HOW THE COURSE THE "MEANING AND NATURE OF SCIENCE" INFLUENCES HOLISTIC VIEWS OF SCIENCE ACROSS GENDERS

A Thesis
by
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Abstract

HOW THE COURSE “THE MEANING AND NATURE OF SCIENCE” INFLUENCE THE HOLISTIC UNDERSTANDING OF SCIENCE ACROSS GENDERS?

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Throughout their college career, students take many courses that shape their life. The course “The Meaning and Nature of Science” taught students, at Appalachian State University, the meaning and essence of the nature of science (NOS). Learning the NOS can shape people’s understanding of everyday topics, such as weather forecasts, politics, and nutrition. The purpose of this study was to see how this course influenced holistic understanding of science in both males and females and to examine the differences in this understanding, if any, between the genders. This course was taught during the Fall 2011 and Fall 2012 semesters. The students, overall, were an even mix of males and females. Students came from a variety of majors ranging from biology to education to music. At the beginning of the semester, the students were asked to respond to the Views on Science-Technology-Society (VOSTS) questionnaire, in order to assess what their understandings were with regard to the NOS. The VOSTS questionnaire was administered again at the end of the semester to gauge differences, if any, that the course made on student understanding of the NOS. A difference in understanding, by genders, from the pre- to post-course questionnaire responses was as certained by *t*-test analysis. Another point of testing the different conceptions on the mid-term and final by gender were the scores on Statements of Critical

Significance (SOCS) written by students, mid-course and at end of the course, also evaluated through *t*-test analysis. The sign test was used to distinguish differences, if any, on the VOSTS survey of all students. The Mann-Whitney Test was used to distinguish gender differences, if any, on the VOSTS survey. Qualitatively, the mid-term and final examination responses were analyzed for understanding of the nine core components of the NOS proposed by McComas in 2004, that the average American should understand. Qualitative analyses of in-class discussions and mid-term and final examination responses, was also conducted during both semesters of this course. Quantitative analysis results indicate there was no statistically significant course impact on the holistic understanding of science. With respect to gender, there were no statistically significant differences in male and female understanding. However, qualitative analysis does suggest a more complete student understanding of the NOS between the mid-term and final. Suggestions for further research are discussed.

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Introduction

It is impossible to ignore the significance of science in today's society. Newspapers, television shows, and magazines are laden with hot-button issues that connect with science: stem cell research; discoveries of new species; ozone degradation; climate change; and prevalence of uncommon diseases. With the rising frequency of these types of stories, it is important for those who read these stories to be well informed about science. Science touches all circles of life, and those who are informed can make sense of everyday scientific issues.

Informing people about science can be accomplished by educating them on the nature of science (NOS). The nature of science is defined as the ideas people hold about science, not their knowledge of scientific principles and theories (Ryder, Leach, & Driver, 1999). Being well informed about the NOS, can be constituted as being scientifically literate or as "one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands the key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes" (Ahlgren & Halberg, 1990, p. ix). It is important to be scientifically literate in several fields, as a consumer, a political leader, a teacher, and as a student. Therefore, understanding the NOS is invaluable. More scientifically literate people are needed in order to make more informed decisions about issues and those who make the rules and regulations regarding these issues. The benefits of understanding the NOS are endless as scientific literacy is priceless in many realms of society (Lederman, 1999; NRC, 1996). Students benefit from understanding the NOS as they realize common misconceptions about science and the features of the scientific methodology that permeate various scientific disciplines. The NOS helps teachers as it influences their teaching styles and how basic scientific principles are presented. Also, armed with a more accurate understanding of NOS, teachers can judge students' test responses more critically and accurately.

There is a gap in the general public's knowledge as to why and how understanding the nature of science is important (Bemis, Leichtman, & Pillemer, 2010). My study aims to investigate the differences between males and females with regard to the influence and benefits they derive from the NOS. It has been shown by previous studies that males are more analytical and quantitative while females tend to be more qualitative (Feniger, 2011). Learning how males and females respond to the NOS could possibly alter the way they are taught.

Looking at the NOS, especially through a historical lens, allows one to see science as an evolutionary process (Abd-El-Khalick, & Lederman, 2000). Through the history of science, the processes of major scientific contributions are observed as a painstaking and revisable practice. The NOS opens a methodology of invention of not only scientific instruments, but scientific processes as well (Erikson, 2010). With a comprehensive conceptual study in the NOS, students, teachers, and future teachers, all stand to benefit.

Investigating the understanding of the NOS by gender allows for further understanding of how the NOS is perceived and taught. Males and females develop understanding of various subjects differently (Luders, Gaser, Narr, & Toga, 2009). Why should the NOS be different? Looking at differences between genders in understanding the NOS, will allow for a more complete understanding of what role gender plays in the accurate understanding of the NOS.

One goal of an accurate understanding of the NOS is developing more scientifically literate people. Scientific literacy is important for many reasons (DeBoer, 2000; Laugksch, 2000; Shen, 1975). Papers, news shows, and magazines are peppered with fanatical science stories and outrageous scientific claims, such as human cloning, impending apocalypse via asteroid, and crypto-zoological ideas. If a person has no scientific knowledge or a basis of general understanding of the NOS, how can correct assumptions be made about these claims and discoveries? Understanding the NOS has nothing to do with being able to correctly identify the chemical products of complex natural processes, such as photosynthesis, rather it is a guide to fundamental concepts of science, or what science is and what it is not (Aikenhead, Fleming, & Ryan, 1987). With increased scientific literacy, misconceptions and fanaticism can be disregarded by applying true principles of science. Scientific literacy is also important because scientific issues are debated regularly in the political arena. Knowing what science is and what it is not, basically the core of the NOS, allows people to make an informed decision about popular science issues and who they choose to represent them and their stance on scientific issues.

With more scientifically literate individuals more informed decisions can be made about scientifically controversial issues (Cross & Price, 1998). NOS related scientific literacy, allows for less debate for commonly accepted theories in the scientific community. If people understand the process of coming to a theory or a resolution of a hypothesis, they would be less likely to question the conclusions resulting from testing the hypothesis (Blanco & Niaz, 1997; Edmondson & Novak, 1993). The NOS emphasizes the repeated testing of ideas through many discoveries and scientifically held certainties, such as the discovery that the world is not flat (Gribbin, 2002). With increased scientific literacy, people can more accurately express and debate their stances on scientific issues in any given arena, including political, academic, religious, or societal, with certainty in the facts of science and the NOS.

Many people will benefit from a holistic study of the NOS. The general public benefits from the NOS, as do students, teachers, and pre-service teaching candidates (Dass, 2005). Students also benefit from learning the NOS. As the NOS touches many other courses, such as philosophy, math, technology, and particularly history, the NOS helps to understand the methodologies and theories of these disciplines (Ahlgren & Halberg, 1990). Students learn the scientific method in almost every science class they take. They learn set protocols, theorems, and laws for chemistry, physics, and other science-based subjects. These protocols are more commonly referred to as the scientific method. The developments of the scientific method are a key component to any science-based subject. The NOS, especially from a historical perspective, evaluates the scientific method and its development over time, thus leading to a better, more accurate understanding of what the scientific method entails (Brush, 1995).

Investigation of students' accurate understanding of the NOS will reveal long-held misconceptions about science (Dagher & Boujaode, 2005; Meyling, 1997). Accurate knowledge of the NOS allows students to learn what science is and what tenets of science are accurate. The understanding of NOS enables students to transform their misconceptions into valid ideas (Dagher & Boujaode, 2005). An instrument for determining these misconceptions versus valid ideas is the Views on Science-Technology-Society (VOSTS) questionnaire. This questionnaire gauges students' ideas about science. Through transforming these misconceptions about these ideas, students can be better informed, therefore student understanding regarding methodology in various scientific disciplines improves (Dobzhansky, 1973). Also, if the NOS is taught through a historical perspective, students can gain a more complete historical timeline for scientifically significant discoveries.

