and (l) scientists participate in public affairs both as specialists and as citizens. After field testing the instrument, it was found to have low reliability and the researchers acknowledged that much work remained on developing an instrument that is both valid and reliable. They made several recommendations for developing a valid and reliable instrument: (a) do not confuse ideas on science with attitudes toward science, (b) identify subscales for reasonable agreement between data sets for different researchers, (c) supplement paper and pencil data with interview data, and (d) consider content specific NOS research.

Lederman and O’Malley (1990) developed a seven-item open-ended questionnaire, which they used with follow-up interviews to investigate high school students' beliefs about the tentativeness of scientific knowledge, various sources of students' beliefs as well as those factors that have altered students' beliefs about science, and the implications of students' beliefs for daily personal and societal decisions. “Open-ended items allow respondents to elucidate their own views regarding the target NOS aspects” (Driver, Learch, Millar, & Scott, 1996; as cited in Lederman et al., 2002, p. 503). The individual semi-structured interviews were used to validate the researchers’ interpretations of the participants’ responses. “During the interviews, participants were provided their questionnaires and asked to read, explain, and justify their responses” (Lederman et al, 2002, p. 504). Three of the seven open-ended questions did not assess the intended students’ beliefs. For example, an item was intended to assess students’ ideas of scientists’ creativity and imagination when performing experiments and investigations and students “simply considered the planning of the investigation” (p. 504). The results reinforced the need for more than just a paper and pencil test. The questionnaire was considered the first form of the VNOS instrument (VNOS-A).

In order to study the factors that mediated the translation of pre-service teachers' conceptions of NOS into instructional planning and classroom practice, Abd-El-Khalick et al. (1998) revised the VNOS-A into the VNOS-B. The questionnaire was still open-ended and intended to have follow-up interviews, but was intended to elicit participants views of the “tentative, empirical, inferential, creative, and theory-laden NOS, and the functions of and relationship between theories and laws” (Lederman et al., 2002, p. 504). Bell (1999, as cited in Lederman et al., 2002) found strong support for the construct validity of the VNOS-B. He used two groups, one with assessed thorough understandings of NOS (expert group) and the other with assessed naïve views of NOS (novice group). The expert group’s responses to the VNOS-B reflected NOS understandings at a rate nearly three times higher than the novice group. Another form of the VNOS was developed, the VNOS-C, which was a modified version of the VNOS-B and aimed to assess views of the social and cultural embedded ness of science and the existence of a universal scientific method. A version of the VNOS was also developed for use with high school students (Schwartz et al., 2001).

All versions of the VNOS had consistent findings in the areas of overlap. The principle source of validity evidence in all of the VNOS assessments stems from the follow-up interviews. Lederman et al. (2002) "hoped that the effort represented in the VNOS along with the concerted efforts of many researchers who have used and continue to use open-ended questions, interviews, and/or other alternative ways to assess NOS understandings would lead the way toward achieving more valid and meaningful assessments of students' and teachers' NOS views" (p. 517). Lederman and his cohorts knew that paper and pencil were not enough. Interviews are necessary for clarification for several reasons. First, is the assumption that respondents understand a certain statement in the same manner that the researchers or instrument developers would, and then agree or disagree with the statement for reasons that coincide with those of the researchers or instrument developers. Second, standardized instruments usually reflect their developers' nature of science views and biases, which are then imposed on the respondents. Lederman et al. (1998) suggested that the current educational research shift is toward more qualitative, open-ended approaches to assessment.

Teachers and Nature of Science

Research continuously shows that secondary students' understandings of NOS are inadequate (Abd-El-Khalick, 2002a; Bell et al., 2002; Clough, 1997; Dawkins &

Dickerson, 2003; Griffiths & Barman, 1993; Kilcrease & Lucy, 2002; Mackay, 1971; Meichtry, 1995; Schwartz et al., 2001). Why? Mullis, Dossey, Foertch, Jones, and Gentile (1991) reported that science instruction promoted students' acquisition of scientific facts, but did not provide the experiences to promote students' scientific thinking. Shepardson (1997) wrote that labs often become a simple manipulation of materials, without a means to think about the processes of science. In a case study, Schwartz et al. (2001) found the teachers' "emphasis remained on building students' skills without purposeful intentions of promoting understanding of those skills" (p. 13). "It is not at all difficult to argue that a teacher who lacks adequate conceptions of the NOS and scientific inquiry, and a fundamental understanding of how to teach these valued aspects of science cannot orchestrate the types of instructional activities and atmosphere, or assess students' progress, as specified in the various reform efforts in science education" (Lederman, 1998, p. 2). Teachers' views of NOS have an impact on the way they present science to their students (Allchin, 1999; Bright & Yore, 2002; Mueller & Wavering, 1999). The data generated from students in the following section includes students' views of NOS before various treatments, such as a summer internship or a specified inquiry program. It can be assumed that those views are largely formed from experiences in science classes. Aghadiuno (1995) suggested that teachers' lack of understanding of NOS may be contributory to students' poor achievement in science. He found that "improvement in students' performance in chemistry would be predicated in part on the amelioration of their teachers' misunderstanding of science" (p. 129). Students' conceptions about science are formed in the classroom (Hodson, 1993) and may even be shaped from the media through movies (Freudenrich, 2000) and news.

Because the classroom is instrumental in teaching science concepts and clarifying misconceptions, teachers' views of NOS are important, along with how their views are portrayed in the classroom and communicated to students.

Lederman (1999) looked at teachers' understandings of NOS and classroom practice. He found that teachers' conceptions of science do not necessarily influence classroom practice. The study consisted of five biology teachers, two new teachers and three experienced teachers, male and female. There were a combination of semi-structured interviews, open-ended questionnaires, classroom observations, periodic informal interviews/discussions, student interviews, lesson plans and instructional materials used as artifacts. Analysis of questionnaires and interviews indicated that each teacher exhibited views of NOS consistent with those identified in the reform movements. The teachers were strongest in their commitment to the idea that scientific knowledge is tentative and many of the ideas in science are constructed explanations for observable phenomena. The two experienced teachers exhibited classroom practices consistent with their views about the nature of science, such as inquiry-oriented activities. However, the interviews and lesson plans clearly indicated that neither teacher was intentionally attempting to teach in a manner consistent with their understanding of NOS. The teachers did not consider NOS when planning for instruction or making instructional decisions. The two beginning teachers did not exhibit evidence of their understanding of NOS in their classroom practice. Interviews revealed that they were struggling to develop an overall organizational plan for their biology courses and were each a bit frustrated by the discrepancy between what they wanted to accomplish and what they were capable of accomplishing with their students. Teaching experience played a role in mediating the relationship between a teacher's beliefs and classroom practice, as was evident in the data discussed between the new teachers and experienced teachers. The new teachers were concerned with classroom management and gave the impression that teaching experiences, as well as the particular students in the classroom influenced their beliefs about teaching.

Brickhouse (1990) examined the possible link between teachers' views of the growth of scientific knowledge and the methods they use to help students construct a knowledge of science. The participants were precollege science teachers who had diverse perspectives on NOS. Interviews, observations and artifacts, such as textbooks, teachers' documents on discipline, tests, quizzes, worksheets, and laboratory activity sheets were used to identify teachers' conceptions of NOS, their roles as teachers, and their students' roles as learners. Each teacher was given a copy of the case study as it portrayed to their individual situations and asked to check it for accuracy and to comment on ideas that they believed to be misrepresented or incomplete. The data from the study illustrated that teachers' views of NOS may be expressed in classroom instruction. In addition, the teachers' views of how scientists construct knowledge were consistent with their beliefs about how students should learn science. However, this study did not examine whether or not teachers were intentional in planning based on their understandings of NOS.

Schwartz and Lederman (2002) did a case study comparison of the knowledge, intentions, and practices of two pre-service teachers as they learned the subject matter of NOS and attempted to teach NOS during their student teaching and their first year of full time teaching. The purpose of the study was to explore the new teachers' progression of knowledge, intentions, and instructional practices regarding NOS. The participants were in a pre-service science teacher preparation program. Data were collected during a summer nature of science/inquiry course, a fall research internship, spring student teaching and the winter of the participants' first year teaching. Data collection included multiple VNOS-C assessments, journaling, interviews, classroom observations, and artifacts such as lesson plans.

The study (Schwartz & Lederman, 2002) suggested that learning and teaching NOS encompasses knowledge, beliefs, intentions, and pedagogical skills for NOS that enable a teacher to address NOS within his/her everyday science instruction. One of the participants described that process as weaving NOS with other science subject matter. The participants in this study were consciously reminded to explicitly teach NOS in their classroom. Their pre-service coursework helped to prepare them and journaling, interviews and observations were a constant reminder. One of the participants said, "Renee [Schwartz] was the poster child for NOS. All I needed to do was look up and see her at the back of my room and it reminded me to do NOS" (Schwartz and Lederman, 2002, p. 234). That may leave the reader with the following question: was any of the data skewed because the participants taught differently when the researcher was present?

Teachers directly influence how students learn NOS and the following implications are important to consider when examining students' understandings of NOS. First, teachers' levels of experience, intentions, and perceptions of students influence classroom practice, but there is a lack of knowledge concerning how teachers who understand NOS transform their understanding into classroom practices that impact students. Second, even though teachers held beliefs of NOS consistent with Lederman's

(1998) tenets, it was the teachers' instructional intentions that affected what occurred in the classroom. Third, there is a need for the origin of teachers' understanding of science and teaching, and the relationship to classroom practice to be addressed. American schooling often encourages control rather than creativity and tends to emphasize learning facts rather than developing understanding (Brickhouse, 1990). Studies show that there are differences in NOS knowledge based on the context of nature of science instruction (Schwartz and Lederman, 2002). By the context of NOS instruction, I am referring to explicit versus implicit instruction, which will be discussed later in this chapter, or simply the lack of NOS instruction. And last, teachers' beliefs in their abilities to effectively teach NOS and in students' abilities to learn NOS are unexplored dimensions of nature of science.

Students Understandings of Nature of Science

Lederman et al. (2003) found a direct link between students' understanding of NOS and their teacher's understanding of NOS. Teachers and students views of NOS were assessed using a version of the VNOS. Teachers who explicitly discussed the inferential, empirical, tentative, and creative aspects of NOS had about 40% of their students showing more informed views of those aspects of NOS, with 60% showing more informed views of at least two of those aspects. Before the instruction, all students demonstrated naïve views of NOS and scientific inquiry. The teachers who had naïve views of NOS were not successful in implementing explicit NOS and SI instruction, and their students maintained naïve views.

The present study indirectly explored implicit versus explicit nature of science instruction. If students increase understanding by learning science through inquiry methods, then maybe NOS has to be explicitly taught in conjunction with inquiry. Schwartz et al. (2001) assessed ninth grade students' understandings of scientific inquiry and NOS following a treatment where one group received a series of six explicit scientific inquiry lessons and the other group received a series of six implicit scientific inquiry lessons. NOS was not directly addressed in the lessons because the teacher "felt that through teaching about inquiry and engaging students in inquiry investigations, the students would learn some nature of science" (p. 6). Pre and post assessments were given along with follow-up interviews. The pre assessment was a series of questions on an overhead and the post assessment was the Views of Nature of Science (VNOS) questionnaire and the Views of Scientific Inquiry (VOSI) questionnaire. The pre assessment revealed that students' views of science were mainly limited to school-based science, which is learning and memorizing facts, according to Brickhouse (1990), and they did not typically expand their thinking to science as an endeavor that creates the knowledge they learned about in school. Responses to the VNOS, VOSI, and interviews revealed that the majority of students held generally naïve views of both scientific inquiry and NOS, with no difference in the two groups of students.

Moss (2001) created a descriptive account of 11^{th} and 12^{th} grade students enrolled in an environmental science class by tracking them over the course of one academic year. Using semi-structured interviews, samples of student work, classroom artifacts, and field notes for data analysis, he found that many students started the year with partial or full understandings of many aspects of NOS. After one academic year, students' beliefs remained consistent in that they held more complete understandings of the nature of scientific knowledge than of the nature of the scientific enterprise. The scientific enterprise is the process by which we gain scientific knowledge. “We continue to believe that students will come to understand scientific inquiry and NOS simply by ‘doing science.’ Such an expectation is equivalent to assuming that individuals will come to understand the mechanism of breathing simply by breathing” (Lederman, 1998, p. 9). Bell et al. (2003) came to the conclusion that students will not learn about science simply by doing science and following a given procedure. “Epistemic demand and reflection appeared to be crucial components in the single case where a participant experienced substantial gains in her understandings of the nature of science and inquiry” (p. 487). Science content can be abstract and counter-intuitive, which can be quite a challenge for students with newly developing cognitive abilities, often poorly developed study habits (Flick & Dickenson, 1997), and a newly developing social life. For students to have informed views of NOS, their teachers must first have informed views of NOS (Allchin, 1999; Lederman et al., 2003), students must receive explicit instruction (Larson, 2000; Lederman et al., 2003; MacDonald, 1996; Schwartz et al., 2001; Stein & McRobbie, 1997), and students must be will to spend more time on the learning task (McComas, 1993). It then seems critical to look at research regarding students who choose to encounter science related activities outside of the classroom.

Bell et al. (2003) examined the impact of an eight week science apprenticeship on secondary students’ views of NOS. “By experiencing the messiness of doing science, science educators hoped that students would go beyond learning science content to experiencing and learning about the process of doing science. Furthermore, opportunities to experience science-in-the making and engaging in discourse with professional scientists could possibly lead to better understandings of the nature of science” (p. 488).

Ten students were selected to participate in the research out of the 18 participating secondary students in the apprenticeship. All students participating in the apprenticeship were considered high ability students and were selected based on participation in previous projects identifying opportunities for high levels of inquiry. “Each high school apprentice worked within a laboratory for eight weeks during the summer, with opportunities to participate in research design, data collection, and data analysis” (p. 490). During week one, a modified version of the *Views of the Nature of Science, Form B* was given to all students “to assess their conceptions of the nature of science and scientific inquiry” (p.490). The same questionnaire was administered as a post test at the end of the eight weeks. In addition to the pre and post tests, follow-up interviews were conducted with the participants, field notes were taken by researchers, and at the end of the program semi-structured interviews were conducted with the scientists who served as mentors. The results of “this investigation did not support the intuitive assumption [made by the researchers] that students will learn about science simply by doing science” (p. 503). The pretest revealed students’ understanding of the “assessed aspects of the nature of science for the most part were inconsistent with those identified in current reform documents” (p. 492). The post-test results and interviews indicated little change in students understanding of the nature of science. Buck (2003), Khishfe and Abd-El-Khalick (2002), and Liu and Lederman (2002) also found that after inquiry oriented approaches or programs there was no significant change in students understanding of NOS.