Teachers can also benefit from a greater understanding of the NOS. Teachers bring their own perceptions and opinions into the classroom. These perceptions influence teaching style (Brickhouse, 1990; Tsai, 2002); however, if some of the perceptions they hold about science are incorrect, they teach students incorrectly, therefore it is important that teachers understand the NOS (Lederman & Druger, 1985). If teachers are accurately informed on the NOS, they can more correctly teach their students (Abd-El-Khalick & Lederman, 2000). Teacher's education on the NOS influences how and what they teach, as well as how it is presented (Lord & Marino, 1993). They can also more effectively teach methodology of many subjects as this is a core component of science and other disciplines. Also, if teachers' understanding is accurate about what the NOS is, they can more accurately guide their students to the correct perspectives of science (Abd-El-Khalick & BouJaoude, 1997).

Gender is an unexplored facet of the understanding of the NOS. Males and females learn differently. Studies have shown men are more analytical and quantitatively geared, so it is to be expected that men would be better with science-based disciplines (Plaisted, Bell, & Mackintosh, 2011). Females, on the other hand, show superior literary skills, and since the NOS tends to be qualitative in nature, it could be argued that females will have a better perspective on the NOS (Maccoby & Jacklin, 1972). Opinions about gender learning differences have both been confirmed and also discounted for many years and are highly questioned theories (Nankervis, 2010). Through the “Meaning and Nature of Science” course, gender learning differences may present themselves. Gender plays a role in subjects taken, skills learned, and overall academic achievement (Maccoby & Jacklin, 1972). Learning how males and females interpret and gain accurate perspectives of the NOS could lead to major breakthroughs in science education. Future benefits could include different ways males and females are taught. More females are coming into the scientific field (Baumann, Hambrusch, & Neville, 2011), as well as in science teaching. For example, according to the Watauga County Schools website (2011), in Watauga County, female science teachers outnumber male teachers 52% to 48% respectively. With more females in the field, an appropriate education for them in the NOS is imperative.

An accurate understanding of NOS can also influence holistic ideas, views, and approaches to science. Significant insights on this influence can be gleaned through observing outcomes of the GS 4404 course (The Meaning and Nature of Science), taught at Appalachian State University. GS 4404 aims to teach the transformations/progression of the scientific method and highlight important discoveries and how society benefitted from these discoveries. This course was offered to future science teachers as the benefits to them would be great; students in the university honors program also participated. An appropriate understanding of the NOS can lead to more accurate views of scientific history and how chief discoveries and inventions, such as the microscope, were made. The NOS helps one to understand what and how ideas are accepted in science. An accurate understanding of the NOS helps develop a more thorough knowledge base in most science related areas, such as physics, technology, engineering, and math (Lynch & Nowosenetz, 2009).

The NOS influences holistic science views and ideas. Significant insights on this influence may be developed by observing outcomes from GS 4404 course description:

> The goal of this course is to help students develop a sound understanding of the nature of science, the process of scientific inquiry, and the reciprocal relationship between science and society through a critical examination of the history of science since the Renaissance (Appalachian State University, 2011).

This course highlights the transformations the scientific method has gone through since the Renaissance. The course also focuses on significant discoveries and the investigations on the way to these discoveries. Through these discoveries, society has benefitted. This course is offered to future teachers with the hope that through learning NOS more accurately they can become better and more effective science teachers.

Through this course the history of science is closely observed in concordance with the NOS. The history of science is important because learning about how discoveries were made and what lead inventors in their thought process; helps understand what produced important refinements in the scientific method. By learning about the revisions of the scientific method, the students, or future teachers, gain a better understanding of what the scientific method is thus reflecting back on the NOS.

GS 4404 also draws attention to the misconceptions about what science is and is not. Students' misconceptions are determined by VOSTS questionnaire. The questionnaire reveals the level of their held perceptions as desirable (D), acceptable (A) or undesirable (U) (Aikenhead, Fleming, & Ryan, 1987; Bradford, Rubba, & Harkness 1995; Dass, 2005).

Though there is not necessarily a right or wrong answer for the items on this questionnaire, the favorable answers provided have varying degrees of accepted views.

The NOS is an integral part of many facets of life (Marra & Palmer, 2005). It helps people become more informed and scientifically literate, which is invaluable, as these people will control the political climate by who they vote into various offices. The accuracy of the understanding of the NOS influences wide-held views and ideas about science. The NOS is possibly understood differently by males and females. The GS 4404 course emphasizes the importance of history in understanding the NOS. This study is designed to investigate whether or not male and female students develop this understanding differently. So this research will 1) indicate if males and females gain knowledge of the NOS differently, and 2) if GS4404 changes students' holistic view of the NOS. It is my hypothesis that females will have a more complete understanding of the NOS, and perform better on the VOSTS survey and the mid-term and final in this course due to its qualitative nature. The accurate understanding of the NOS will be of great benefit to all involved and touched by the world of science.

Methodology

This study was conducted in the Biology Department's General Science 4404, also listed as Honors 3515, lecture course at Appalachian State University, during the fall 2011 and the fall 2012 semesters. This course is a requirement to attain a B.S. in Biology, Secondary Education. For Honors students this class was offered as a junior/senior seminar course. During each semester, both the GS 4404 and HON 3515 were taught as one joint class. This course concentrated on the history of science and the characteristics of the NOS. Permission to conduct research with human subjects was granted by the IRB on August 24, 2011. Copies of the Informed Consent for students are attached as Appendices A and B.

Participants

Instructor

During both semesters, this course was taught by Pradeep Maxwell Dass, who holds a Doctoral degree in Science Education with a concentration in the History & Philosophy of Science. He has 30 years of teaching experience.

Students

In the fall of 2011, 16 students enrolled in the course. Ten of them were listed as GS 4404; the other six were listed as HON 3515. In the fall of 2011 there were eight males and eight females enrolled. In the fall of 2012, six total students enrolled in the course. Five of them were listed as GS 4404; and one HON 3515 student. In the fall of 2012 there were four male and 2 females enrolled. For higher statistical analysis power, all the data for the two semesters were combined, for a total of 22 students, 12 males and 10 females. During both semesters, the class met on Tuesdays and Thursdays for an hour and a half from 2:00pm until 3:30pm. The breakdown of student enrollment is presented in Table 1.

Table 1
Student enrollment and gender categorization (M=males and F=females).

Semester	*Enrolled Total* *M/F*
Fall 2011	**16** 8/8
Fall 2012	**6** 4/2
Total	**22** 12/10

Quantitative Data Collection and Analyses

The Mid-Term and Final Exams

It should be noted that all statistical analyses were conducted using IBM SPSS Statistics 20. To assess students' understanding of the NOS, their mid-term and final exam grades were analyzed. The instructor posed the following question to students halfway through the term and again at completion of the term:

As we progress from Renaissance to the Enlightenment and beyond, we see the rise of the so called "scientific method" in investigating various aspects of the universe.

1. *Articulate your understanding of the chief characteristics of the scientific method as evident in the historical examples encountered in this course.*
2. *Then explain, using appropriate examples and arguments, how and why it is possible (or not possible) that knowledge gained through scientific investigations, correctly employing the scientific method, may still change in the future.*
3. *Finally, discuss what makes scientific knowledge, which may be considered "tentative" in many respects, reliable to make sense of the universe from astronomical all the way to subatomic levels.*

In order for students to answer this question, they were to compose five **S**tatements **O**f **C**ritical **S**ignificance, or SOCS. SOCS were grouped into three types: $SOCS_{A,}$ $SOCS_B$, and $SOCS_{C.}$ $SOCS_A$ were statements representing substantive content of a specific reading.

These types of statements expressed one coherent idea (not a collection of ideas) which capture the substantive content (essence or spirit) of the specific reading. $SOCS_B$ were statements regarding the nature of science as it emerged through various readings; the relationships (comparisons, contrasts, similarities, etc.) between examples, peoples, and events presented in different readings were highlighted in this type of SOCS. $SOCS_C$ were based on implications. $SOCS_C$ statements represented action-level thinking on the part of the students once they began to understand the NOS. To answer their mid-term and final exam question, the students were allowed to use any combination of the different types of SOCS. The SOCS were graded on a scale from 1 to 5, with 5 being the top score. The comparison of scores on the mid-term and final exams allowed for interpretation of course impact, if any. Unfortunately, there were no examples of SOCS collected at the beginning of the course to identify any student progress during the first half of the course.