McComas (1993) explored how summer intensive laboratory internship experience, including internship duration and the nature of the internship experiences, would alter students' knowledge of the philosophy of science. Once again, the students were considered high-ability students based on their class rank, letters of recommendation, and prior achievements. Twenty students participated in an eight week internship, and a group of forty students participated in a six week internship. Internship experiences varied for the students, but they all had daily contact with researchers through their role as lab technicians. The Test of Understanding Science (TOUS), developed in the 1960's, was used to assess students' understanding of the philosophy of the nature of science. At the time this research was conducted, the TOUS was considered the most effective instrument, even though criticized by some researchers, because of its frequency of use and the fact that there were very few instruments from which to choose. A pre and post test was administered, and like the previous research discussed from Bell et al. (2003), there was no significant change. The difference is that the TOUS started with high mean scores for students understanding of the nature of science. When other variables were evaluated individually, such as gender, ethnicity, number of high school science classes completed, academic achievement, and length of internship, only the length of internship showed a significant increase in participants' understandings of NOS from pre to post test. McComas wrote that "if time-on-task is a factor in the increase in knowledge about any aspect of the essential character of scientific research, the logical recommendation would be to increase the length of time that student spend working in this area" (p. 14). Other studies (Larson, 2000; Lederman et al, 2003; MacDonald, 1996; Schwartz et al., 2001; Stein & McRobbie, 1997) credit explicit NOS instruction with increased NOS understanding.

McGee-Brown et al. (2003) investigated the impact of Georgia Science Olympiad on students, teachers, and science curriculum at the middle and high school levels. Science Olympiad is discussed at more length later in this chapter. Of interest to this study is the impact on students. The project was a three year project, involving four case study schools and 16 associate schools. Students, teachers, and parents at the case study schools were involved in interviews, observations, document collection, and questionnaires. The interviews and questionnaire data were analyzed using the constant comparative method in an effort to explain the experiences of the students and the impact of Science Olympiad. The data showed that students gained an in-depth understanding of science concepts and principles and that students learned science processes and techniques. During interviews, the coaches asserted that students:

> gain a greater in-depth understanding of selected areas rather than a broad understanding of a large number of areas because students compete in small segments of events and become the expert for the team in their selected areas; learn and apply many skills of science research; begin to understand science techniques that are somewhat universal; exhibit increased critical thinking skills; exhibit significantly enhanced laboratory skills; and have an opportunity to explore science and science concepts beyond the 'norm. (p. 8)

The coaches also described ways that students' understandings of NOS matured, such as (a) understanding the role of trial and error, (b) improved problem solving, and (c) improved critical thinking. Students mentioned how "enthusiastic" (p. 14) they became about science. They characterized their experiences as "fun" and "challenging" (p. 14) and discussed the importance of collaboration.

> Students indicated that they think it is important for scientists to collaborate, and then provide supporting 'evidence' for their positions from their own experiences of collaboration in Science Olympiad. The primary reasons collaboration is important from students' perspectives are: increase effectiveness; increase efficacy; share/pool knowledge; increase

> creativity and problem-solving. While collaborating in Science Olympiad, students found that they learned to compromise, challenge each other's ideas, stimulate creativity, improve problem solving, research and learn more in-depth, and combine thinking skills. (p. 15)

The research from Bell et al. (2003) and McComas (1993) involved students participating in science in an extracurricular sense, but not with the enthusiasm that the Science Olympiad research showed. One reason may be that Science Olympiad requires planning, materials preparation, identification of diverse resources and research, due to the broadly defined events. The students are also in competition against Science Olympiad teams from other schools; often rival schools at every level, during the regional competition. On the other hand, an internship situation may involve more of the "grunt" work and more rote tasks. With the positive impacts regarding students' understanding of NOS and attitudes toward science, as described by McGee-Brown et al. (2003) more research is warranted to specifically look at Science Olympiad students' understandings of NOS and to learn why they decided to participate in Science Olympiad, which is considered an extracurricular competition at the high school level.

Inquiry

A clear understanding of what is happening in the classroom related to NOS would not be complete without a brief discussion of inquiry. "If a single word had to be chosen to describe the goals of science educators during the 30-year period that began in the late 1950s, it would have to be inquiry" (DeBoer, 1991, p. 206). DeBoer noted the two ways inquiry was interpreted in education, either as a set of skills students should know or a method of teaching. The National Standards (NRC, 1996) defined inquiry as

> the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and

> understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (p. 23)

Hurd (1997) discussed scientific inquiry as a discipline bound to the classroom. Beyond the laboratory, science concepts take on a different meaning. He said social inquiry supplements scientific inquiry as an important goal in science education. Social inquiry "is a process of utilizing science concepts for resolving personal, social, and economic actions" (pg 16). Kilcrease and Lucy (2002) defined scientific inquiry "as the search for scientific knowledge, scientific investigation, and a scientific question" (p. 2). Hassard (1992) said "inquiry is a term used in science teaching that refers to a way of questioning, seeking knowledge or information, or finding out about a phenomena" (p. 20). Scientific inquiry includes the traditional science processes, but also refers to the combining of these processes with scientific knowledge, scientific reasoning and critical thinking to develop scientific knowledge (Schwartz et al., 2001). Gunstone, Loughran, Berry, and Mulhall (1999) differentiated between inquiry, inquiry learning, and scientific inquiry. Inquiry was defined as the search for knowledge, an investigation, or a question, and inquiry learning was learning and teaching approaches for inquiry. Scientific inquiry was then defined as the "ways in which science develops, ways in which it can validly be argued that new concepts are constructed in science, new ideas emerge, new perspectives are formed and justified and accepted" (p. 1). Through inquiry activities in the classroom and explicit discussions, students would hopefully learn scientific inquiry, which is most inline with the aspects of NOS that will be examined in this research.

The National Research Council (2000, p. 29) lists essential features of an inquiry oriented classroom: (a) Learner engages in scientifically oriented questions, (b) learner gives priority to evidence in responding to questions, (c) learner formulates explanations from evidence, (d) learner connects explanations to scientific knowledge, and (e) learner communicates and justifies explanations. The features are listed with variations along a continuum of learner self direction and direction from teacher or material. At the highest level of learner self direction and the lowest level of direction from the teacher, the learner is posing the questions, designing data collection, analyzing and explaining the data. On the other end of the continuum, the teacher provides the question, the learner is given a procedure, and guidelines for analyzing and explaining results.

Science Olympiad students are provided with event sheets that contain the parameters of their events several months before the competition so they may prepare. Study events list topics students should understand, and the event itself generally contains application questions related to the topic. The students are responsible for collecting their own study materials, with the coach serving as a facilitator in the preparation. The lab based events sheets also include the topics and parameters. The Science Olympiad coach will facilitate by setting up practice labs, although we do not know what the event facilitator at the competition will have planned. Students working on the engineering events know in advance what their “machine” should be able to do and the parameters for construction. Examples of construction events include (a) robots with arms to pop balloons and gather small objects into a box, (b) a catapult that will throw an object the farthest, but they do not know the exact mass of the object until the competition, and (c) a car that will travel a range of distances, with the exact distance given at the competition. Generally the students start preparation by researching the event, drawing several designs and then construct several protocols. While the students know the objectives of their events in advance, they are required to design and collect data during lab and building events, and in all events, they must interpret and analyzed data.

With the push for inquiry oriented teaching (AAAS, 1990; AAAS, 1993; NRC, 1996), science teachers may try to have students “discover” relationships. But, Abd-El-Khalick and Lederman (2000) found the relationship between engaging in inquiry activities, science by inquiry methods, and understanding the process of knowledge development to be indirect. Participating in inquiry activities was shown to enhance science process skills, but did not promote understandings of NOS. Westbrook (nd) raised the issue of state-mandated accountability exams and the fact that science teachers did not invest in inquiry oriented practices because they did not perceive the laboratory as a source of instruction. She felt that science teachers did not “know how to meld the processes of outcomes of laboratory investigations with the students’ constructions of science content” (p. 1).

With laboratory work considered the vehicle for students to learn about scientific inquiry, and in turn develop more informed understandings of NOS (Nelson, 2001), it is necessary to know how students perceive laboratory work. Gunstone et al. (1999) interviewed students in grades 10 and 11 both informally during lab activities and formally outside the lab to explore their perceptions of lab work. The interviews revealed that in closed labs (where the apparatus and method is clearly stated, such as a verification exercise), completion of the task and getting the “right” answer were the primary goals for students. In open lab tasks (where students may be given an overriding question, but design their own method and try to answer the question based on their data), completion was again the overriding goal and they believed the teacher would provide the answer in the end, so there was a “why bother” type of attitude. The students interviewed viewed lab work as making science more interesting and enjoyable and assisting their understanding of theoretical concepts, rather than simply taking notes, doing book work, and then memorizing facts for a test. While Science Olympiad students also seek to get the right answer, I was interested in the aspect of Science Olympiad that parallels the scientific process. The students do their own research in study events, design and build their own protocols in the engineering events, and design, collect and interpret their data in the lab-based events.

Dembrow and Molldrem-Shamel (1997) discussed a cyclical nature of inquiry, starting with a topic of interest to learn and explore, and continuing with the development and implementation of a plan, data collection and analysis, and plans for further inquiry. As science teachers, we have to ask ourselves, how interested are our students in learning and exploring the topics we assign in labs? Real world situations, linked to students' content understanding, helped students perform inquiry (Lee & Songer, 2003). Volkmann and Abell (2003) made several suggestions that involved placing the lab outside the classroom and into the students' world.

Chang and Mao (1999) recommended “science instruction should provide opportunities for students to think independently and solve problems cooperatively” (p. 345). Science Olympiad, which is discussed in the next section, gives students those opportunities. There are significant correlations between students' perceptions of their laboratory learning environments and the students' attitudinal and achievement outcomes (Fisher, Henderson, & Fraser, 1997). More specifically, students appreciated student cohesiveness, integration, rule clarity, and a good material environment with updated, working equipment. Science Olympiad, discussed in the next section, at the high school level is a competition with voluntary student participation. The events are often staged in the description as a real world problem or scenario, and the students buy into the scenario. They particularly tend to enjoy being part of a team and competing against teams at rival high schools.

Science Olympiad

The research discussed previously looked at students' views of nature of science based on various types of instruction. The findings continuously showed no significant difference in students' views of science between pre and post-tests, or that students simply had naïve views of NOS. There is a gap in the nature of science literature where voluntary science competitions are involved, specifically science Olympiad (National Science Foundation, n.d.).

High ability students were studied in summer internships, as previously discussed (McComas, 1993), and based on the researcher's experience working with science Olympiad, most science Olympiad students would be considered high ability. The difference between the internship and the science Olympiad is the assumption that students take ownership in the events in which they participate. In addition, science Olympiad allows students to participate during middle and high school, so students have the opportunities to build on their knowledge and learn from their mistakes. A study funded by the National Science Foundation (n.d.) showed that with experience, a "second chance" to participate in the events and collaboration with teammates, students learned about the scientific process and the scientific enterprise.

One of the fundamental recommendations set for by the National Research Council (1996) for reforms in science education was that students should be actively engaged in activities that help them construct new knowledge by using the skills and processes of science. Science Olympiad involves students in “developing and using science skills and scientific reasoning to build new content knowledge and increase their interest in science” (Abernathy & Vineyard, 2001, p. 269). Students involved in Science Olympiad perceived learning something new as rewarding. “The events may be tapping into students’ natural curiosity and providing new context for them to learn in, without rigid curriculum or grading constraints” (p. 274).

Science Olympiad’s mission is to improve student interest in science and to improve the quality of science education (Science Olympiad Inc., 1999). Stazinski (1988), Wilson (1981), and Westmore (1978) support the mission statement to improve student interest in science. Science Olympiad is an international organization with rigorous tournaments that consist of a series of individual and team events, which students prepare for during the year. The current study was not trying to assess how participation in Science Olympiad impacts students’ understandings of NOS. Science Olympiad students were chosen as participants because they are a group of students who are interested in science and I wanted to know how Science Olympiad students understand NOS and how experiences contributed to their understandings. The events are balanced between biology, chemistry, computers, earth science, physics, and technology, and may require knowledge of science facts, concepts, processes, skills or science applications. Competitions are at regional, state, and national levels and are hosted by Colleges at each level. The coaches’ manual, which is published each year, has specifics on each event, with a description of how the event will be judged. Some events are paper/pencil and are graded like a normal test. In other events, such as engineering and building events, points are earned by direct comparison with other teams. Ribbons or medals are generally awarded for top teams within each event and then scores are tallied for all events. Winning teams are then invited to move on to the next level of competition.

According to the National Science Foundation (n.d.), the majority of students characterized their experiences in Science Olympiad as challenging and fun. They claimed that their:

> Experiences directly impacted their views about the importance of collaboration among scientists. They found that pooling knowledge, experience, and skills stimulated created problem-solving among participants that resulted in more focused applications of science, engineering, and mathematics concepts. Students found application of science to 'real world' problems a challenge that required identification and use of new resources. (p. 5)

Summary

Nature of Science is one of the areas targeted for inclusion in school curriculum by current science education reform efforts on the grounds that it will develop scientifically literate citizens who will be able to make informed scientific, economical, and societal decisions, and continue the United States' standing as a world power. The achievement of scientific literacy is viewed as the educational solution to the many economical, social, and environmental challenges for the 21st century. Therefore, it is necessary to assess students' understandings of NOS as well as to learn why students do or do not have informed understandings of NOS. Based on the review of NOS literature, this study was designed to assess high school Science Olympiad students' understandings of NOS. Research from Buck (2003), Khishfe and Abd-El-Khalick (2002), Liu and Lederman (2002), Moss (2001), McComas (1993), and Schwartz et al. (2001), found no significant difference in NOS pre and post tests for a given course, internship, or inquiry based unit, but McComas (1993) suggested that experience with science may have an effect on students understanding of nature of science. The main question that was addressed in this study was: Does exposure to science through high school science courses and Science Olympiad affect students' understandings of nature of science? Through in depth interviews, focus groups and the VNOS-HS questionnaire, the researcher hoped to reveal if students experienced explicit NOS teaching and the experiences students feel most contributed to their understandings of NOS. In addition, the researcher was interested to find out why the students decided to participate in Science Olympiad.

CHAPTER 3

METHODOLOGY

Introduction

The purpose of this study was to assess high school students' understandings of nature of science and learn about the experiences that formed their understandings. The following questions directed this inquiry:

1. How do Science Olympiad students understand different nature of science aspects?
2. How do experiences in and out of the classroom contribute to Science Olympiad students' understandings of nature of science?

An interpretive, qualitative, case study method was used to focus on these research questions. The main forms of data collection were the Views of Nature of Science – High School Version (VNOS-HS) questionnaire, semi-structured individual interviews, and a focus group. Participants' views of nature of science were best understood using a constant comparative method (Glaser & Strauss, 1967) as each phase of data collection was completed.