First, a sign test was conducted in order to determine if there was an overall course impact on all students who enrolled in the course. Second, the mid-term and final exam scores were analyzed by a two-sample *t*-test in order to determine any possible gender differences in course impact.

The Questionnaire

The "Views on Science-Technology-Society" (VOSTS) questionnaire (Appendix C) was given as pre- and post-course survey to quantify course impact. This questionnaire was developed (Aikenhead, Fleming, & Ryan, 1987) and has been used in both high school and colleges to gauge perceptions of the NOS (Bradford, Rubba, & Harkness, 1995; Dass, 2005). The questionnaire consists of 118 multiple-choice questions that are designed to test different concepts; however researchers may select questions that suit individual research purposes (Aikenhead, Fleming, & Ryan, 1987). For this particular study, I selected 21 questions (Figure 1) that included facets of the nine core components of the NOS that the average American should understand (McComas, 2004). The pre-course questionnaire was given out during the first weeks of fall semesters in mid-August 2011 and 2012. Students had approximately a week to complete and return the questionnaire (Appendix B).

In addition to the 21 selected questions, the VOSTS also contained 28 other questions that were not statistically analyzed due to their lack of similarity to the nine core tenets of the NOS (McComas, 2004). The post-course questionnaire was administered during the last week of the class and again students had approximately a week to take it and return it. The purpose of administering the questionnaire twice for this particular study is to evaluate overall course impact and course impact by gender.

Aspects of the nature of scientific activity and knowledge (constitutive aspects internal to science):

1. Defining science is difficult because science is complex and does many things. But MAINLY science is:
2. Scientific observations made by competent scientists will usually be different if the scientists believe different theories.
3. Many scientific models used in research laboratories (such as the model of heat, the neuron, DNA, or the atom) are copies of reality.
4. When scientists classify something (for example, a plant according to its species, an element an element according to the periodic table, energy according to its source, or a star according to its size), scientists are classifying nature according to *the way nature really is*; any other way would simply be wrong.
5. Even when scientific investigations are done correctly, the knowledge that scientists discover from those investigations may change in the future.
6. When scientists investigate, it is said that they follow the scientific method. The scientific method is:
7. The best scientists are those who follow the steps of the scientific method.
8. For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists *discover* scientific LAWS. Others think that scientists *invent* them. What do you think?
9. For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists *discover* scientific HYPOTHESES. Others think that scientists *invent* them. What do you think?
10. For this statement, assume that a gold miner "discovers" old while an artist "invents" a sculpture. Some people think that scientists *discover* scientific THEORIES. Others think that scientists *invent* them. What do you think?

Social contexts of scientific activity:

11. Community or government agencies should tell scientists what to investigate; otherwise scientists will investigate what is of interest only to them.
12. Politics affects scientists, because scientists are very much a part of society (that is, scientists are not isolated from society).
13. Scientific research would be better off if the research were more closely controlled by corporations (for example, companies in high-technology, communications, pharmaceuticals, forestry, mining, manufacturing).
14. Within the U.S. there are groups of people who feel strongly in favor of or strongly against some research field. Science and technology projects are influenced by these special interest groups (such as environmentalist, religious organizations, and animal rights people).
15. Some communities produce more scientists than other communities. This happens as a result of the upbringing which children receive from their family, schools, and community.

Societal implications of scientific activity:

16. Loyalties affect how scientists do their work. When scientists work together for a company, their loyalty to the ideals of science (open-mindedness, honesty, sharing results with others, etc.) is replaced by a loyalty to the company (for example, the company is always right).
17. Most U.S. scientists are concerned with the potential effects (both helpful and harmful) that might result from their discoveries.
18. Scientists should be held responsible from the harm that might result from their discoveries.
19. Scientists and engineers should be the ones to decide on future biotechnology in the U.S. (for example, recombinant DNA, gene splicing, developing ore-digging bacteria, or snow-making bacteria, etc.) because scientists and engineers are the people who know the facts best.
20. Scientists should be the ones to decide what techniques will be used with unborn babies in the U.S. (for example, amniocentesis for analyzing chromosomes of the fetus, altering embryo development, test-tube babies, etc.) because scientists are the people who know the facts best.
21. We always have to make trade-offs (compromises) between positive and negative effects between science and technology.

Figure 1. Stems of VOSTS items used as numbered in the questionnaire but classified by components of NOS.

There are no right or wrong answers to items in the VOSTS questionnaire. However, certain responses are considered more acceptable or desirable as they reflect the contemporary view of the NOS while other choices represent a more traditional view of the NOS, thus less desirable. So, each response choice was designated one of three categories based on previous studies using the VOSTS questionnaire (Rubba, Bradford, & Harkness, 1996; Dass 2005):

- Desirable (D): The choice expresses a contemporary view.
- Acceptable (A): The choice expresses a view that includes a number of legitimate points.
- Undesirable (U): The choice expresses a view that is inappropriate or not legitimate (does not match any aspects of the contemporary view).

The answer responses of "I don't understand", "I don't know enough about this subject to make a choice", and "None of these choices fits my basic viewpoint" were assigned "U", an undesirable choice, since they do not address the student's basic viewpoint.

In order to run statistical analysis, VOSTS choices were assigned a numerical point value as follows: D=3, A=2, U=1. A nonparametric *t*-test was used to test for differences in pre- and post-course performance and the Mann-Whitney U test was used to test for gender differences in performance. Using non-parametric tests assures precision, and does not require the sample to fit a normal distribution (Glover & Mitchell, 2002). Referring to my study objectives, the VOSTS questionnaire and comparison of students' mid-term and final test grades determines if students' holistic understanding of the NOS has changed over the span of the course, and, if there are differences, whether they can be attributed to gender. The sign test allowed me to test for differences in pre- and post-course response choices. When $p > 0.05$, the null hypothesis cannot be rejected, the null hypothesis being course and/or gender have no impact on students' views on science. When $p \leq 0 .05$, the null hypothesis is rejected in favor of the alternative hypothesis that course and/or gender had some impact on students' overall understanding of the NOS. For example, if a student in the pre-test selected a choice that corresponded with 'U' but in the post-test then selected a choice the corresponded with 'A' or 'D' they were considered positive differences. Responses in the opposite direction were considered negative differences. Students who picked the same choice for the pre- and post-test questionnaire were considered as numeric ties. A sample of a VOSTS item with all response choices and a scoring scheme is provided in Figure 2.

Scientific ideas develop from hypothesis to theories and finally if they are good enough, to being scientific laws.
Your position basically: (Please read from A to H, and then choose one.)

Hypotheses can lead to theories which can lead to laws:
U/1 A. because a hypothesis is tested by experiments if it **proves** correct, it becomes a theory. After a theory has been **proven** true many times by different people and has been around for a long time, it becomes a law.
U/1 B. because a hypothesis is tested by experiments, if there is **supporting evidence**, it is a theory. After a theory has been tested many times and seems to be **essentially correct**, it's good enough to become law.
U/1 C. because it is a logical way for scientific ideas to develop.
A/2 D. Theories can't become laws because they both are different types of ideas. Theories are based on scientific ideas which are less than 100% certain, and so theories can't be proven true. Laws, however, are based on facts only and are 100% sure.
D/3 E. Theories can't become laws because they are both different types of ideas. Laws **describe** things in general. Theories **explain** these laws. However, with supporting evidence, hypotheses may become theories (explanations) **or** laws (descriptions).
U/1 F. I don't understand.
U/1 G. I don't know enough about this subject to make a choice,
U/1 H. None of these choices fit my basic viewpoint.

Figure 2. VOSTS item with response choices and scoring scheme.