Overview

An interpretive, qualitative, case study methodology was used to explore high school students' understandings of nature of science. The participants were Science Olympiad students, who were generally high achieving students and had positive attitudes toward science. High achieving science students take high level science courses and perform well in the courses. Students are recommended for high level science courses based on high academic achievement in previous science courses. Qualitative methodology is based on the constructivist philosophy (Denzin & Lincoln, 1994) in that researchers are interested in understanding the meaning people have constructed. Individuals build their constructions of reality by attaching meaning to phenomena. It is assumed that meaning is embedded in people's experiences and that this meaning is mediated through the investigator's own perceptions (Patton, 1990). In interpretive research, "education is considered to be a process and school is a lived experience" (Merriam, 1998, p. 4). If meaning is constructed through experience and school is a lived experience, then students' school science experiences shape their views of nature of science. In an attempt to get at the heart of the focus questions, a case study was the specific type of qualitative research employed. Merriam (1998) describes case studies as a suitable design if the researcher is interested in process. Researchers using case studies are interested in insight, discovery, and interpretation rather than hypothesis testing. "By concentrating on a single phenomenon or entity (the case), the researcher aims to uncover the interaction of significant factors characteristic of the phenomenon" (Merriam, 1998, p. 29). In this study, the case was students' understandings of NOS and the experiences forming students' understandings of NOS were the factors the researcher was looking to "uncover".

Setting and Participants

The participants in this study were selected based on purposeful and convenience sampling (see Figure 4). Patton (1990) defined the minimum sample size "based on

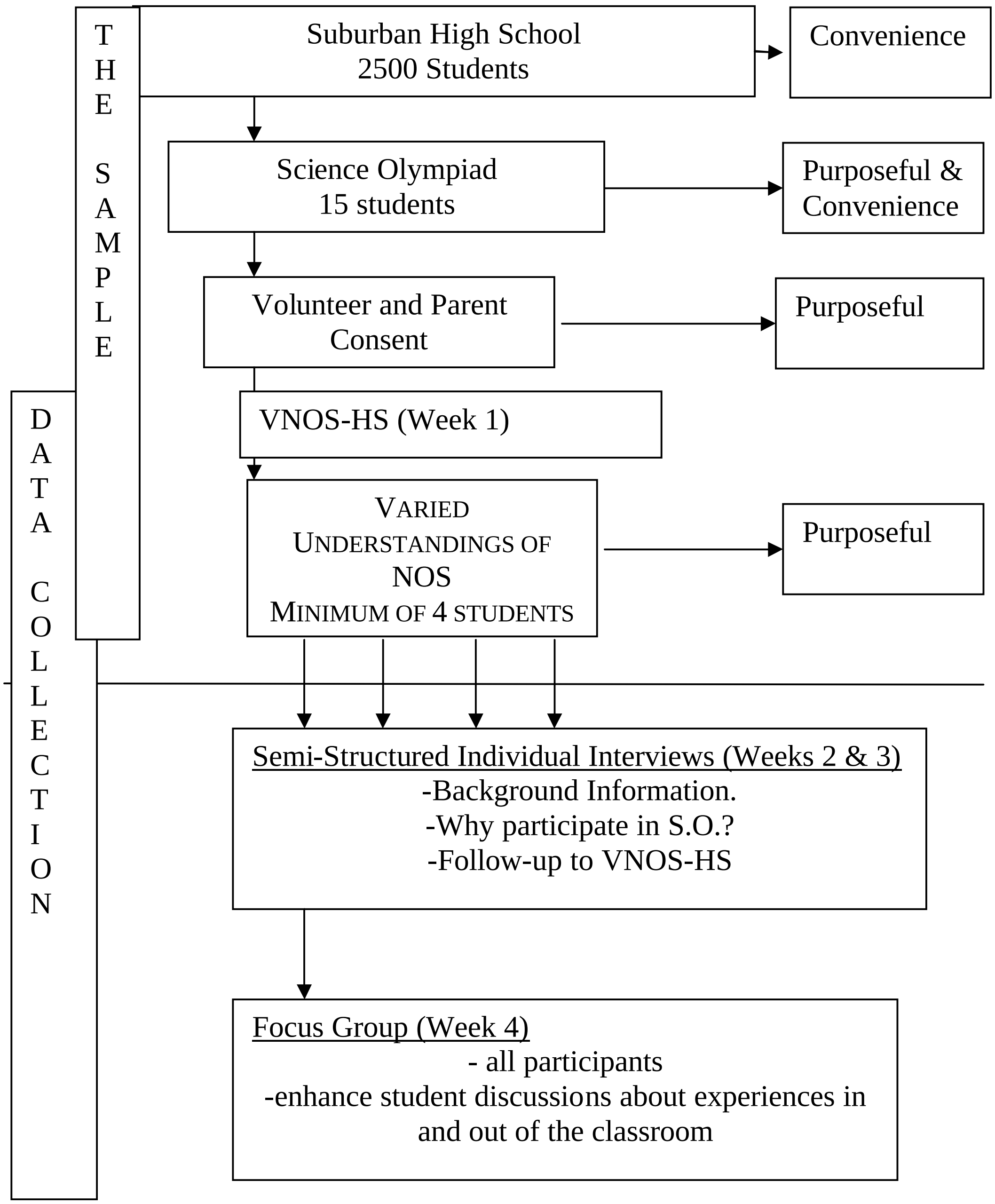

Figure 4. Participant Selection and Data Collection. Overview of the sample selection and data collection.

expected reasonable coverage of the phenomenon” (p. 186), to be four participants. Purposeful sampling is the deliberate selection of information-rich sources (deMarrais & Lapan, 2004), and is the method of choice for most qualitative research (Merriam, 1998). Purposeful sampling is based on the assumption that the investigator wants to discover, understand, and gain insight and discover relationships linking occurrences. The sample was selected based on convenience sampling. The study was feasible at this suburban high school and the site happens to be fairly homogeneous with respect to demographics and socioeconomic status. The school enrollment is just over 2500 students with a demographic breakdown of approximately 87% white, 2 % black, 8% Hispanic, 2% Asian and 1% other. Fewer than 10% of the school’s population qualify for free and reduced lunch. Regarding standardized test scores, this high school scored in the top 20 for SAT scores in the metro area and has an 82% pass rate for the state science graduation test. In addition, almost 80% of the graduating class is eligible for the HOPE scholarship. Homogeneity among the students lessens the effect of dissimilar science educational experiences as a confounding factor in data interpretation. Because case studies are not generalizable, homogeneity was not an issue in this study.

The Science Olympiad team, made up of 15 students, was the specific population used in the sample. A total of eight of the 15 team members participated in the study. Twenty five percent of the students, or two students out of eight, were Middle Eastern, and the other 75%, or six students, were Caucasian. All eight students answered the VNOS-HS questionnaire, five of the eight students participated in the individual interviews, and six of the eight students participated in the focus group. The participants represented a convenience sample in that I am the Science Olympiad coach, and purposeful in I wanted to specifically assess high achieving students who enjoy science. As defined in Chapter 1, high achieving science students participate in gifted programs and take multiple high level courses (Farenga & Joyce, 1998; McHale, 1994), have high perceptions of involvement and affiliation (Huang & Waxman, 1996), and move at a faster pace, requiring more demanding lessons (Mills, 1998). Stombler (2000) identified the majority of Science Olympiad students in Georgia to be A/B students who participated in multiple extracurricular activities, such as band, sports, and academic clubs. From the Science Olympiad team, students were initially selected based on their willingness to volunteer and parental consent. A VNOS-HS questionnaire (see Appendix A) was administered in my classroom after school to the volunteers who obtained parental consent. Participants for the study were purposefully selected based on the varying levels of understandings of NOS on the VNOS-HS questionnaire, and again, availability to participate in the remainder of the study.

The purpose of this study was not to generalize to all cases, rather to give a rich, thick description and ultimately offer educators guidance in making choices regarding instruction in the classroom as it specifically related to nature of science. Patton (1990) argues that qualitative research should “provide perspective rather than truth, empirical assessment of local decision makers’ theories of action rather than generalization and verification of universal theories, and context bound explorations rather than generalizations” (p. 491). While the students participating in the study were not my students, I was the Science Olympiad coach and felt that this relationship would allow more genuine communication to occur than if students were chosen from a different school.

Data Sources

In this study, multiple methods were used to assess Science Olympiad students' understandings of NOS and the experiences that formed those understandings. The data collection occurred in three stages, and was conducted in my classroom immediately after school. The VNOS-HS questionnaire was administered as a form of purposeful selection for the sample and also served as the first description of students' understandings of NOS. Once the participants were selected, semi-structured individual interviews were conducted. This interview served as a source of background information, such as age, schools attended, science classes and experiences that may have helped form these students' understandings of NOS, as well as a follow-up interview for the VNOS-HS questionnaire and to learn why the participants wanted to participate in Science Olympiad. The third stage of data collection was a focus group. Glesne and Peshkin (1992) suggest that interviewing more than one person at a time sometimes proves very useful, and that some topics are better discussed by a small group of people who know each. Students may be emboldened to talk, and elaborate on experiences in the classroom, media, or at home that contributed to their understandings of NOS, which was the case with the group of students who participated in the focus group. The dialogue of the focus group interviews helped to generate a broader range of participant input. And finally, as I was putting all of the data together, students were available via email or phone if any clarification were necessary, as school was over for the school year.

The Views of Nature of Science questionnaire- high school version (VNOS-HS), used by Schwartz et al. (2001), and originally modified from Lederman et al's. (2002) VNOS-C, was previously validated for use with students in grades seven through 12.

"The nature of science aspects targeted on the VNOS-HS include that science is: (a) tentative, (b) based on empirical observation, (c) influenced by subjectivity, (d) the product of human inference and creativity, and (e) composed of theories and laws that are fundamentally different types of knowledge, based on different types of data" (Schwartz et al., 2001, p. 8). Questionnaires have been widely used to assess views of nature of science, but many of the questionnaires have received criticism (Lederman et al., 1998; Lederman et al., 2002; Munby, 1983). Open ended questionnaires with follow-up interviews proved to have the highest reliability, specifically versions of the VNOS with follow-up interviews. The questionnaire that was used in this study is found in Appendix A. As suggested by Lederman et al. (2002), I administered the questionnaire to students after school and it too them 45 minutes to complete the questionnaire. Lederman et al. (2002) cautioned not to set time limits due to the open-ended nature of the questionnaire.

A follow up interview to the VNOS was suggested by Schwartz et al. (2001). During the first individual interview (see Appendix B), students were asked to include school science and Science Olympiad experiences leading to their responses on the survey. I tried to determine why students chose to participate in Science Olympiad, and participants were also asked to explain what they learned while preparing for their events and from the various competitions. All interviews were semi-structured with the same outline of questions, but I was flexible enough to "respond to the situation at hand, to the emerging worldview of the respondent, and to new ideas on the topic" (Merriam, 1998, p. 74).

Data collection took place over a four week period and was conducted in my classroom after school. The VNOS-HS was administered to eight students during week one and concluded the purposeful sampling. Semi-structured individual interviews were then conducted with five of the eight students during weeks two and three. Six students participated in the focus group during week four. During weeks five and six, I transcribed interviews and began to compile data, as described in the next section. The participants all agreed that I may contact them by phone or email if any questions arose during data analysis.

Analysis of Data

Case studies do not claim any particular method for data analysis (Merriam, 1998). Because the plan in case study design is an emergent design, "in which each incremental research design depends on prior information" (McMillan & Schumacher, 2001, p. 398), a constant comparative method of data analysis was employed. Glaser and Strauss (1967) developed the constant comparative model as the means of developing grounded theory, which consists of categories, properties, and hypothesis, which are the conceptual links between the properties and categories. The basic strategy is to constantly compare (Merriam, 1998), so before moving to the next stage of data collection, responses to the VNOS questionnaire were analyzed and ranked on a scale of one to five, as described in Chapter 4. All interviews were transcribed and coded to look for emerging themes to help answer the second research question, what experiences contributed to students' understandings of NOS? Comparisons between data led to tentative categories, which reflected the purpose of the research. I made a table with each column representing a question asked during the individual interviews and the focus group. Each row represented the participants. I then color coded the emerging themes across columns and students. For example if a participant referred to a parent in an area other than where I specifically asked if their parents influenced their interest in science, it was color-coded with a color designated for responses discussing parents. Coding was the process of analyzing data to develop categories and relationships, and occurred at two levels- identifying information about the data and interpretive constructs related to analysis (Strauss &Corbin, 1990). With regard to the first level of coding, each questionnaire needed identifying notations for access during analysis and from the notations I created guiding questions to use during the first individual interviews. Common themes with differences in thoughts, opinions, and experiences that emerged during the individual interview guided the discussion during the focus group. Qualitative analysis required me to create or adapt concepts relevant to the emerging data. Lederman et al. (2002) suggested reaffirming the validity of the VNOS in the context in which it is being used by systematically comparing NOS profiles generated by the separate analysis of interviewees' questionnaires and interview transcripts. Students' understandings of NOS from the VNOS-HS were analyzed using the guidelines established by Lederman et al. (2002). See Appendix C.

After questionnaires were completed, they were read carefully and used to guide the interview questions. The questionnaire was designed so:

> Participants can demonstrate their NOS understandings in several contexts. This approach allows one to check for deep understanding of an NOS aspect versus superficial reiteration of key terms by examining the consistency, or lack thereof, in respondents' answers across VNOS items. (Lederman, et al., 2002, p. 512)

Inconsistencies between aspects of NOS across items on the questionnaire were addressed during the interviews. Lederman et al. recommended that interview data be given priority to the questionnaire data. The interviews were audio taped and transcribed and the data, including the VNOS-HS questionnaires, was then used to guide the focus group discussion, as previously described.

Trustworthiness of the Data

Lincoln and Guba (1985) introduced four criteria, credibility, transferability, dependability, and confirm ability, which collectively could be combined to determine the trustworthiness of qualitative data. Satisfying these criteria accounts for the data's validity and reliability used to measure trustworthiness of the data in more positivist, quantitative research.

Credibility

Credibility addresses the issue of confidence in the data of a particular inquiry with regards to the participants' responses and the context in which the research was carried out. How well does my account agree with reality? Lincoln and Guba (1985) suggested member checks as being the most crucial technique for establishing credibility. My interpretations of the interviews were emailed to the participants and the participants were asked to review the interpretations of the interview to make sure it is reflects the views they were actually trying to convey. This study addressed credibility through triangulation of the data and member checks. Triangulation is a technique advocated by Denzin (1970) for validating observational data. By using multiple methods, such as open ended questionnaires and interviews, a holistic understanding of students' views of nature of science was formed.

Confirmability

Confirmability in qualitative research replaces neutrality in quantitative research. The degree to which the findings of inquiry are determined by the participants and not by the biases, motivations, or interests of the researcher determines confirmability. To ensure confirmability in this study, triangulation of data and an audit trail were used. Interviews were audio taped, transcribed, and member checked. I kept a log book identifying all dates, times, and participants involved in data collection along with any notes I took during data collection. In addition, a record was kept that explains my methods for developing categories, codes, and themes. "If we cannot expect others to replicate our account, the best we can do is explain how we arrived at our results" (Dey, 1993, p. 251).

Dependability

Dependability refers to the consistency of the results obtained from the data (Lincoln & Guba, 1985). The results should make sense to someone outside of the study, given the data collected. "The question then is not whether findings will be found again, but whether the results are consistent with the data collected" (Merriam, 1998, p. 206). Triangulation of data and an audit trail ensured that results in this study are dependable and consistent, and that the data supported the implications.

Transferability

How well are the results from a study transferable to another situation? Before we can be concerned with the extent to which the findings of one study can be applied to another situation, the study at hand must be internally valid as discussed previously. On the other hand, if a researcher goes too far in controlling factors, the results are only transferable to artificial situations (Merriam, 1998). Transferability is achieved by providing a detailed, rich description of the setting studied, so that readers are given sufficient information to be able to judge the applicability of findings to other settings which they know (Lincoln & Guba, 1985). Rich information about the setting and participants is provided, and all raw data was maintained for further review.

Human as Instrument

According to Lincoln and Guba (1985), reality is “a multiple set of mental constructions, made by humans; their constructions are in their minds, and they are, in the main, accessible to the humans who make them” (p. 295). Because I was the primary instrument of data collection in this study, interpretations of the participants’ reality were accessed through a questionnaire and interviews. Merriam (1998) believes that in qualitative research, it is important to understand the perspective of those involved in the phenomenon being studied, and to present a holistic interpretation of what is happening.

In order to best present a holistic interpretation, I first had to gain access to the participants. LeCompte and Preissle (1993) suggested living among the participants as claim to high internal validity. In a sense, I did live among the participants by being part of their community, their school, and by working with them while we prepared for the Science Olympiad competition. I was in contact with the students on a weekly basis and felt that I had opportunities for continual data analysis and comparison because I was a teacher at the school where the research was conducted and I was the Science Olympiad coach. The coach’s role is to help students prepare for the competitions by setting up practice events, coordinating event teams, and assisting with building events. The Science Olympiad students knew me as their Science Olympiad coach, but grades and team performance were in no way tied to this research. I felt that the participants communicated openly with me through the questionnaire, individual interviews, and the focus group.

Summary

This study was an interpretive, qualitative case study exploration of high school students’ views of NOS. The design included a VNOS-HS questionnaire, individual interviews, and a focus group. There were eight participants who were high achieving high school students, and participated in Science Olympiad at a suburban high school I had access to the students because I was the Science Olympiad coach. The data was interpreted using the constant comparative method of inductive analysis. The questionnaires were the initial assessment of the participants NOS understandings and were coded using Lederman et al.’s (2002) guidelines in preparation for the individual interviews. The individual interviews provided background information about the students and also served as a follow-up to the questionnaire. After the individual interviews, the students’ understandings of NOS were reevaluated and I coded for common experiences and looked for possible relationships to NOS understandings. The focus group was the main source of data collection for students experiences related to their NOS understandings and were again coded according to similar experiences. The results were used to develop assertions regarding high school Science Olympiad students’ NOS understandings and experiences that contributed to their NOS understandings.

CHAPTER 4

RESULTS

Introduction

The purpose of this study was to explore high achieving high school students' understandings of nature of science (NOS). More specifically, this study looked at students' understandings of the tentative nature of science, the role of human imagination, creativity and inferences in experimental design and data analysis, the empirical nature of science, and the difference in and relationship between theories and laws to describe students' understandings of NOS. The high school students were high achieving students who enjoyed science classes and chose to participate in Science Olympiad as an extracurricular activity. This study also investigated Science Olympiad students' science classroom experiences and other experiences that may have shaped their understandings of NOS. A constructivist theoretical framework was used to focus on the guiding questions of this research:

1. How do Science Olympiad students understand different NOS aspects?
2. How do experiences in and out of the classroom contribute to Science Olympiad students' understandings of NOS?

This chapter is divided into two key sections addressing the two research questions.

The Views of Nature of Science- High School Version Questionnaire (VNOS) modified and used by Schwartz (2001) from Lederman et al. (2002), follow-up interviews, and a focus group were used to identify students' understandings of NOS.

Eight students completed the VNOS-HS (see Appendix A) after school, taking them approximately 45 minutes. I asked the students to complete the questionnaire to the best of their ability, with no resources available, and ensured they could further discuss items on the questionnaire at the follow-up interview. After the questionnaires were read and scored using guidelines (see Appendix C) established by Lederman et al. (2002), follow-up individual interviews were arranged with five students based availability after school. Chosen to provide a range from naïve to informed understandings of NOS, the follow-up interviews took place after school in my classroom, and were used to clarify inconsistencies in the questionnaire and also to acquire background information. I had guiding questions for the interviews, but occasionally probed students for more explanation or clarification. After the individual interviews were transcribed and coded for experiences contributing to understandings of NOS, a focus group was conducted after school in my classroom with six of the eight students who completed the questionnaire, based on availability. The purpose of the focus group was to create an environment with familiar students in an effort to spawn discussion and elaborate on experiences in the classroom, media, or at home that contributed to their understandings of NOS. Table 1 identifies each student's contribution to the three data points.

To serve as an introduction to each of the participants, grade level, years of participation in Science Olympiad, science courses completed and definitions of science have been included in Table 2. The science classes each student completed confirm my assumption that the Science Olympiad students are high achieving students. Each participant was asked in the VNOS-HS to define science. The participants had two main types of definitions for science. Science was either defined as (a) the study or process of,

Table 1

Students' Roles in Data Collection

Participant	***VNOS-HS***	***Individual Interview***	***Focus Group***
Allen	x	-	x
Bill	x	-	x
Jim	x	x	x
Peter	x	x	x
Pam	x	x	x
Rich	x	x	-
Sam	x	x	x
Steve	x	-	-

and a methodological way of investigating or (b) a scientific knowledge as a product of investigating. Understanding each participant's concept of science is important in obtaining a better insight into his or her understanding of NOS.

Research Question 1: How do Science Olympiad Students Understand Different Nature of Science Aspects?

The results for the first research question are subdivided into the participants' understandings of the tentative nature of science, the role of human imagination and creativity, the empirical nature of science, inferences in experimental design and data analysis, and the difference in and relationship between theories and laws. The results of the VNOS-HS questionnaire, follow up interviews, and the focus group were used to generate five categories to help describe the participants' levels of NOS understandings, similar to work done by Walker and Zeidler (2003). The participants were primarily placed in categories in reference to the guidelines established by Lederman et al. (2002), as shown in Appendix C. The categories are a scale of one to five. A score of "1"

Table 2

Participants' Science Backgrounds and Definitions of Science.
(The names are pseudonyms.)

Participant	***Grade***	***Years in SO***	***Science Courses***	***Definition of Science***
Allen	11th	5	AP Prep Biology IB Biology AP Prep Chemistry AP Chemistry	"Science is the process through which life in general occurs."
Bill	12th	4	AP Prep Biology AP Prep Chemistry AP Chemistry AP Physics	"A systematic, social way of using reason to understand natural phenomena so that the results are verifiable."
Jim	12th	4	AP Prep Biology AP Prep Chemistry AP Chemistry AP Prep Physics AP Physics Anatomy/Physiology	"Science is the study of the physical interaction between objects."
Peter	12th	3	AP Prep Biology AP Prep Chemistry AP Chemistry IB Biology Physics Anatomy/Physiology	"Science is a methodology that insures the integrity of conclusions and the research supporting those assertions. Its rules and standardizations allow the freedom for new situations without compromising the discoveries through shoddy work."
Pam	10th	3	Biology AP Prep Chemistry AP Chemistry	"I think that science is the study of things that are all around us and within us. It could be as simple as the study of the water cycle or as complicated as quantum theory."
Rich	11th	3	AP Prep Biology AP Prep Chemistry AP Chemistry Physics	"The littoral study of the environment and all of its components around us; everything."
Sam	11th	1	Physical Science AP Prep Biology AP Prep Chemistry AP Chemistry Astronomy	"Science is the study of everything in this world that needs an explanation and can further our way of life."
Steve	12th	1	Physical Science AP Prep Biology AP Prep Chemistry AP Chemistry	"To me, science is the study of everything we can see, hear, tough, taste, smell, think, etc. To understand where something came from, its purpose and its impact on us in the future is science."

demonstrated strong evidence of naïve understandings, a “2” demonstrated no evidence of understandings, a ”3” demonstrated mixed understandings, a “4” demonstrates evidence of informed understandings, and a “5” demonstrates strong evidence and explanations of informed understandings. Strong evidence of naïve understandings was ranked below no evidence of understandings because there was evidence supporting naïve understandings. Participants showing no understandings did not have responses fitting Lederman’s guidelines.

The tentative nature of science

In reference to the tentative nature of science, all of these students responded yes on the VNOS-HS with regards to the idea that scientific knowledge learned in school and found in books will change in the future. Explanations to participants’ yes responses generally showed informed understandings of NOS, based on Lederman et al.’s (2002) guidelines (as shown in Appendix C), yet some participants struggled with the idea that theories and laws were subject to change. Table 3 shows a continuum based on the participant’s understandings of the tentative nature of science. The guidelines suggest the following as a naïve understanding of the tentative nature of science: *If you get the same result over and over again, then you become sure that your theory is proven.* And, an informed understanding would consist of a statement similar to the following: *Everything in science is subject to change with new evidence and interpretation of that evidence. New evidence may call a theory or law into questions, and possibly cause modification.* All participants agreed that scientific knowledge was subject to change, but Bill and Peter most closely met the criteria established by Lederman, et al. (2002) for an informed understanding.

Table 3

Science Olympiad Students' Understandings of the Tentative Nature of Science.

1 (naïve)	***2***	***3 (mixed)***	***4***	***5 (informed)***
		Jim	Allen Pam Rich Sam Steve	Bill Peter

While all participants believed that scientific knowledge could change, Bill, Peter and Sam had naïve beliefs that theories were subject to change with better technologies and new evidences. Sam believed that "a theory in science about something cannot be proven right or wrong. It has been tested but it could be overturned later" (VNOS-HS questionnaire), yet he had the misunderstanding that a law is "something that has been proven right that can always be used" (VNOS-HS questionnaire). This example of not understanding theories and laws will be discussed in more detail later in this chapter. Bill and Peter did not have discrepancies of theories and/or laws being proven. Their responses most closely illustrated an informed understanding of NOS. Bill said, "A law may appear to be absolutely true today, but in the future some unknown variable may change, or we may gain access to more powerful technology that reveals the presence of other variables" (VNOS-HS questionnaire). Likewise, Peter discussed the concept of the Earth being flat at one point and said "static science is an oxymoron" (VNOS-HS questionnaire).

Allen, Pam, Rich, Sam and Steve also provided evidence of informed understandings of the tentative nature of science in their responses, however, they all gave evidence in their responses that they believed theories and/or laws could be proven with evidence. Allen believed that “as time goes on, the model of an atom will change” (VNOS-HS questionnaire) and that science is “dynamic and kind of spontaneous” (VNOS-HS questionnaire). Rich, Sam and Steve all believed that new discoveries and experiments led to the tentative nature of science.

> Rich: You have Galileo’s famous experiment where he threw two cannon balls of the Tower of Pizza and you have….it’s like someone asked how I was doing and I said fine, but I could change just because I think things will change eventually. We are always learning more stuff just like I’m sure 2000 years ago when the Greeks thought light came form your eyes it seemed pretty logical, but now I know better. So I think that what we know now will eventually change. Experimentation causes us to know different. (individual interview)

Sam said, “Just as it has in the past, new discoveries will be made. Science is an always changing field that can only be made better over time” (VNOS-HS questionnaire). Likewise, Steve said, “Scientists are always finding new evidences and postulating new theories. It’s very possible that science will change in the future due to its ability for growth and reform” (VNOS-HS questionnaire). And while Pam also mentioned discoveries, she thought technology also played a role in the tentative nature of science, as did Bill. Pam believed “Scientific knowledge will change because scientists are always discovering new facts with better technology” (VNOS-HS questionnaire). Jim believed that scientific knowledge could change in the future, but he had a very absolutist approach to science. When asked about his favorite subject, Jim replied that it was math because “It is very clear cut. It’s right or it’s not” (individual interview). In response to explaining why scientific knowledge will change in the future, Jim wrote “Science has a historical precedent of self-correction. For example, spontaneous generation” (VNOS-HS questionnaire). Jim’s favorite science course was physics because “we had a problem, we had a set of rules you could apply to the problem and you use the rules to find what you are looking for" (individual interview). When asked if the rules could change, Jim believed "they studied it until they gathered enough evidence to determine it was true or true enough" (individual interview).

Based on the eight participants in this study, the grade and exposure to science seemed to have little to do with students' understandings of the tentative nature of science. Jim, a 12^{th} grader, who took six science classes and participated in Science Olympiad all 4 years of high school had the most naïve understanding of the tentative nature of science.

The role of human imagination and creativity

It was interesting that the participants overall had mixed understandings of the role of human imagination and creativity in science. A continuum of one to five was again used to rank participants' understandings of the role of human imagination and creativity based on responses from the VNOS-HS, individual interview and focus group. See Table 4. Based on Lederman et al. (2002) naïve views consisted of the following types of responses: *A scientist only uses imagination in data collection, but there is no creativity after data collection because the scientist has to be objective.* And, informed views had responses such as: *Logic plays a role in the scientific process, but imagination and creativity are essential for the formulation of novel ideas…to explain why the results were observed.*

All participants believed that scientists determined the representation of the atom through a variety of experiments and testing and that what is currently know about dinosaurs is strictly data driven. Allen thought what we know about the atom today was

Table 4

Science Olympiad Students' Understandings of the Role of Human Imagination and Creativity in Science.

1 (naïve)	***2***	***3 (mixed)***	***4***	***5 (informed)***
	Bill	Allen		Peter
	Rich	Jim		
	Steve	Pam		
		Sam		

determined "mathematically, logically, and experimentally" (VNOS-HS questionnaire). Bill thought possible models were formulated and tested. Jim said the atom was based on "experiments that lead to indirect measurements" (VNOS-HS questionnaire). Pam, Rich, Sam and Steve all thought the atom was determined from experiments and testing. Pam went on to say she thought you had to be able to visualize what you were trying to explain. Lederman et al. (2002) classified understandings as naïve if the participants did not show evidence of understanding that creativity and imagination also play a role in explaining and interpreting data. On the VNOS-HS questionnaire, Peter's response was probably the closest this group of participants came to the idea that it takes imagination and creativity to design the experiments. "They started with a list of known properties discovered through experimentation and starting sketching models until they set upon one that was simplest and fit the criterion most exactly."

Jim talked about physics having a "mind set of rules" that you could apply; he said it was not of a creative mindset, showing a naïve understanding. Yet, while discussing brainstorming ideas for the construction of a catapult for Science Olympiad, Jim showed a more informed understanding. He said the final model was based on what made the most sense and a little input from a dad who was a physicist. Jim hinted at the creativity in their design.