A Mann-Whitney U test was conducted in order to decipher differences on the VOSTS questionnaire based on gender. A Mann-Whitney U test was used as it is designed to test for differences between two groups that are non-normal, that is non-parametric.

Qualitative Data Collection and Analyses

Mid-term and Final

To assess students' mid-term and final exam, they were analyzed by hand, in order to look for emerging contemporary NOS core components (McComas, 2004). They were analyzed for overall course impact as well as gender-based course impact by picking key words and phrases that identified a theme of a contemporary NOS view. I looked carefully at each student's mid-term and final, and drew on any progression the students made from mid-term to final examinations.

I decided to employ a "mixed methods" approach to students' mid-term and final examinations. Mixed methodology allows exam responses to be analyzed both quantitatively and qualitatively (Lee, 2012). As previously stated, the quantitative component of the mid-term and final exam responses were subjected to a sign test and a two sample independent *t*-test. For a qualitative component, I took students' exam responses and hand coded them. Referring back to McComas' (2004) nine core components of the NOS. I focused on the three components that were mentioned in the exam question: (2) In spite of commonalities there is no single step-by-step scientific method by which all science is done; (3) Scientific knowledge is tentative but durable; and (8) Science and technology impact each other, but they are not the same.

Knowing which tenets were dealt with in the exam question, allowed me to go through responses and focus on parts of student responses that dealt with these three core components.

Results

The goal of this study was to decipher the impact of the course the “Meaning and Nature of Science” on students’ perceptions of the NOS. Also, to distinguish any gender-based differences in NOS understanding between males and females enrolled in the course during the fall 2011 and fall 2012 semesters.

Mid-term and final exam scores were analyzed quantitatively and qualitatively, while the VOSTS survey responses were analyzed only quantitatively using a Sign test and a Mann-Whitney U test.

Analysis of Mid-Term and Final Exam Scores

The mid-term and final consisted of the same basic question:

As we progress from Renaissance to the Enlightenment and beyond, we see the rise of the so called “scientific method” in investigating various aspects of the universe.

1. Articulate your understanding of the chief characteristics of the scientific method as evident in the historical examples encountered in this course.

2. Then explain, using appropriate examples and arguments, how and why it is possible (or not possible) that knowledge gained through scientific investigations, correctly employing the scientific method, may still change in the future.

3. Finally, discuss what makes scientific knowledge, which may be considered "tentative" in many respects, reliable to make sense of the universe from astronomical all the way to subatomic levels.

Examinations were scored on a scale from 1 to 5, where 5 is the highest score. A paired *t*-test was conducted to measure overall difference in class performance between the mid-term and final scores. The paired *t*-test is used when two small sets of data are related in a specific way. In this case, the two small sets of data were the mid-term and final exam scores, and were related as the same question was administered twice during the period of the course. Then a two-sample Independent *t*-test was performed in order to decipher any gender-based differences. Two-sample Independent *t*-test was chosen because these gender observations are isolated from one another and not intrinsically related.

Students were given approximately one week to answer the exam question in the form of five SOCS. Each of the five SOCS was given a score and the scores were averaged and given an overall score. The mean scores of student exams were as follows:

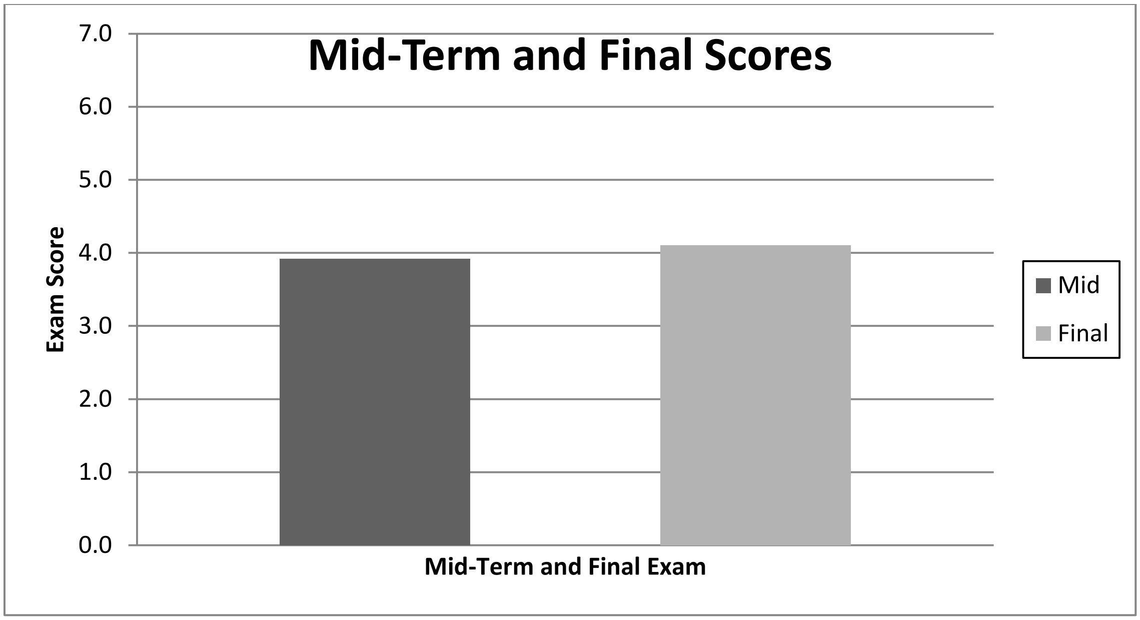

Figure 3. Average Student scores of the Mid-Tem and Final Scores of Fall 2011 and Fall 2012. N=22.

There is a slight increase in scores from the mid-term to the final exam, yet the confidence intervals intersect zero, showing that the difference in exam scores is not statistically significant. These score differences were derived from a running a paired *t*-test (Table 2).

Table 2.
Paired *t*-test to determine overall test differences

	Paired Differences					t	df	*p*-value
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Final – Mid	.187	.914	.190	-.208	.582	.981	21	.337

This study also aims to see if there are any gender-based differences between Mid-terms and final exam changes. This was determined by doing a two-sample, independent *t*-test on mid-term and final exam scores of both the males and the females (Tables 3 and 4).

Table 3.

Descriptive Statistics for the

Two-Sample Independent *t*-test to test for gender differences

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Diff	Male	12	.25	.754	.218
	Female	10	.09	1.136	.343

Table 4.
Two-Sample Independent *t*-test to test for gender difference

		Levene's Test for Equality of Variances		*t*-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed) p value	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Diff	Equal variances assumed	1.621	.217	.399	21	.694	.159	.399	-.670	.988

Table 3 examines descriptive statistics in gender. It shows the mean differences in gender on the mid-term and final examination of 0.25 for males and 0.09 for females respectively, meaning male scores improved more, but not enough to be statistically significant. Table 4 assumes that male and female scores have an equal variance, which would eliminate the possibility of getting a result by chance alone. The *p*-value in Table 4 is 0.694, higher than 0.05, indicating no significant statistical difference. Also, the two confidence intervals include zero, backing up the lack of significant difference.

Based on the hypothesis, females were expected to have a slight advantage due to higher qualitative skills (Nankervis, 2010). In order to determine if that is accurate in reference to this course, the differences between male and female scores were analyzed using a *t*-test. Figure 4 is a graphical representation of average student mid-term and final exam scores, broken down by gender. In Figure 5, the difference in the average mid-term and final exam scores are broken down respectively by gender. In comparison to my original hypothesis, this outcome is surprising as males had more examination score increase between the mid-term and final, though not statistically significant.

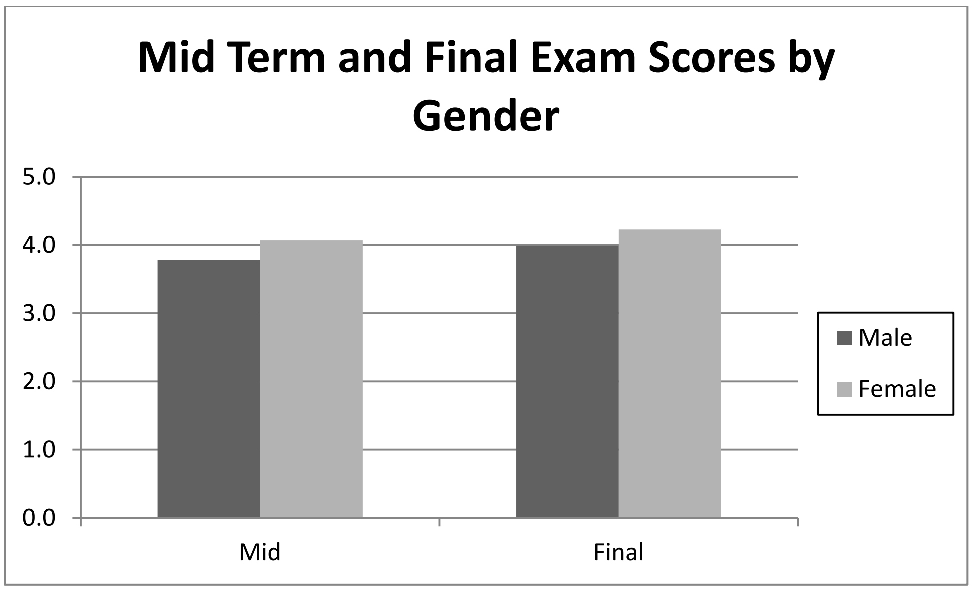

Figure 4. Mid-Term and Final Exam Scores by Gender. N=22 Males= 12 Females=10

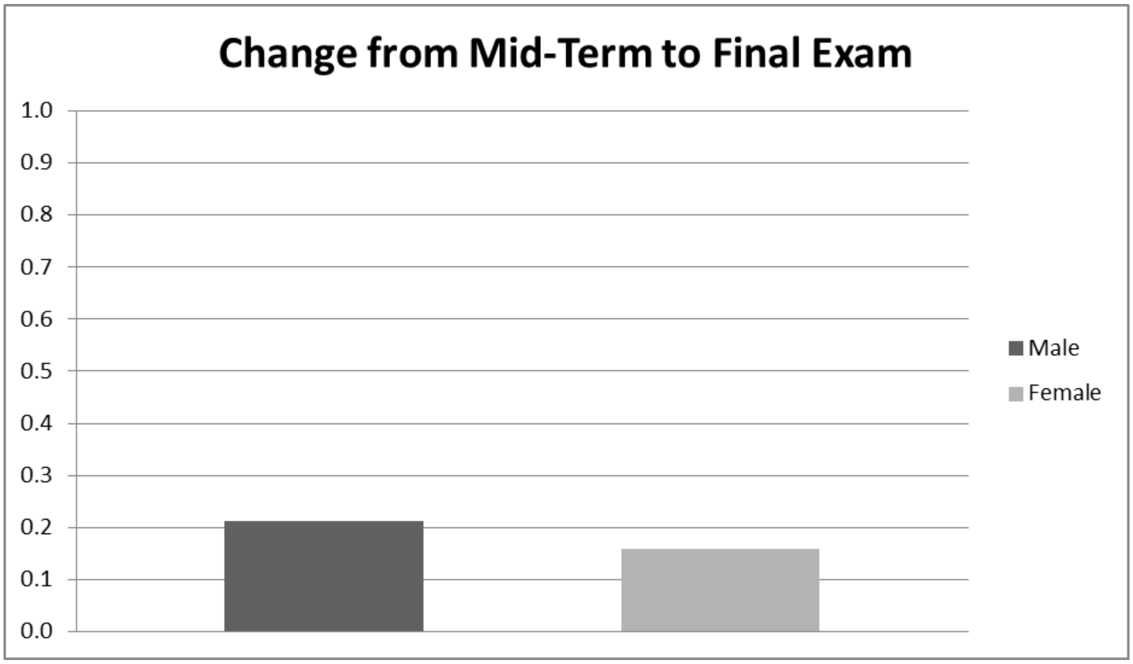

Figure 5. Average Mid-Term and Final Exam Scores differences by gender. N=22 Males= 12 Females=10

Qualitative Analysis

For the purpose of qualitative analysis, I chose two data points. I evaluated the mid-term and final exam responses against two of McComas' core components of the NOS, as they were specifically referenced in the exam question. For this, I examined one component at a time and matched them with corresponding points made by the students on their mid-term and looked for improvement in their final. For example, a female student on the mid-term said this about the scientific method:

> *By comparing the practice of the scientific method by the first true scientists, Gilbert and Galileo, it is evident that they set the standard on how to conduct science in an appropriate fashion. They demonstrated the need for experiments to be verifiable, repeatable, and testable by others. Both Gilbert and Galileo set the stage for future scientists to explore their studies in a more reliable fashion rather than simply relying on logic and reason as was previously done* (Gribbin, 2002).

Clear thought progression can be seen in her opinion of the scientific method on the final:

> *Science is constantly evolving and changing with the discovery of new information and ideas through the use of the scientific method to conduct experiments and make observations. When new information surfaces through the use of the scientific method, the previously accepted understanding is reevaluated and refined if necessary in light of new understandings. For example, the scientific method was used to study the model of the atom and it slowly developed and formed over many years due to the works and experiments of many scientists such as Thomson, Rutherford, and Bohr. The atomic structure model started with a very simple understanding and slowly progressed into how we view it today, the Bohr Model* (Gribbin, 2002).

It seems the teachings of the course influenced how this student viewed the impact of the scientific method. In the mid-term she lays out the characteristics of the scientific method, yet in the final she goes on to explain the importance and role of the scientific method in discovering new scientific information.

Another student, a male, reflected on the relationship between science and technology:

> *While reading the book, we have talked about the impact of technology on science and the scientific method. One part of science that has greatly been impacted is the science of chemistry. The lack of findings in early chemistry was not due to the inability of scientist's minds but the lack of technology. The author clearly states this when talking about the advancement of chemistry saying, "They [scientists] simply lacked the tools for the job." (242) The author hits it right on the head with this*

statement. When we look at the other sciences, they can be observed without needing instruments to perform an experiment, if instruments were needed they were very simple. This need for technology impacted the scientific method as well because one needs accurate data to understand if their hypothesis is correct or not as well as understand their data.

This statement clearly shows that the student is aware of McComas (2004) core component that science and technology are related but not the same. But his perspective improves further after the final when he said this:

The knowledge gained through use of the scientific method can change. Like stated earlier, it seems that it changes with the inventions of new technologies but this does not mean that the prior knowledge is invaluable. There had to be a starting point for everything in science. I think that we see this starting point a lot in the book, specifically the predictions many scientist made. The best example of this is in astronomy and physics. Urbain Leverrier used calculations to accurately predict, "…the presence of Neptune on the basis of Newton's laws and the way in which the orbits of other planets were being perturbed by an unseen gravitational influence." (475) Then in physics, Dirac presented a wave equation for the electron and then realized the equation, "…was actually predicting the existence of a previously unknown particle, with the same mass as an electron but positive charge." (521) Although these are two very different predictions, they can be looked at as very similar. Scientists at the time lacked technology to see either of these things. Neptune was too far to see with the best telescope and a positron was too small to see with the best microscope. Both men used the scientific method in different ways but concluded *that there was something out there that could not be seen. Of course with better technology their predictions were found to be correct, but I think it's important to note that jumping off point that starts the scientific method. The starting point is very important to science and the knowledge gained should not be forgotten even if it changes.*

This student's response on the final, links technology further to science by linking it to the scientific method and its processes, showing clear progression of thought about the huge impact that technology has on science.

Mid-Term and Final SOCS Responses Based On McComas' Components

(2)In spite of commonalities there is no single step-by-step scientific method by which all science is done

Students' responses dealt a lot with the scientific method since that was one of the foci of the exam question. Students often referred to the scientific method as the only "proper" way to carry out scientific experiments. Students offered different opinions on the scientific method, especially from the mid-term to the final. On the mid-term, one male student commented: *"The transformation of the scientific method from an absent concept to one of concrete qualifications and requirements forced scientists to be much sound in their reasoning and experimenting and therefore allowed for much more sound investigation."* Another mid-term response concerning the scientific method:

To understand how the scientific method works, it is helpful to examine the work of a person who did not utilize the scientific method, Tycho Brahe. He did not perform any experiments to test hypotheses, and therefore did not employ the scientific method.