> Jim: To design it, Peter and I, we brainstormed for a while and came up with several ideas. My dad is a physicist and research scientist and so we threw some ideas at him and he said that would work, or it would work better if you did it this way…. We got it right, close to right. As far as launching it – man did it launch. We got it 53 yards on the football field. Our problem was the counterweight. We assumed they would give us closer to the higher end and they gave us the lower end. I think we should have shaved it down some. We also changed some of the weights. One of the rules is that the arm cannot exhibit motion when it doesn't have the counterweight on it. Ours did, but when it was balanced, it would not give any energy to the launch. But I guess the judges don't really like to change the rules. We actually got it to go backwards pretty far. (individual interview)

Jim demonstrated a mixed understanding of the creative and imaginative nature of science.

Allen, Peter, and Sam said several times that science requires imagination and creativity, demonstrating informed understandings. With further questioning, their ideas of creativity were different. Allen wrote on the questionnaire that science was different from other subjects he studied because it involved imagination and was very hands-on. In the focus group, he elaborated, "on this idea, I would say science is all about breaking boundaries. To break boundaries, you have to have imagination; you have to have a certain creativity for ideas that have never even been thought of." Allen went on to give examples of advances in technology. Sam's idea of imagination and creativity were similar to Allen's understanding, but with a specific goal to better society. "Science has applications to the future of our society. Science will lead the way in the next generations and enable our society to move on…Scientists are like artists, and they try new things" (individual interview). Sam likened a scientist to an artist and Peter likened science to art:

> I think that creativity is an essential part of any scientist because if you think about it, there's been times where I came upon a piece of science or a piece of engineering and thought, wow it is so beautiful. A lot of people who walk into the Louvre and see the *Mona Lisa* and say oh, how beautiful, how mysterious, and there are some of us nerds who walk into a chemistry lab and say oh crap, that reaction is so beautiful. The same things that appeal to us in art, appeal to us in literature, appeal to us in chemistry, appeal to us in science as well b/c it really is a way of self-discovery. Discovering what you are made of. (individual interview)

Peter had the most informed understandings of human imagination and creativity in science and was very clear in all of his responses that it takes imagination and creativity to design experiments and interpret results.

The participants might agree, based on their responses, that imagination and creativity have a place in science, but overall they did not make the connection between imagination and creativity in experimental design and explaining results. During the individual intervals, I asked how they thought various scientists came to their understandings of the atom; they all talked about the data, but never the imagination and creativity in interpreting the data. In the focus group, I again specifically asked what they thought of imagination and creativity in data interpretation. The participants understood that experiments and data are essential parts of valid scientific research, but they did not make the connection to the creativity involved in designing experiments. Nor did they credit creativity and imagination in explaining results. In discussing Rutherford's Gold Foil Experiment, Pam said, "I think Rutherford probably already had an idea of what he was expecting and that's probably why he came up with the idea he did" (individual interview). Pam did not understand that Rutherford based his expectations on an accepted model of the atom at the time, and ended up with results very different from his original thinking. Rutherford then took his "surprising" data, and used imagination and creativity to create a new model of the atom.

The empirical nature of science

The participants all showed naïve views of the empirical nature of science in response to the VNOS-HS and individual interviews. Lederman et al. (2002) described naïve understandings as: *Science is concerned with facts. We use observed facts to prove that theories are true*. An informed understanding would consist of: *Much of the development of scientific knowledge depends on observations. I don't believe the goal of science is the accumulation of facts. Rather, science involves abstraction.* Table 5 shows the categories for participants' understandings of the empirical nature of science.

Bill, Rich, Sam and Steve all acknowledged that data was subject to change, yet they all agreed that a law is a theory that has been proven. Bill thought data was limited to the context in which it was obtained. With further questioning, Bill was taking into account the point of view of the observer. Rich said, "a book just holds data, as humans we interpret it." Sam said, "some people say nothing can be completely proven." And Steve thought an "atom [was] subject to change by experimentation." That is as close as the participants' responses came to informed understandings of the empirical nature of science.

Allen, Jim, Peter and Pam all believed science is based on empirical evidence and must be proven. For example, Peter said, "specific empirical evidence is necessary to verify a law" (VNOS-HS questionnaire). And Jim said, "science is based entirely on empirical evidence" (VNOS-HS questionnaire).

Table 5

Science Olympiad Students Understandings of the Empirical Nature of Science.

1 (naïve)	***2***	***3 (mixed)***	***4***	***5 (informed)***
Allen	Pam	Rich		
Jim		Sam		
Peter		Steve		
		Bill		

Inferences in experimental design and data analysis

Participants' responses on the VNOS-HS and individual interview showed evidence of informed understandings of inferences in experimental design and data analysis. Lederman et al. (2002) gave the following as an example of informed understandings: *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.* A naïve understanding would allude to having to see something to be sure of it. Table 6 shows the categories from naïve to informed understandings for each participant.

Table 6

Science Olympiad Students' Understandings of Inferences in Experimental Design and Data Analysis.

1 (naïve)	***2***	***3 (mixed)***	***4***	***5 (informed)***
	Jim	Bill	Allen	
			Pam	
			Peter	
			Rich	
			Sam	
			Steve	

Allen, Pam, Rich, Sam and Steve all believed that data is interpreted, but never mentioned inferences in experimental design. Allen, Sam and Rich thought people interpret data differently, and Steve wrote, “The reason scientists have different conclusions with the same data is because they view the data in a unique way” (VNOS-HS questionnaire). According to Pam, “no one has ever seen an atom and the model is based loosely on theories which could be true” (VNOS-HS questionnaire). In discussing the conflict over the cause of dinosaur extinction, Peter wrote:

> Where there are two witnesses to an event there will be two different stories. The problem is that they are trying to witness an event 65 million years ago. There are holes in the complete story and what is left must be interpreted. (VNOS-HS questionnaire)

Bill and Jim were not clear in their understanding of inferences. Bill referred to “guessing” if the data was limited. To a more naïve understanding of inferences, Jim was very particular in his responses about needing conclusive evidence, as was in line with his absolutist views of science exhibited so far. When asked how Jim thought physicists came up with rules, Jim responded, “Scientific method. They find empirical evidence. And they studied it until they gathered enough evidence to determine it was true” (individual interview).

Difference in and relationship between theories and laws

The participants generally held very naïve understandings of theories and laws in science. According to Lederman et al. (2002), a naïve view of theories and laws is: *Laws started as theories and eventually became laws after repeated proven demonstration.* Allen, Bill, Peter and Steve had a statement very similar to Lederman’s idea of a naïve view on their VNOS-HS questionnaire. Allen thought a “scientific law is a theory that has been proven irrefutable;” Bill said, “a scientific law is a theory that has large amounts of corroborating evidence and no probable counterclaims that has withstood careful scrutiny over many years;" Peter said, "a law is a scientific theory for which either specific empirical evidence has been found to confirm its validity, or has been verified by logic;" and Steve said, "a scientific law is a theory that has been tested by experimentation and has yet to be contradicted or proven incorrect."

Jim, Rich and Sam did not say that a law was a theory, but they still believed laws were proven. Jim said, "a law is a postulate that does have enough supporting evidence to be considered true;" Rich said, "a law is an undisputed scientific fact, within reason;" and Sam said, "a law is something that has been proven right that can always be used."

An informed understanding theories and laws would be (Lederman et al., 2002): *A scientific law describes quantitative relationships. Scientific theories are made of concepts that are in accordance with common observation or go beyond and propose new explanatory models for the world.* Pam had the most informed understanding of laws. She said, "It is a statement or equation that summarizes an observation made through experimentation." Table 7 shows the categories for participants' understandings of theories and laws.

Table 7

Science Olympiad Students' Understandings of Theories and Laws.

1 (naïve)	***2***	***3 (mixed)***	***4***	***5 (informed)***
Allen	Jim	Peter		Pam
Bill		Rich		
Steve		Sam		

With respect to theories, Peter and Pam had the most informed understandings. They both discussed a theory as an explanation and did not mention a theory being proven on their VNOS-HS questionnaire responses. Peter said, “a theory is a well supported generalization on the nature of something;” and Pam said, “a theory is an explanation of general principles of the subject of study.”

Allen, Bill, Jim and Steve had very naïve understandings. They thought theories were either a process or had enough supporting evidence to be accepted as true. Allen said, “a theory is a process by which outcomes are made from laboratory experiments; making a prediction, then testing it;” Bill said, “a theory is a hypothesis with evidence that is generally accepted to be scientifically valid;” Jim said, “a theory has enough supporting evidence to be accepted as true;” and Steve said, “a theory is an idea that someone thinks will happen and can be tested through experimentation.”

The questionnaire asked for examples of theories and laws, and it was interesting to see that some participants could not even think of an example. It was also interesting to see that when they thought of an example, they still were not able to correctly explain theories and laws.

Summary of students’ NOS understandings

The participants had varying levels of NOS understandings, as a whole and between the different aspects of NOS investigated. Table 8 summarizes the students’ understandings of all aspects of NOS, with a one to five continuum. A one was used for the most naive understandings, a three was mixed understandings, and a five was the most informed understandings. Overall, students had the most informed understandings of the tentative nature of science and the role of inferences in science. The empirical

Table 8

Summary of Science Olympiad students' NOS understandings.

	Tentative Nature of Science	Imagination and Creativity	Empirical Nature of Science	Inferences	Theories and Laws
Allen	4	3	1	4	1
Bill	5	2	3	3	1
Jim	3	3	1	2	2
Pam	4	3	2	4	5
Peter	5	5	1	4	3
Rich	4	2	3	4	3
Sam	4	3	3	4	3
Steve	4	2	3	4	1

nature of science and students understandings of theories and laws were the most naïve understandings of the aspects examined in this study, while the students had mixed understandings of the role of imagination and creativity in science.

Research Question 2: How Do Experiences In and Out of the Classroom Contribute to Science Olympiad Students' Understandings of NOS?

The VNOS-HS was primarily used to address the first research question, while the individual interviews and focus group were used to address both research questions, with more of an emphasis on the second research question. During the focus group, the students had to be reminded to speak one at a time and wait their turn as they were engaged in the discussion that ensued from the questions. The data for the second research question is subdivided into experiences related to school, experiences leading to an interest in science, and intrinsic versus extrinsic factors. The experiences are then specifically discussed in reference to students' understandings of the aspects of NOS addressed in this study.

Steve did not participate in the individual interview or the focus group, so he will not be mentioned in this section of the results. Allen and Bill did not participate in the individual interview, but they were present for the focus group. Rich participated in the individual interview, but was not present at the focus group. The participants who most contributed to this section by participating in the individual interviews and focus group were Jim, Peter, Pam, and Sam.

Experiences related to school

While all participants said they enjoyed science classes, it was interesting that only Peter and Sam said science was their favorite subject. Pam liked English or history best, while Rich enjoyed history the most. Jim liked math best because when asked about his favorite science topic, Jim said physics, "for the same reason. Pam said she most enjoyed English because you "get to be creative with writing" (individual interview) and Rich liked history because of its "analytical nature." Peter and Sam enjoyed science the most. During the individual interview Peter said:

> I couldn't spend time analyzing literature, but I have spent the entire day in a lab and been perfectly happy. I guess it is the discovery and the more physical nature of science. The other subjects except for math are extremely subjective and science is more objective and that way it is a better scaler I guess what we can weigh the world. And it's the ability to do something with your hands to build and create and engineer something

> that can then be used by other people to do something that makes a difference.

Sam enjoyed science most because it was interesting to him. He thought atoms and theories and the way the universe worked was really interesting, as he explained in the individual interview:

> It's the fact that it explains the universe and why things work they way they do and you know, existence and everything. The whole universe is explained by physics and why, how it got there. And it will eventually lead to why we are here and what our purpose is and if there is other life out there.

When specifically asked about a favorite science topic, Pam, Rich, and Sam all said that studying cellular biology was dull and boring. As previously mentioned, Jim enjoyed physics because he thought it was the most math oriented science course and Math was his favorite subject due to it is "right" or "wrong" nature. Sam enjoyed physics the most because: "I like theoretical physics because it has to do with quantum physics and all that… mostly I like physics because of the ideas behind it, but I haven't really taken physics yet, only physical science" (individual interview). Peter enjoyed chemistry the most and he thought that all other disciplines in science involved chemistry:

> I love chemistry the most because it seems that everything is based on chemistry. If you look at biology, all of it has to do with chemical reactions and chemical make-up and every biology course has a section on the chemistry of life. And then you go into physics and you are like oh, this is how this works and you go into a section on particles and how they work in order to make this physics work and then you go into chemistry and you are like, wait, there is no biology or physics in chemistry? And it seems to be like a baseline that you can then measure everything else against. (individual interview)

While agreeing that chemistry was a fun course, Jim and Rich did have chemistry at the top of their lists. Rich thought chemistry was hard to apply, unlike physics. Rich said,

> I think physics. I liked the application of it, chemistry is more molecular and it’s hard to actually apply it to something, while physics, you see something moving and you can understand the forces acting on it. (individual interview)

When asked about the structure of a good science class, Jim, Peter, Pam, Rich, and Sam all enjoyed classes with labs, or hands-on type activities. Peter said,

> I’ve also liked the random practical experiments. [physics teacher name] created an area of low pressure in a milk bottle and we watched the egg go down. I especially love the experiments in where the teachers says they are not going to tell you how it works, but you do this and show yourself how this will work and here’s a lab explaining everything and figure it out. Where you know there is an answer out there. You just have to follow procedures carefully and you will eventually get it. (individual interview)

Peter’s statement about “following procedures carefully” is consistent with the findings on participants’ naïve understandings of the creative and inference based nature of science in experimental design. Students are so accustomed to being handed a set of directions, they must not think about how someone originally came up with the experimental design.

Sam and Rich both mentioned how labs make the science content they are learning seem more relevant, which turned out to be a large qualifier for a good science course. Rich said,

> I like labs because you get to apply what you learned and get to see some uses for it. But it also puts in perspective what you are doing and why it is important. Kind of like math, they try to give you an example problem that’s like real life and actually prove to you that what you are learning has relevance. Labs are that for science. It is fun and gives you an incentive to learn it. It is not just empty information anymore; it’s actually something with relevance. (individual interview)

And Sam thought labs made science classes enjoyable, as he discussed during his individual interview.

> Well, the chemistry labs, like burning stuff, calorimetry, burning marshmallows and stuff, mixing chemicals and the fizzing and putting copper and HCl. We had to do the calculations for what was going on. It was kind of neat, like when you figured out, like when we did electrochemistry and the two solutions actually made a volt. You know if you would have had stronger solutions you could have actually lit a light bulb or something. And, you know we used certain amounts of liquid and things like zinc and copper to create that current. It's just kind of cool to know that you made the calculations. It's like when you are making molarities, you are mixing liters with that so you know how much you are supposed to use. It's like you are making it happen and the reactions are cool.