On the final, student responses seemed to show slight improvement in comprehension of the scientific method for example: *"...scientific methods are followed while researching specific topics, conclusions resulting from those methods can still be questioned and/ or changed."* However, students realize that often the scientific method justifies that scientific knowledge changes.

> *Science is dynamic in nature due to the fact that conclusions are allowed to evolve or be replaced over time. Contrary to this aspect, science course are often taught using a set of defined scientific principles. All answers derived via the scientific method can be "questioned".*

Students in essence believe that the steps of the scientific method produce valid scientific outcomes: *"Overall, the scientific method has the ability of producing sound, fundamental truths…yet there is also a temporal and evolutionary aspect to the nature of science."* Students realize the impact that the scientific method has on the fundamental ideas held about the way the world works: *"As the scientific method becomes more widely accepted the more ideas and beliefs change."* Through this course students also discovered that when the scientific method was applied correctly it can correct past experiments and validate age-old scientific truths: *"Many attempts have been made to correctly apply the scientific method and amend flaws of past experiments…"* Though there was some small improvement of students' ideas about the scientific method, they tended to believe the scientific method was made up of discreet steps, which represented the more traditional view of the NOS instead of McComas (2004) contemporary view.

(3) Scientific knowledge is tentative but durable

Students had varying opinions on the tentativeness of science on the mid -term one female said: *"Scientific knowledge seems tentative when it defies common sense, but when its predictions are evident then the scientific theories can be useful tools."*

Through this course students learned that science is not always absolute but can stand the test of time, and do more than "defy common sense." Students illustrated this point through pulling examples from the text (Gribbin, 2002) that tested hypothesis through the process of the scientific method on final exam responses *"...predictions that could be proven correct through experimentation illustrates how science may be tentative but still reliable."* Science's tentative nature was realized during the class because science often does not answer a question totally, McComa's (2004) ninth core component: *"Scientific knowledge is often viewed as tentative because it lacks the ability to provide absolute truths."*

(8) Science and technology impact each other, but they are not the same

Students did not underestimate the impact of technology on science: *"Technology is vital for the advancement of scientific knowledge."* Students often talked about how science had to wait for technology to progress *:"(Science) has to wait on the correct technology to evolve."* Through the course of the class students' realized the impact technology had on science: *"...advancements in technology (lead) to new experimental options."* Students also realized that science had a tremendous impact on technology as well: *"...science can almost always improve technology to make it more efficient and more accessible to the masses, as well as change the way technology is perceived."* Technology changed the way the world was viewed, and students were quick to realize this throughout the course: *"As technology progressed through time, the ability to observe the universe, from the subatomic to* *macrocosmic scale, has changed the ability of humans to formulate hypotheses predicated upon those observations."* Their responses on the mid-term and final concerning science and technology stayed relatively the same; this indicated that students had a firm grasp on the relationship between science and technology, regardless of the timing of the exam.

It also is useful to look at the SOCS type progression over the span of the course (Table 5). It can be assumed that over the span of the course, more $SOCS_C$ would be written at the time of the final as they represent a higher level of critical thought. Table 5 shows the breakdown of SOCS types written on both the mid-term and the final, as well as broken down by gender. By examining the table, males increased in type B SOCS from the mid-term to the final. Males had lower counts of type C at the time of final and type A stayed generally the same from the mid-term to the final. Females increased in type A from the mid-term to the final, decreased in type B, and stayed the same concerning type C between the mid-term and final. Overall, regardless of gender, there is progression in type A SOCS and type B SOCS. Type C SOCS decreased overall between the mid-terms and final. However, these progressions and regressions are not large enough to show statistical significance.

Table 5.
SOCS Conception by Mid-term and Final exam and gender.

		MID-TERM				**FINAL**		**Total**
SOCS TYPE & GENDER	**A**	**B**	**C**		**A**	**B**	**C**	
Female	33	10	7		36	7	7	**100**
Male	37	8	15		37	14	9	**120**
Total	**70**	**18**	**22**		**73**	**21**	**16**	**220**

VOSTS Survey Analysis

The results of the VOSTS pre- and post-course questionnaire were analyzed as follows. These scores are expected to show the effect of "The Meaning and Nature of Science" course on students' understanding of the NOS. Students' perceptions of the NOS varied by VOSTS items. For example, on pre-course questionnaire item 1, the majority of males and females held an undesirable conception (55%). When asked to define science, a majority of students selected "Mainly science is a body of knowledge, such as principles, laws, and theories, which explain the world around us (matter, energy and life)." When the desirable choices were "Exploring the unknown and discovering new things about our world and universe and how they work" and "An organization of people (called scientists) who have ideas and techniques for discovering new knowledge."

Table 6 presents a Sign test of the VOSTS survey results. The Sign test analyzes change along the pre-determined ordinal data (3-2-1 scale). The *p*-value indicates significance of the differences in students' pre- and post- course survey. If the *p*-value is less than 0.05, it can be assumed there was a significant difference between the pre- and post-course response. The negative box monitors a decrease in students' ordinal scores. For example, if one student picked a "Desirable" choice on the pre-course survey, earning a three, then on the post-course survey picked an "Undesirable" choice, earning a one, which is noted in the negative column. If the example was reversed, that the student picked an "Undesirable" score on the pre-course survey, and a "Desirable" choice on the post-course survey, that difference is noted in the positive column. Ties denote no change between the pre- and post-course survey.

Table 6.

Sign test to test for overall student differences on VOSTS

	p-value	Original VOSTS Number	Negative Difference	Positive Difference	Ties	N
1	0.774	**1**	7	5	10	22
2	1.000	**5**	4	4	14	22
3	0.508	**6**	6	3	13	22
4	1.000	**7**	0	1	21	22
5	0.453	**8**	2	5	15	22
6	1.000	**11**	4	5	13	22
7	0.453	**12**	2	5	15	22
8	1.000	**13**	4	5	13	22
9	1.000	**14**	6	5	11	22
10	0.289	**17**	2	6	14	22
11	1.000	**18**	4	3	15	22
12	1.000	**20**	8	7	7	22
13	1.000	**37**	3	3	16	22
14	0.227	**38**	8	3	11	22
15	1.000	**39**	3	3	16	22
16	0.508	**40**	3	6	13	22
17	1.000	**42**	2	2	16	20
18	0.180	**43**	7	2	13	22
19	1.000	**47**	5	4	13	22
20	0.727	**48**	3	5	14	22
21	0.180	**49**	2	7	13	22

A Mann-Whitney U Test was conducted to decipher any gender-based differences in the VOSTS questionnaire responses. This test is designated to decipher differences, if any, between two population means that come from the same population. In this case, the two population means are the mean questionnaire score between males and females, both from the “Meaning and Nature of Science” course.

Table 7.

Mann-Whitney U Test to decipher gender response differences on VOSTS.

Ranks					
Question	Gender	N	Mean Rank	Sum of Ranks	*p* -value
1	M	12	10.33	124.00	0.381
	F	10	12.90	129.00	
	Total	22			
4	M	12	10.71	128.50	0.539
	F	10	12.45	124.50	
	Total	22			
5	M	12	10.25	123.00	0.346
	F	10	13.00	130.00	
	Total	22			
6	M	12	10.50	126.00	1.000
	F	8	10.50	84.00	
	Total	20			
8	M	12	10.63	127.50	0.497
	F	10	12.55	125.50	
	Total	22			
10	M	12	11.08	133.00	0.771
	F	10	12.00	120.00	
	Total	22			
12	M	12	11.00	132.00	0.722
	F	10	12.10	121.00	
	Total	22			

A Mann-Whitney U Test was employed in opposition to a regular *t*-test as the samples are non-normal, or not equally distributed. The test essentially calculates the difference between each set of pairs and analyzes these differences (Glover & Mitchell, 2002).

Choice of VOSTS Items for Analysis

Seven items were chosen for additional analysis. Items 1, 4, 5, 6, 8, 10, and 12 were deemed to be significantly important for content, less so for statistical difference. Also these items included common issues that came up in the course texts as well in class discussion. Research has shown these items influence students' conceptions of science as they influence scientific learning strategies (Edmundson & Novak, 1993) and relate directly to the core components of the NOS (McComas, 2004).

Analysis of VOSTS Items

VOSTS Item 1

Item 1 of the VOSTS questionnaire referred to the definition of science and what science really is. This item relates several of the core components of the NOS: (1) science demands and relies on empirical evidence; (2) there is no single step-by-step scientific method by which all science is done; (5) science is a highly creative endeavor; (6) science has a subjective element; (7) science is a complex social activity; and (9) science cannot provide complete answers to all questions (McComas, 2004). All of these components are essential in defining science. Science would not be possible and verifiable without empirical evidence. Science is done via the scientific method, therefore the definition of the scientific method relates directly to the definition of science. Science is creative, social, and subjective as science often serves to answer curiosities of the common man. It is also important to understand that science is not absolute and does not answer all questions that are posed, knowing these tenets help to define science fully.

Defining science is difficult because science is complex and does many things. But MAINLY science is:
Your position, basically: (Please read from A to K, and then choose one.)
U/1 A. a study of fields such as biology, chemistry, and physics.
U/1 B. a body of knowledge, such as principles, laws, and theories, which explain the world around us (matter, energy, and life).
D/3 C. exploring the unknown and discovering new things about our world and universe and how they work,
D/3 D. carrying out experiments to solve problems of interest about the world around us.
A/2 E. inventing or designing things (for example, artificial hearts, computers, space vehicles).
A/2 F. finding and using knowledge to make this world a better place to live in (for example, curing diseases, solving pollution, and improving agriculture).
D/3 G. an organization of people (called scientists) who have ideas and techniques for discovering new knowledge.
U/1 H. No one can define science.
U/1 I. I don't understand.
U/1 J. I don't know enough about this subject to make a choice.
U/1 K. None of these choices fits my basic viewpoint.

Figure 6. VOSTS item 1 response choices and scoring scheme.

Student responses overall were undesirable on both the pre- and post-test. However, no student picked any "Acceptable" answer choices. Students either picked an "Undesirable" choice or a "Desirable" choice. It should be noted that half of the males picked an "Undesirable" choice while the other half picked a "Desirable" choice. Though, not statistically significant, the majority of "Desirable" choices on the post-course questionnaire declined, while "Undesirable" choices were more popular on the post-course questionnaire, especially in males. The females also showed a decline in "Desirable" choices. On the pre-test six females picked "Undesirable" choices, and on the post-test 14 females picked "Undesirable" choices. This could possibly suggest that the course "Meaning and Nature of Science" influence students' understanding of science negatively.

It should be noted that frequency tables should be read first horizontally for the pre-test and vertically for the post-test. For example in Table 8, there were six females that picked an undesirable choice on the pre-test and six males that picked and undesirable choice on the pre-test. On the post-test, five females picked an undesirable choice, one female picked an acceptable choice, and four females picked a desirable choice. For the post-test nine males picked an undesirable choice, zero males picked an acceptable choice, and three males picked a desirable choice.

Table 8.
Student response choices by category for item 1 on pre and post course questionnaire.

				Post 1		
				Undesirable	Acceptable	Desirable
				Count	Count	Count
Pre 1	Undesirable	Gender	F	2	1	3
			M	5	0	1
	Desirable	Gender	F	3	0	1
			M	4	0	2

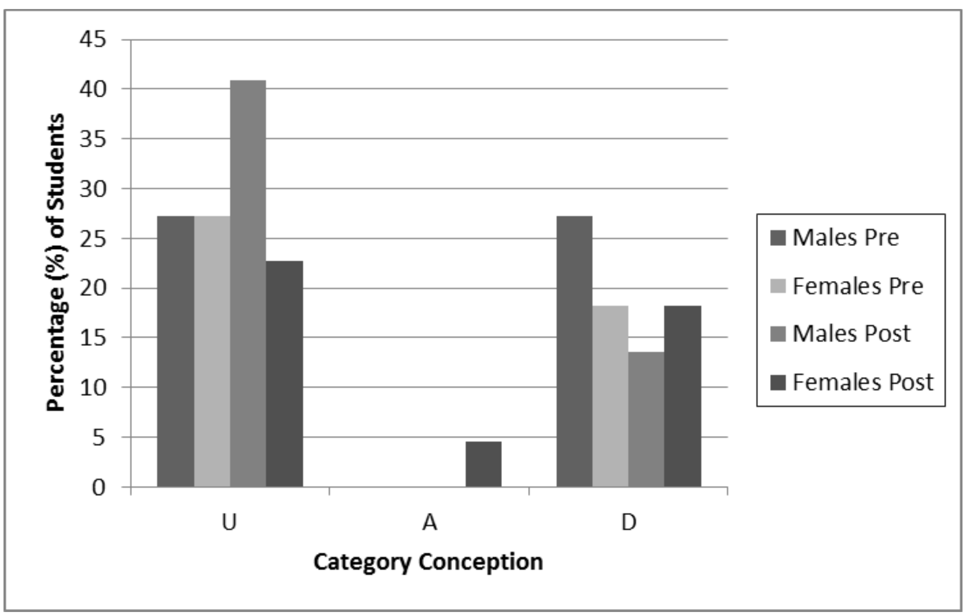

Figure 7. Percentage of students that selected each category conception on pre and post-course questionnaire for item 1, N=22.

VOST Item 4

VOSTS item 4 gauges students' perception of how scientists view nature. Of the core components of the NOS, (3) scientific knowledge is tentative but durable and (6) science has a subjective element, are tenets of vast importance (McComas, 2004). This item is of particular importance because the course viewed how various scientists' perceptions changed or were different than that of scientists of their time (Gribbin, 2002).

When scientists classify something (for example, a plant according to its species, an element according to the periodic table, energy according to its source, or a star according to its size), scientists are classifying nature according to *the way nature really is;* any other way would simply be wrong.
Your position, basically: (Please read from A to I, and the choose one.)
U/1 A. Classifications match the way nature really is, since scientists have proven them over many years of work.
A/2 B. Classifications match the way nature really is, since scientists use observable characteristics when they classify.
A/2 C. Scientists classify nature in the most simple and logical way, but their way isn't necessarily the only way.
D/3 D. There are many ways to classify nature, but agreeing on one universal system allows scientists to avoid confusion in their work.
D/3 E. There could be other correct ways to classify nature, because science is liable to change and new discoveries may lead to different classifications.
D/3 F. Nobody knows the way nature really is. Scientists classify nature according to their perceptions or theories. Science is never exact, and nature is so diverse. Thus, scientists could correctly use more than one classification scheme.
U/1 G. I don't understand.
U/1 H. I don't know enough about this subject to make a choice.
U/1 I. None of these choices fits my basic viewpoint.

Figure 8. VOSTS item 4 with response choices and scoring scheme.

The majority of students in the pre and post-course questionnaire picked a "Desirable" choice. This shows students understand that science can change and that not all scientists classify nature in the same way. Students picked choice D most often, which states the complexity of nature and the lack of exactness of science, and that more than one classification scheme, could be correct; this correlates directly with the core component of the NOS has subjective elements and scientific knowledge can be tentative.

Table 9.
Student response choices by category for item 4 on pre and post course questionnaire.