In addition to lab-based classes, Jim and Peter commented that they liked a good mix of lectures. They both liked informal lectures where the teacher would take time to answer questions. Rich thought content being in appropriate order and dynamic classes were also important.

When asked about characteristics of a good science teacher, Jim, Peter, Pam and Rich all said the teacher must know his/her content well. Pam and Rich also commented that they liked the teachers who used the book as a reference, rather than teaching from the book. Jim and Peter thought the teacher's interaction in the class was also important. Peter gave a detailed description of his ideal science teacher during the individual interview:

> The kind of person who likes lots of questions, who is able to interact with their class very well. Not necessarily just explain, but admit that they are wrong sometimes and that they don't know all of it and allow people to explore what they don't know already. Who doesn't mind staying before or after school to help with a fuzzy area or kind of promotes the environment where it's ok if you don't know, I don't everything either. Come in we'll talk about it and figure it out together. There's no shame in not knowing. I feel a lot of teachers are very much the vibe of I have a personal life and I really don't want you bothering me. But a good science teacher is very active in the learning process of what their students are doing and is able to adjust to fit the needs of every single student in the classroom. A lot of the time I get the feeling teachers feel that you are the students, I'm right, you're wrong. Listen to me, shut-up and do what I tell

> you to do. And it's not the way to promote learning especially among the higher level student. You have to earn their respect, you have to earn their intellectual respect knowing that you do know more than they do, but you also have to know what your limits are and you don't pretend to know more than you actually do. So I mean it's not so much what a really good science teacher is, but teachers in general. It's the ability to ask questions so it stimulates students to want to know the answer, not to have to know the answer.

Rich and Sam thought it was important for the teacher to recognize various interest levels and abilities in the class by using real life application to hold all students' interest and attention. Sam said the following about a good science teacher:

> Well, probably one who understands if it's in high school, one who understands some of the kids are probably taking the class for the credit, just b/c they have to to graduate. I mean a lot of kids want to learn, but some kids are just in there for the heck of it and I think the science teacher would understand that not everyone wants to be there and they need to make it interesting and incorporate learning into interesting things so they don't know they are learning and even though they don't like, they probably aren't going to use it again in their life unless they have to take it in college. And just kind of make sure they have an understanding of everything. And if they are not making great grades, help them out, but they probably don't want to do that great, so there is probably nothing you can do if the person does not [inaudible]. I guess just try your best and help the kids who want to learn and at least let the kids who don't want to learn a little bit. It may seem unfair. If someone doesn't want to learn, you can't force it on them. The kids who do want to learn should be able to learn and more. (individual interview)

When asked to rank science classes on a scale of one to five with five being the highest, Jim, Peter, Pam and Rich gave their classes a four. They all agreed that none of the classes were perfect, so they could not give a five. Jim liked the informal nature of lecture based classes and the variety of "educational methods" used. Peter thought the courses were education and productive, but thought the ratio of busy work versus learning time kept him from scoring the courses a five. Rich thought he always had a good teacher and that the classes were well-structured and well taught, but none of them were perfect. While Pam rated her classes a four, she said they were all very good, but sometimes got really boring with the topics, as she mentioned with cellular biology. Pam thought the boring topics “could have been made more interesting to catch students’ attention” (individual interview). Sam rated his course a three because he felt they have been average.

Experiences related to an interest in science

During the individual interviews, Pam, Rich, and Sam all said that they were interested in how things worked. Pam said, “I guess I’ve always liked science. I’ve just always been interested in how things work,” and Rich said, “I really like to know how things work. My friends goat [kid] me because I have random information and because I am interested in how everything works. So that’s sort of led me to it.” Likewise, Sam’s said,

> It’s not like I really experienced a certain event, it’s just being in the world and wondering how things work and what everything means and how it works and like trying to figure out everything in the universe, trying to understand everything. (individual interview)

Jim and Pam acknowledge science teachers in helping shape their interest in science. Jim had a good experience with a middle school teacher who he had all three years of middle school and Pam enjoyed her elementary science teacher’s classes because they were “hands on and she explained things really well” (focus group). Allen, Bill, Jim, and Rich all have a parent in science related fields and they said that contributed to their interest in science. Allen’s dad has a Masters degree in chemical engineering, Bill’s dad is a microbiologist at the CDC, Jim’s dad is a physicist and research scientist, and Rich’s dad is an electrical engineer. Ben described how his dad’s career may have been an influence,

> My dad is a microbiologist and it [interest in science] has always kind of been there. I know what he does on a daily basis, to see his lab and the cool stuff he does.” Rich described more specific experiences based on his dad’s career, “Dad was an electrical engineer for 21 years. I always had that to go on whenever I needed help and my mom’s a nurse. I remember when I was younger I could always ask my dad how things worked and we would build things. I remember when I was younger I asked my dad how a light bulb worked and we built one. It didn’t work very long. (focus group)

When Jim was asked if his dad being a physicist and research scientist influenced him, he responded,

> I think it did because the field he is in, it’s something he likes and he always had a lot of books around, and then he always liked to talk to us about stuff and lecture us about stuff. He’s a very thorough explainer. Sometimes it’s hard to understand what he’s explaining, but once you get it, it always is a very good explanation. (focus group)

Jim and Sam both had an interest in books and science related programs on television, which they say contributed to their interest in science. Jim said he, “read a lot of books as a kid. I read a lot of everything, but that included a lot of science books- about dinosaurs, which leads to paleontology, which leads to archeology and it all just kind of branched out” (focus group). Sam said, “Watching the history channel and discovery channel and that *NOVA* thing- the three hour episode on string theory. I guess TV, reading stuff, going on line. Looking at the space station and what they are doing” (focus group). As science programming was discussed in the focus group, I asked if the students if they thought science in the media could be taken as reliable. Bill and Peter immediately responded with concern over bias, reliability, and how the many viewers would interpret the report. Bill had the following to say:

> It’s [science] always been used as a tool by whoever wants to manipulate results. Statistics for example is a kind of science in how you gather the data and interpret the data and you can use that to manipulate the way you want b/c it is made of language. Scientists are under a lot of pressure

> sometimes to generate certain results and that can lead to biased research. They have to make their grants. There are definite problems with how science portrayed in the media.

Peter added, saying:

> I think the vast majority of Americans and people in general are very, very ignorant to what a scientific study means in the large scope of things. One study is a single data point and doesn't tell you anything. To say that a study is demonstrated doesn't prove anything until people replicate it and get the same data point. A lot of time the news casters come on and say breaking news- a new study shows that hair dye causes cancer, or whatever. Apparently everything causes cancer these days. It seems like a lot of people don't understand what science means. A lot of people think scientifically proven means. And interpreting science is interpreting a painting. You have to understand how science works and how everything comes together before you can truly say, oh this is how it is.

Peter said his experience with Governor's Honors elevated his interest in science and also talked about the universal language of science. In the interview and focus group, Peter often referred to science as cool:

> Well, I was originally born in Canada. When I went to school there I went to a bilingual school. And the way that worked is that k-6, we learned French. 7-12, we learned English. By the time you are done with your high school career you are equally fluent in French and English. I moved here in the middle of 3rd grade, so I had been learning to speak, read, and write French at this point. And I spoke English in the home, so I was fluent in spoken English, but not in reading or writing. And I had to struggle with that, but the one thing that was always constant is the math was the same and the science was the same. So I was able to grab on something that was familiar and keep working with it and keep moving forward. And the system in Canada was at a slightly higher level. Everything you look for has some method of science or the scientific method or the basic assumptions of an area of knowledge of science. So you are just like, it is just something that becomes a part of you for better or worse and taints your image of everything around you and you are able to apply what you learned to something else. A result of that is that I like to sit down and think about where phrases come from- like the origin behind various phrases or various customs and I use scientific method when I'm trying to figure this out. All of it melts together into this system that just works. Science is just cool. It is something I love to do, that I can spend hours doing and that I love to learn about. Of course there are some experiments you do just for fun and some you do for academic value that explains how

> things interact. You can take all this stuff and attach it to so many different things. (individual interview)

When asked why these participants joined Science Olympiad, Allen, Bill, Phil, Rich, and Sam all mentioned that there were cool things to do. They were interested in the events, particularly the building events. Sam wanted another extracurricular activity and Science Olympiad was the only activity he found that involved science. Jim, Peter, and Pam were all invited to the meetings by a friend and Jim and Peter were hooked once they learned about the events. Pam enjoyed the events, but it was more about the opportunity to work with her friends. On the aspect of friends, Peter enjoyed being in an environment with other students who were interested in science. Peter said,

> I got hooked because the science behind it is fun, the ability to go to an environment and have people make jokes about science and have people just freeform it. Being able to go to an environment were we are all nerds and all enjoy the same thing is really great because people are always very supportive. If you say oh I've heard of this new scientific breakthrough on the news, instead of saying oh you are such a nerd, they are like oh, cool. (focus group)

When asked if preparation for Science Olympiad had an impact on how the students thought of scientists or science in general, they overwhelmingly mentioned the dynamic nature of science and the vast amount of knowledge in science. Pam chose to participate in events in which she did not have background knowledge and felt that studying for the events helped her at least gain a little bit of an understanding of that topic. She viewed Science Olympiad as a learning tool. Likewise, Rich thought that in preparing for the building events, he learned about planning and truly gained more of a deeper understanding of electrical engineering during the robot event. They did not think Science Olympiad truly imitated the work of scientists because as Peter put it,

> In Science Olympiad, everything is so well defined; where you have the same things over and over every year and you are trying, like in forensics, you are trying to examine this case of murder and you know that only going to have these chemicals here or these specific fibers are fair game. But when you are actually working in a forensics lab, everything is fair game. So it's a good stepping stone, but I don't think it's an accurate representation. (focus group)

Allen talked about science being repetitive in nature and that "science can be repetitive at times." However, Allen also thought science could be spontaneous and he thought Science Olympiad represent that aspect to an extent because, "there are events where you go and they give the purpose and you have to make a procedure for it" (focus group). Bill thought the many different types of events represented the different and diverse fields of science. Similarly Spencer thought the diverse events represented the various topics in science and because of the large amount of information, Spencer said, "you kind of have to focus on one thing and do that well. You can't know how to determine the names of bugs and size of glaciers" (focus group).

Extrinsic versus intrinsic factors leading to an interest in science

The participants' responses tended to be a mix between extrinsic factor and intrinsic factors, which contributed to their interest in science and ultimately contributed to their understandings of NOS. When Allen responded to experiences that led to his interest in science during the focus group, he talked about his dad being a chemical engineer and then said, "the whole nature versus nurture." Well, that spawned a little side discussion, which I found insightful and worth sharing in the results. Peter and Jim agreed that it was option "c", in that it was a mix between extrinsic and intrinsic factors. Peter said,

> I would like to say that it is option c because I do think that I have an aptitude for science and I think certain aspects of my personality groom

> me to be more scientific, but at the same time, if my dad was a poet, I would probably love poetry and I believe that a lot of this argument is based on certain predispositions that we have and how they are influenced based on what we do and who we … like I know I would not be as much into science as I am, if I had not gone through GHP [governor's honors-students are nominated by teachers and then go through an interview process and the students selected spend several weeks at a camp where they work with a researcher and have intense classes], had I not done so. At the same time, I could be incredibly talented in science and not have done any serious lab work. (focus group)

On the other hand, Sam did not feel that he really had extrinsic influences, although he did mention watching history and discovery channels. Sam said his parents did not necessarily encourage him, but they bought him a telescope for his birthday because of his interest in astronomy. He said,

> I know it was something that was just me. I felt it, I wanted to do it. My dad was just --- and my mom is a nurse and it is nothing to do with any kind of science field, so they haven't really pushed me to do science, it was just me personally who wanted to do it. They know I like science. But it's not like I go around talking about it all the time. They don't really understand. They bought me a telescope for my birthday, but I can't find anything in it. And I guess the only outside influence would be learning about things that happen in science [through various sources of media]. (focus group)

Summary of Students' Experiences

Table 9 shows a summary of the experiences each participant described during the study. The students are loosely ordered in the table based on their understandings of the aspects of NOS previously discussed, with Jim having the most naïve understandings and Sam having the most informed understandings. Steve is not included in the table because he only participated in the VNOS-questionnaire and did not participate in the individual interview or the focus group. The VNOS-questionnaire was designed to answer the first research question, while the focus group and individual interviews were designed as

Table 9

Summary of Students' Experiences Contributing to their Interest in Science and Possible NOS Understandings

	Jim	Allen	Bill	Rich	Peter	Pam	Sam
Favorite Course	Math			History	Science	English	Science
Preferred science instruction	Lecture and group projects			Labs/ hands-on	Lecture	Lab/ hands-on	
Parent in science field	Yes	Yes	Yes	Yes			
Interest in science	Middle school teacher; Books				GHP and universal language	Elemen-tary teacher	television
Participa-tion in Science Olympiad	Fun; sister	Cool stuff	Cool stuff	Likes building events	Cool; people	friends	No other science clubs
Science Olympiad as indicator of scientists' work		Repe-titive, like their work	Various events equal various fields		No; time and boundaries		No; Too much to focus on

follow up to the VNOS-questionnaire and to understand how students' experiences formed their NOS understandings. Some students have more data than others based on participation in the individual interviews and/or focus groups.

The participants' favorite courses were indicators that preferences and view played a role in their understandings of NOS. Jim said his favorite subject was math because, "it was very clear cut. It's right or it's not" (individual interview) with physics being his favorite science course, for the same reason, "It's more math involved" (individual interview). Throughout data collection, Jim's absolutist view was evident. It was interesting to note that participants whose parents worked in a science related career overall had more naïve understandings of NOS. There were mixed feelings of how the participants' work preparing for the Science Olympiad competition resembled the work of scientists, but they all agreed that Science Olympiad was fun science extracurricular activity.

Student's Experiences and their NOS understandings

Tentative Nature of Science. Overall, the students had informed understandings of the tentative nature of science and they discussed experiences through the various stages of data collection that may have contributed to these informed understandings. Explanations for why they believed scientific knowledge will change in the future were given on the VNOS-HS questionnaire. The responses were based on content that was explicitly taught in science, such as a historical perspective of the atom.. Allen talked about the "geocentric model of Earth changing to the heliocentric model" (VNOS-HS questionnaire), a topic more than likely discussed in science and/or history courses. Pam wrote about the history of experiments leading to our understandings of the atom (VNOS-HS questionnaire).The students also talked about how the model of the atom changed with better technology. Overall the students agreed that better technology, new evidence or an unknown variable, and scientists varying perceptions contributed to the tentative nature of science. All of these ideas are generally explicitly taught in science books, as students study the Earth in middle school, and focus on atomic theory in chemistry.

Imagination and creativity. The participants as a whole had mixed understandings of the role of imagination and creativity in science. Pam thought you had to be able to visualize what you were trying to explain, even though you may not be able to see it. However, neither Pam nor the other participants connected imagination and creativity in explaining data, recognizing a problem, or in experimental design. They were mostly simplistic in their understandings of how scientists came to understand the atom and what we know about dinosaurs (questions on the VNOS-HS questionnaire). All participants, with the exception of Peter, thought that our current understandings of the atom and dinosaurs were determined from experiments and testing. They never discussed scientists' imagination and creativity in data analysis or even designing experiments to learn about what we cannot see. While all of the students mentioned enjoying hands-on and labs as a part of their science classes, Peter pointed out that procedures were given and they never had to design an experiment meet an objective. And Sam talked about many of the labs being verification of what was being covered in class, which takes away from creativity in determining results. On the other hand, Jim talked about the brainstorming, trial and error, and continual re-evaluation in preparing for the storm the castle event. The students were given parameters and objectives, but had to design and build a catapult to launch an object the farthest. The unknown variable was a counter weight they would be given at the competition, so the catapult design had to accommodate for a range of counterweights, which were given in the event sheet.

The empirical nature of science. The empirical nature of science is closely linked to students' ideas on the relationship between theories and laws. As previously discussed, the students predominantly thought that theories turn into laws and are then proven.

There was little discussion about observations. Sam enjoyed watching science programs, such as *Nova*, and while observations may be presented, students are overwhelmingly "fed" facts in science courses, particularly high level courses with large content requirements. As Sam said, "I think just because it was an AP class and we were getting ready for the AP test…there is so much to learn and we needed to make sure we knew it all" (individual interview). Sam mentioned that many labs in class are verification labs, which means collecting data and trying to make it fit with the concept being taught. Sam thought it was great to be able to see what they are learning in practice and specifically talked about electrochemistry examples. Being data driven in labs and fact driven to score well on tests, students do not think about observations, only specific questions they have to answer.

Inferences. Overall, the students had informed understandings of the role of inferences in science. The talked about how scientists have different opinions and interpret data differently. During the focus group, when asked about their interest in Science Olympiad, the students enjoyed being able to bounce ideas off each other, both in preparing for the events and while working in pairs during the competition. The experiences discussed that were directly linked to their understandings of inferences were from classes when they would get "off topic" and end up in a large discussion, such as the debate over stem cells. Bill and Peter's thoughts about the portrayal of science in the media had a different spin on inferences. Bill was concerned with scientists making biased inferences when they were under pressure, mainly monetary or grant renewal, to generate certain findings. Peter was concerned with how the American public would interpret findings reported on the news. He thought they needed to understand that one study does not mean absolute truth and that you really have to know more about the design to know the reliability of the study. Both Bill and Peter were concerned with society making decisions based on facts from the media, rather than making informed decisions based on experimental design and data.

Theories versus Laws. Overall, the understandings of theories and laws were naïve. There was not discussion of experiences that may have contributed to the naïve understandings of this aspect, other than the examples of theories and laws that they learned in science classes. On the VNOS-HS questionnaire, the students gave valid examples of theories and laws, but still thought theories turned into laws and could not explain the difference between the two.

Summary

The VNOS-HS questionnaire responses, individual interviews, and focus group showed evidences of Science Olympiad NOS understandings and experiences that may or may not have contributed to their NOS understandings. The students had informed understandings of the tentative nature of science and the role of inferences in science. However, the students did not have informed understandings of the role of imagination and creativity in science, the empirical nature of science, or an understanding of theories and laws. The students' experiences were classified as experiences related to school or experiences related to their interest in science, whether intrinsic or extrinsic. Explicit instructions on historical perspectives of the atom or the Earth's shape were discussed with students' understandings of the tentative nature of science. Verification labs and labs where procedures were given were discussed in reference to the role of imagination and creativity in science and the empirical nature of science. Collaboration in and preparing for and competing in Science Olympiad, along with “off-topic” class discussions were identified as contributing to students’ understandings of inferences and in the case of Science Olympiad, also contributed to understandings of the role of imagination and creativity. There were no experiences identified for the students’ understandings of theories and laws.

CHAPTER 5

CONCLUSIONS

In this study high achieving Science Olympiad students' understandings of nature of science were explored and the experiences creating their understandings were investigated. Science Olympiad students were chosen, not as an evaluation of Science Olympiad itself, but because the students who participate are interested in science and pursue that interest through an extracurricular science activity. In addition, I had access to that group of students because I worked with the Science Olympiad team. A Views of Nature of Science Questionnaire, designed for high school students, and follow-up interviews were primarily used to asses the students' understandings of NOS. A focus group allowed the students to discuss experiences in science classes, Science Olympiad, and at home that contributed to their understandings of NOS.

In this chapter, I will discuss the research findings from Chapter 4. The discussion will be centered on five assertions that emerged from the data presented. I will conclude the chapter with implications for science education research, recommendations for future research, and the major contributions of this study.

Major Assertions

Assertion 1: This group of Science Olympiad students had informed understandings of the tentative nature of science and inferences in experimental design and data analysis.

All of the students believed that scientific knowledge is subject to change. The students' believed changes in scientific knowledge were mainly due to better technology, experimentation, and new evidence. While all of the students thought scientific knowledge could change, there were only a few examples given. Peter talked about the original concept of the Earth being perceived as flat and Rich talked about the Greeks' idea of light coming from the eyes. The other students talked about how the model of the atom had changed or that science is an always changing field. This study is inline with other research in which students have an informed understanding of the tentative nature of science. Walker and Zeidler (2003) and Moss (2001) found that the high school students in their study had an excellent grasp of the tentative nature of science. As proponents of explicit NOS instruction, Walker and Zeidler felt it was important that NOS centered discussions should be conducted along with in-depth learning activities.

Often in high school labs, students are given "conclusion questions" to answer. These are intended to cause students to think about their data and try to make inferences about their data. Six of the eight students who participated clearly understood that scientific data had to be interpreted. In response to the question on dinosaurs on the VNOS, the students understood that scientists may interpret the same data differently. Taking it a step farther, the participants in this study felt very strongly about how science is portrayed in the media for the public to interpret. They felt that results could be manipulated by the language when given to the public via the media. Peter felt very strongly about how the media portrays an individual study as "the way it is" and the general public may take it for truth. Walker and Zeidler (2003) suggested that students should be "explicitly directed in what constitutes scientific data and evidence and how to formulate sound arguments" (pg. 26) when interpreting research findings.

Assertion 2: This group of Science Olympiad students did not have informed understandings of the role of human imagination and creativity, the empirical nature of science, and the difference in and relationship between theories and laws.

Thinking about how science classes are structured, students are commonly provided a lab sheet with a set procedure to follow and less commonly required to imitate the role of scientists in designing their own experiment. In this teacher-directed mode, students are so driven to finish the lab and get the “right answer” (Gunstone, et al., 1999; Shepardson, 1997), that they do not allow themselves the freedom to be more thoughtful and creative in explaining their results. It should not then be surprising that students have naïve understandings of the creative and imaginative nature of science. They simply do not take the time to think about the experimental design because it is handed to them. Sadly, Blosser (1988) pointed out that much of the research done on the role of labs found no statistical difference in achievement or attitude or even lab skills between experiment based lessons and lecture based lessons. Many of the participants in this study admitted they enjoyed lecture based classes. Kilcrease and Lucy (2002) found 11^{th} grade students to have naïve understandings of nature of science and suggested it was based on their lack of understandings of experiments. Schwartz, Lederman, and Thompson (2001) suggested that “doing science is certainly a start, but students need to reflect on what it is they are doing. They need to be engaged in discussions of why scientific investigations are designed in certain ways.” (p. 24)

Along those same lines, students may get so caught up in memorizing terms, rules, and formulas that they do not give credit to the importance of observations in science. Schools often end up control over creativity and tend to emphasize learning facts rather than developing understanding (Brickhouse, 1990). During lab time, students are often concerned about finishing the lab and getting the right answer and they do not pay attention to what is happening to the variables they are manipulating. In general students are very concerned about the numbers that go in the data table for a calculation, which is in line with their responses on the VNOS regarding the empirical nature of science. The participants overwhelmingly believed that while data may need to be interpreted, scientific knowledge is based on tangible facts and evidence, and must be proven, which is in line with Abd-El-Khalick (2004). With regard to students' concerns over filling in the data table correctly with the "right" numbers, German and Aram (1996) found that students often do not follow the given procedures correctly, and do not record their data correctly. For some the data actually made no sense and the students did not pick-up on that. Observations and common sense seem to go out the window! Is it because they have no ownership in the experimental design? Volkmann and Abell (2003) pointed out that for a lab to represent inquiry, as opposed to the cookbook labs generally used in science courses, student must be engaged with scientifically oriented questions and formulate evidence based explanations. The suggested that questions should guide the lab rather than a set of step by step directions.

The students had naïve understandings of theories and laws. Seven of the eight students said a theory that is proven irrefutable becomes a law. Three of the eight students at least understood that a theory is an explanation. The questionnaire asked for examples of theories and laws, and the students struggled with this. Some students did not even respond to that portion of the questionnaire. Examples for theories were the Big Bang, String Theory, Dark Matter, Theory of Relativity, and the Cell Theory. The Laws of Motion, Universal Gravitation, and the Law of conservation of Matter were given for examples of scientific laws. It was interesting that even the students that gave cell theory and laws of motion for examples still said that a theory becomes a law. In early science classes during elementary school and possibly middle school, the scientific method is taught in a very linear fashion with the two end points being theories then laws (Lederman, 1998). That idea must stick all through higher level science courses, and unless it is explicitly addressed by the teachers, there is no point where the misconception can correct itself. Abd-el-Khalick (2004) had similar findings with undergraduate and graduate college students. Out of 153 participants, 90% believed laws are certain because they are repeatedly proven and 97% believed in the hierarchical relationship between theories and laws, just as the high achieving high school Science Olympiad students thought.

Assertion 3: High level science classes and participation in Science Olympiad did not translate to varying levels of understandings of Nature of Science.

There did not seem to be a particular trend in experiences leading to the participants' varying levels of NOS understandings. The only data that stood out as directly linked to naïve understandings was Jim's absolutist view of science. Much of the previous NOS research showing naïve understandings of NOS was with the typical science student, who may not have had an interest in science (Abd-El-Khalick, 2002; Bell et al., 2002; Kilcrease and Lucy, 2002; Schwartz et al., 2001). It was interesting to find that this group of high achieving science students, with a myriad of AP science courses, and keen interest in science, expressed and evidenced by Science Olympiad participation, did not have overall informed NOS understandings. Bell et al. (2003) found that high achieving science students who participated in a science apprenticeship had little gains in their understandings of NOS and said that students do not learn science simply by doing science. McGee-Brown et al. (2003) thought Science Olympiad coaches felt strongly that students who participated gained a more real nature of science understandings. But one also commented, “I do not think many of them understand experimental design very well” (p. 9). Additionally, Abd-El-Khalick (2004) found that college students also had naïve understandings of NOS. Teachers may also disagree as to what NOS is, and research shows that many teachers have naïve understandings of NOS (Abd-El-Khalick, 2002; Bell et al., 2002; Clough, 1997; Dawkins & Dickerson, 2003; Griffiths & Barman, 1993; Kilcrease & Lucy, 2002; Mackay, 1971; Meichtry, 1995; Schwartz et al., 2001).

When students were asked what qualified a science teacher as being a good science teacher, they unanimously said a teacher who knows their field and does not teach straight from the book. It was interesting that many of the students enjoyed a more traditional classroom setting with the teacher “lecturing” but being flexible enough to explore students’ questions. They thought it was important for the teacher to make the class relevant to the real world and useful for all students, regardless of their future career plans. Aghadiuno (1995) found a slight predictor in that the attitude of the teacher toward science influences students’ attitude toward science. Likewise, Penick, Yager, and Bonnstetter (1986) found that exemplary science teachers feel enthusiasm for science teaching and feel well qualified to teach science, which was a major concern for the participants in this study. They wanted a teacher who knew what they were talking about and had experiences to tie the classroom to their world. Several students contributed their interest in science to a science teacher. Two students talked favorably about teachers in nurturing their interest in science. Pam had an elementary teacher that explained very well and planned many hands on activities. It’s important to note that Pam was the youngest in this group of students, the only female, and had the most informed understandings of NOS. Jim talked about a middle school teacher being influential in his interest in science.

Several students commented that they enjoyed labs and hands-on activities during science classes. Rich commented that in labs you get to apply what you learned and that it “puts what you are doing and its importance into perspective” (individual interview). However, Peter pointed out that students often have trouble following the directions or procedure for a lab, which leads to an interesting point. The students overwhelmingly had naïve understandings in the role of imagination and creativity in experimental design, which may be partially attributed to their lab experiences. If they are given a procedure for a lab, then they are not learning what is involved in thinking about how to investigate a problem. Peter’s statement about students having trouble following the procedure leads me to believe that students get caught up in the directions and do not think about the design and the process. This will be further discussed in reference to “cook book labs” in the implications.

While interest in science, shown by participation in Science Olympiad, may not have been a clear indicator of more informed understandings of NOS, many students commented that they enjoyed participating and working with their friends. They enjoyed working with other students who had the same interests and friendships were established based on their common love of science. Abernathy and Vineyard (2001) similarly found that Science Olympiad students enjoyed being part of a team and thought the experience prepared them for their future and ranked working with friends as one of the benefits. In addition, the building events and collaborative work in preparation for and during the competition, created a mixed understanding of the role of imagination and creativity in science.

The students did not feel like Science Olympiad necessarily reflected the work of scientists. Peter was candid in his response that study events usually only required cramming a few days before the competition, where he thought a scientist would be thorough in research. He also commented that Science Olympiad has set parameters and guidelines. If there was an event with an unknown, the students knew in advance to possibilities for the unknown, where anything was fare game for a scientist with an unknown. Sam commented that scientists are generally specialized in their area of research and would not be expected to be experts on astronomy and glaciers, like two of the events in which he competed.

While this study did not investigate implicit versus explicit NOS instruction, the common factor between experiences and more informed NOS understandings came from those experiences that were explicitly taught. The tentative nature of science and the role of inferences were two of the five aspects of NOS investigated in this study in which the students overall had informed NOS understandings. They talked about scientific knowledge being tentative because of how ideas of the atom have changed and how new technologies, or new data can change previous ideas, all things explicitly discussed in science textbooks and as part of the science curriculum. Examples for the role of inferences in science all included explicit example of differing ideas and opinions, both from scientists studied in class and from classmates during discussions and in interpreting lab data. These two aspects of NOS being explicitly taught and leading to more informed understandings of NOS is consistent with findings from Larson, 2000; Lederman et al., 2003; MacDonald, 1996; Schwartz et al., 2001; Stein & McRobbie, 1997.

Assertion 4: Experiences outside of school may not directly contribute to students' understandings of NOS, but the experiences shaped their interest in and ideas about science.

Interestingly, the only piece of data consistently present in students with more naïve understandings was the fact that they all said their parents were in a science related field. The students with more informed understandings said they did not have a parent in a science related field. Because there was no other research supporting that finding, it may simply be coincidence. Other than parents' careers, there was no one particular experience outside of school that was linked directly to naïve or informed understandings of NOS, although several interesting topics emerged. Students talked about their parents' influences, reasons whey they are interested in science, and whether their interest in science is intrinsic or extrinsic.

Five students had parents in a science field, such as chemical engineering, electrical engineering, microbiology, and physics. These students did not think they were interested in science solely because of their parents' careers, but because it was an intrinsic interest that their parents may have then helped nurture. The students mainly thought their parents contributed to their interest in science by giving detailed explanations to questions about how things work and by making books readily available. The main types of books mentioned were on topics such as dinosaurs, animals, and space, and were read to students during their preschool years. Sam's parents, who he qualified as not working in a science field (although his mom is a nurse), supported his interest in space by giving him a telescope for his birthday, although he admits he needs help learning how to use it! Jim had an older sister who helped to get him involved in Science Olympiad.

All of the students expressed an interest in watching the Discovery Channel, the History Channel and NOVA specials. From an early age they wanted to know how things worked, and that is where the conversation switched from their interest in science being intrinsic or extrinsic. Most of the students chose “option c” as their interest in science being a mix of intrinsic and extrinsic factors. The students agreed that they had to have an aptitude for science and several said they always enjoyed learning how things work. At the same time, they credited extrinsic factors, such as going to Governor’s Honors, television programs (although stated that their initial interest in the programs was intrinsic), and parents being in a science related field. Again, some thought their parents’ interests influenced their interest and they classified that as extrinsic. Others thought they may have more of a predisposition to science because of their parents, so they classified parent influence as intrinsic.

Implications and Recommendations

Science Classrooms

One of the findings in this study is that high level science courses do not necessarily promote students’ understandings of NOS. Similar findings came from research with general science courses (Khishfe & Abd-El-Khalick, 2002; Moss, 2001; Schwartz et al., 2001). In talking to the students during the interviews, they mentioned that there was a certain amount of material they had to cover for the AP tests in a certain time frame and that they were often bombarded with information. While probing students to learn about their understandings of the role of human imagination and creativity, I was surprised to find their lack of understanding of the role of imagination and creativity in experiments. The students thought that yes, it took imagination to foresee what society may want as creature comforts or what may benefit society, but they did not see a connection to imagination and creativity in experiments, nor did they see the link to imagination and creativity in interpreting data. The discussion eventually boiled down to the fact that they were handed a procedure for a lab and they would basically be verifying something they learned in class. One underlying assumption in science classes is that students will come to learn science simply by doing science, and as Lederman (1998) put it, “such an expectation is equivalent to assuming that individuals will come to understand the mechanism of breathing simply by breathing” (p. 9). Volkmann and Abell (2003) suggested moving from cookbook labs to inquiry, where questions guide the inquiry. They defined cookbook labs as procedure-oriented and preceded by a lecture. Moving to more inquiry oriented labs means that learners are engaged with scientifically oriented questions, learners give priority to evidence and formulate evidence based explanations, the merit of their explanations are compared among other groups, and the lecture or discussion then follows the lab. However, if there is no discussion about how what the students did in the lab is similar or different to NOS, even with more inquiry activities, then students will still not make the connection. In the case of AP courses where there are set labs students must participate in, the creativity and imagination in experimental design can be explicitly taught to students by having them reflect on what they did procedurally and why it was important, and how it contributed to the knowledge learned in the lab. Lederman (2004) suggested that teachers may have misunderstandings of NOS and furthermore that they may not know how to create inquiry based labs. He suggested professional development in these areas and said “NOS and scientific inquiry are as much an aspect of subject matter as the reactions of photosynthesis, atomic structure, plate tectonics, or pH” (p. 302). The *National Science Education Standards* (NRC, 1996) include nature of science as a content standard. And, The *Georgia Performance Standards (*Georgia Department of Education, *2006)* explicitly name nature of science as a co-requisite for characteristics of science at all levels and implicitly require nature of science as a content standard in the descriptions of the standards.

On a traditional class schedule with the class length being approximately 55 minutes, it can be difficult to complete a lab, given time to take attendance, introduce the lab, clean-up and then have discussion time, not to mention a time for students to think about their data and what the data means. However, a plethora of research (Khishfe & Abd-El-Khalick, 2002; Larson, 2000; Lederman, 2004; Lederman et al., 2003; MacDonald, 1996; Schwartz et al., 2001; Stein & McRobbie, 1997) says explicit instruction of NOS is necessary. The time for discussion after a lab is essential and students should communicate their findings and support them with data. In addition to teachers having informed understandings of NOS and creating relevant inquiry activities, teachers must explicitly teach NOS before, during, and after labs and include explicit NOS instruction during class discussions.

Lederman (2004) felt strongly about the relevancy of the subject matter included in K-12 curriculum as it relates to the quality of pre-college and undergraduate science education. Are students able to apply what they are learning in school science classes to make informed decisions regarding personal and societal information? That is the goal of a scientifically literate society. The Science Olympiad students believed a good science teacher could make what they were learning in class relevant to their lives. They also thought a good science teacher would try to engage all students, even the students who were only in the class because it was required for graduation.

Teacher Education

A nature of science course should be built into every teacher education program, or at a minimum, NOS standards need to met by science teacher education programs. To effectively teach nature of science, teachers must have informed understandings of NOS. The course should have a pre and post NOS assessment with clear explicit NOS instruction throughout they course. They must also be exposed to the research to see that explicit NOS instruction is the only way students are going to have informed understandings of NOS (Khishfe & Abd-El-Khalick, 2002; Larson, 2000; Lederman et al., 2003; MacDonald, 1996; Schwartz et al., 2001; Stein & McRobbie, 1997). In addition, this course should not only emphasize the need for explicit NOS instruction in the classroom, the teacher educators should learn numerous methods of how to actually teach NOS in the classroom for the various disciplines.

In addition to a nature of science course, preservice teachers should not only learn general classroom management techniques, they need to go into the classroom with clear ideas on classroom management during lab time. How will supplies be dispensed? How do you ensure everyone has a role? How do you build in time for a good explicit discussion after the lab, without having the students rushed and only concerned with finishing, rather than thinking? How do you ensure a safe environment? Those are all basic issues that have to be considered before a lab and before effective NOS learning can really take place. In teacher preparation programs, students should develop inquiry-oriented labs that are manageable in the classroom and in line with the curriculum for the various disciplines.

At the local level, teachers must be provided with time for collaboration and should receive content specific professional development. Some teachers end-up teaching unfamiliar content and need that support. Other teachers need fresh ideas. And, many teachers may have no idea what NOS is! Professional development does not mean the county spends thousands of dollars bringing in a speaker. With a little instruction, possibly from the science education unit at a local college, the teachers can collaboratively design lessons and share them. Schuster and Carlsen (2006) found that treating the teachers as professionals during the professional development had a positive impact on their attitudes toward learning about nature of science. When the professional development instructors recognized the teachers' unique knowledge and skills and used them during the professional development, their knowledge and skills were further developed. An interesting piece of the study was that middle school science teachers were more likely than high school teachers to gain more informed understandings of certain aspects of NOS.

Suggestions for Further Research

An area for further research in this study would be to discern whether specific events in Science Olympiad contribute to more informed understandings of NOS. For instance, there are study events, events that involve designing an experiment to reach a desired end, and building or engineering events which are often times trial and error.

Every year after the competition, the students talk about what they want to do the following year to better prepare or compete in their events.

Another area for future study would be focusing on elementary students' understandings of NOS. The sophomore in the study who spoke of her elementary teacher as being influential in her interest in science because of the great explanations and fun hands-on activities the teacher planned may be of interest. Are students' understandings of NOS shaped as their interest in science is formed? While students at that age may not grasp some of the terms used, their imaginations, creative thinking, openness to new ideas, and excitement about learning may be the perfect time to influence their understandings of NOS. If elementary students' understandings of NOS are studied, it would also be necessary to note elementary teachers' understandings of NOS.

An addition area for further study is a different line of research, but needed as we optimize educational opportunities that will allow graduates of public school to thrive in the global community so strongly influenced by science and technology. During the interviews, the students talked about their interest in science, and for all of the students it started at an early age. What are the best ways to stimulate and sustain our students' interest in science?

Major Contributions of this Study

As mentioned throughout this chapter, this study has confirmed many earlier research findings by others in this field. No matter the ability level, or the students' interest in science, high school students tend to have naïve understandings of NOS, and some studies showed the same for college students and teachers. However, in this study, one of the research questions explored experiences that contributed to the students' understandings of NOS. Experiments where the procedures are given tend to contribute to these naïve understandings. Another interesting point is that the student with the most naïve understandings of NOS mostly enjoyed math because it was described as being either right or wrong. He was very absolutist in his views. The present study verifies what other research found, but supports the need for more qualitative research to learn other factors that contribute to students' understandings of NOS. Much of the research that gives clues as to why the students have naïve understandings of NOS is based on a pre-post NOS assessment with a specific treatment involved. While that gives researchers a great starting point in identifying red flags in NOS education, there is value in speaking with students about there experiences. For instance, this study gives the impression that conceptions of NOS are developed far before high school as students develop an interest in science and have eight years of science in school before they even reach high school. The plethora of NOS research may not be reaching k-12 science teachers, as evidenced by the naïve understandings of NOS that students predominantly hold. The best and easiest place to address that is in teacher education programs, for all grades.

Summary

We are in a technological and science driven global society and it is more important than ever that students are scientifically literate. The purpose of this study was to examine one aspect of scientific literacy, nature of science, in a group of high achieving students who were passionate about science. Students need to understand how research is conducted and conclusions are reached from data so they can better make informed decisions about medical treatments, pesticides, fertilizers, cleaning products, and political issues. The students in this study pointed out that the media is able to twist the facts according to how they want it portrayed, and they felt it was important to discern what the media is saying and learn how to investigate further if it is research of interest. Abd-El-Khalick (2004) thought “scientifically literate students who, as future citizens, are capable of meaningfully engaging in public discourse about science and making informed decisions regarding science-related personal and societal issues” (p. 420). Also summarize your findings here.

The students in this study took high level science courses and they were interested in Science, as evidenced by their participation in Science Olympiad as well as in their responses during the individual interviews and focus group. Overall, the students had relatively informed understandings of the tentative nature of science and the role of inferences in science, while overall the students had naïve understandings of the role of human imagination and creativity, the empirical nature of science, and the difference between theories and laws. The informed understandings were linked to experiences that were explicitly taught or discussed. Students’ naïve understandings may stem implicit experiences, “cook book” labs, and possibly the teachers’ naïve understandings of NOS.

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APPENDIXES

Appendix A

Views of Nature of Science – High School (VNOS –HS) Questionnaire

1. What do you think "science" is?
2. What do you think makes science different from other topics you might study (like math, English, or religion)?
3. Do you think that the scientific knowledge you learn about in school and find in books (facts, laws, and theories) will change in the future?
   Please Circle one: Yes [Please answer part (a) if you circled "yes"]
   No [Please answer part (b) if you circled "yes"]
   (a) If you circled "yes," please explain why you think scientific knowledge will change in the future.
   (b) If you circled "no," please explain why you think scientific knowledge will not change in the future.

4. (a) What is a scientific theory?
   (c) Give an example of a scientific theory.
5. (a) What is a scientific law?
   (b) Give an example of a scientific law.
6. All matter is made up of atoms. Atoms are very small: even a single cell is made up of millions and millions of atoms, yet scientists have never actually seen an atom. The atom is shown as having a nucleus in the center with electrons moving around it.
   [include figure from book]
   Scientists hold **different** views about this representation of the atom. Some scientists believe that this is a true and exact representation of the atom. Other scientists believe that this representation is just a model since we can not know whether this representation of the atoms is true and exact.
   (a) What is your view on this issue? Why do you hold this view?
   (b) How do you think scientists determined the representation of the atom shown above?
7. Scientists agree that about 65 million years ago the dinosaurs became extinct. However, scientists **disagree** about what caused this extinction. Some scientists believe that massive and violent volcanic eruptions were responsible for the extinction of the dinosaurs. Other scientists believe that a huge comet (or asteroid) hit the Earth 65 million years ago and led to a series of events that caused extinction.
   (a) Have you heard about this issue before? Please circle one: Yes No

(b) Does it surprise you that scientists disagree about the cause of the extinction of the dinosaurs? Please explain your answer.

(c) It is known that all the above scientists have access to and use the **same** set of data. How could it be that these scientists use the **same** data and still arrive at different conclusions regarding the cause of the extinction of the dinosaurs?

(d) How might this controversy be resolved?

APPENDIX B

Semi-structured Individual Interview Questions

Background Questions

1. What science course are you currently taking?
2. What is your favorite subject? Why?
3. What is your favorite science topic? Why?
4. What is your least favorite science topic? Why?
5. On a scale of 1 to 5 with 5 being the highest, how do you feel about science classes? Why? Describe some experiences.
6. How would you describe a good science teacher?
7. Why did you decide to participate in Science Olympiad?
8. What did you learn while preparing for Science Olympiad events and from the various competitions.
9. What experiences led to your interest in science?

Follow-Up VNOS-HS Questionnaire Questions

-Participants will be specifically asked about inconsistencies between responses on various items on the questionnaire.
-Participants may be asked for further examples or explanations to responses.

Focus Group Questions

1. Why did you decide to participate in Science Olympiad?
2.Did preparation for any of the events have an impact on how you think of scientists or even science in general? Please explain.
3. What experiences led to your interest in science?
4. What was your favorite science class?
5. Can portrayals of science in the media be taken as reliable? Give examples.
6.Questions based on VNOS-HS responses and the first individual interview. Clarify inconsistencies between participants; probe for further examples.

APPENDIX C

Guidelines to Analyze VNOS-HS Questionnaire Responses.
-Modified from Lederman et al. (2002)

NOS Aspect	Naïve Views	Informed Views
Tentative NOS Questions 1,2,3,6	If you get the same result over and over again, then you become sure that your theory is a proven	Everything in science is subject to change with new evidence and interpretation of that evidence. New evidence may call a theory or law into questions, and possibly cause modification
Human Imagination and Creativity Questions 1,2, 6, 7	A scientist only uses imagination in data collection, but there is no creativity after data collection because the scientist has to be objective.	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.
Empirical Questions 1,2,6,7	Science is concerned with facts. We use observed facts to prove that theories are true	Much of the development of scientific knowledge depends on observations. I don't believe the goal of science is the accumulation of facts. Rather, science involves abstraction.
Inferences Questions 1,2,6,7	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.	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.
Relationship and differences between theories and laws Questions 1,2,4,5	Laws started as theories and eventually became laws after repeated proven demonstration	A scientific law describes quantitative relationships. Scientific theories are made of concepts that are in accordance with common observation or go beyond and propose new explanatory models for the world.