				Post 4	
				Acceptable	Desirable
				Count	Count
Pre 4	Undesirable	Gender	F	0	3
			M	0	2
	Desirable	Gender	F	0	7
			M	2	8

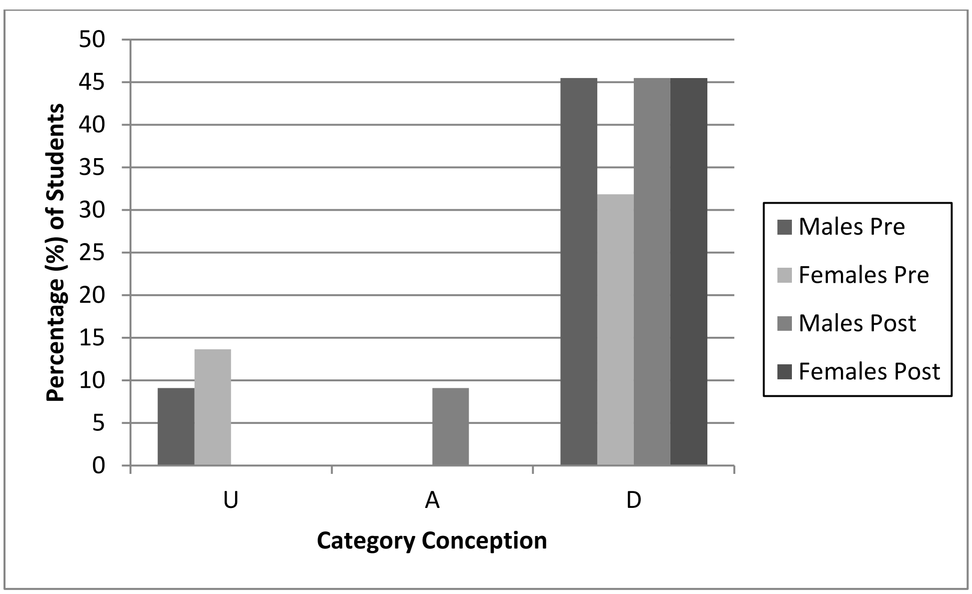

Figure 9. Percentage of students that selected each category conception on pre and post-course questionnaire for item 4, N=22.

VOSTS Item 5

VOSTS item 5 asks students about their opinion of the changing nature of scientific knowledge. This plainly points to (3) scientific knowledge is tentative but durable and (5) science is a highly creative endeavor (McComas, 2004).

Even when scientific investigations are done correctly, the knowledge that scientists discover from those investigations may change in the future.
Your position, basically: (Please read from A to G, and then choose one.)
Scientific knowledge changes:
A/2 A. because new scientists **disprove** the theories or discoveries of old scientists. Scientists do this by using new techniques or improved instruments, by finding new factors overlooked before, or by detecting errors in the original "correct" investigation.
D/3 B. because the old knowledge is **reinterpreted** in light of new discoveries. Scientific facts can change.
A/2 C. Scientific knowledge APPEARS to change because the **interpretation** or the application of the old facts can change. Correctly done experiments yield unchangeable facts.
U/1 D. Scientific knowledge APPEARS to change because new knowledge is **added on to** old knowledge; the old knowledge doesn't change.
U/1 E. I don't understand.
U/1 F. I don't know enough about this subject to make a choice.
U/1 G. None of these choices fits my basic viewpoint

Figure 10. VOSTS item 5 with response choices and scoring scheme.

Overall, the answers were "Undesirable", but did improve over the course, but not significantly so. Again, students both picked "Desirable" or "Undesirable" choices. This question deals with the mercurial nature of science and its ability to change over time. This can be seen clearly in the text of the course from the changing of the model of the solar system to the theory of evolution (Gribbin, 2002). Due to the answers chosen, students do not seem to grasp that scientific knowledge changes and does so often, especially when looking at the NOS in a historical context.

Table 10.
Student response choices by category for item 5 on pre and post course questionnaire.

				Post 5	
				Undesirable	Desirable
				Count	Count
Pre5	Undesirable	Gender	F	3	4
			M	8	2
	Desirable	Gender	F	1	2
	M	2		0	

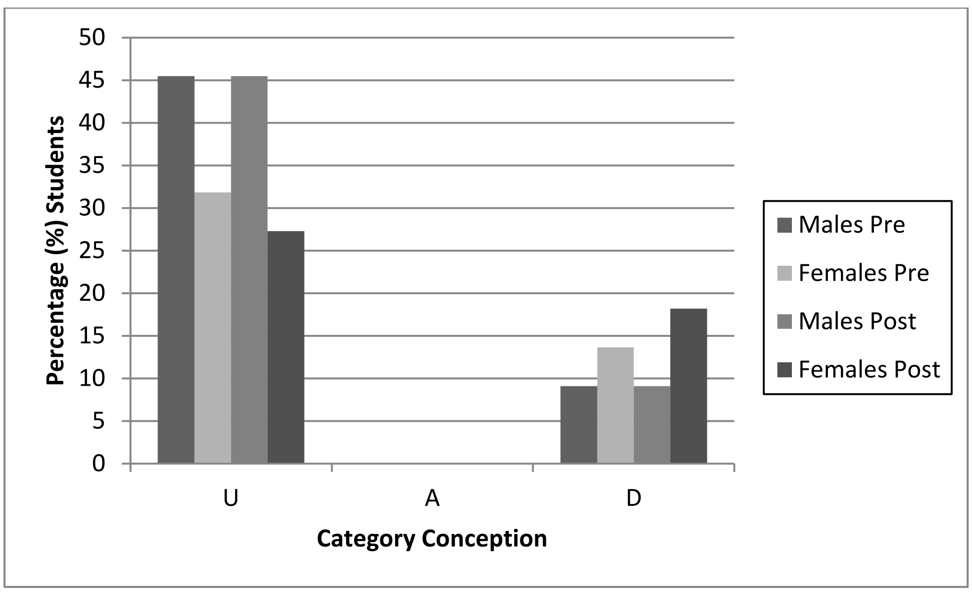

Figure 11. Percentage of students that selected each category conception on pre and post-course questionnaire for item 5, N=22.

VOSTS Item 6

VOSTS item 6 deals with the definition of the scientific method paralleled by McComas (2004) in spite of commonalities there is no single step-by-step scientific method by which all science is done. This is especially important, as the scientific method is commonly taught as one fixed procedure in all scientific disciplines in both school and college science courses.

When scientists investigate, it is said that they follow the scientific method. The scientific method is:
Your position, basically: (Please read from A to M, and then choose one.)
A/2 A. the lab procedures or techniques; often written in a book or journal, and usually by a scientist.
A/2 B. recording your results carefully.
A/2 C. controlling experimental variables carefully, leaving no room for interpretation.
U/1 D. getting facts, theories or hypotheses efficiently.
U/1 E. testing and retesting — proving something true or false in a valid way.
U/1 F. postulating a theory then creating an experiment to prove it.
A/2 G. questioning, hypothesizing, collecting data and concluding.
A/2 H. a logical and widely accepted approach to problem solving.
A/2 I. an attitude that guides scientists in their work.
D/3 J. Considering what scientists actually do, there really is no such thing as the scientific method.
U/1 K. I don't understand.
U/1 L. I don't know enough about this subject to make a choice.
U/1 M. None of these choices fits my basic viewpoint.

Figure 12. VOSTS item 6 with response choices and scoring scheme.

Students picked mainly "Acceptable" choices when it came to their perceptions on the scientific method on both the pre- and post-course questionnaire. This shows students knew key tenets to the scientific method but did not realize the abstract nature of the scientific method, or as it is referred to in the "Desirable" answer choice, "there really is no such thing as the scientific method" (Aikenhead, Fleming, & Ryan, 1987). In reference to this question, there were only 20 valid responses (opposed to 22 in all other questions) because two females left this question blank. In both the pre- and post-course questionnaire students answer choices were overall "Acceptable" and did not change over the span of the course.

Table 11.

Student response choices by category for item 6 on pre and post course questionnaire.

				Post 6		
				Undesirable	Acceptable	Desirable
				Count	Count	Count
Pre 6	Undesirable	Gender	F	0	1	0
			M	0	1	0
	Acceptable	Gender	F	1	6	0
			M	1	9	0
	Desirable	Gender	M	0	0	1

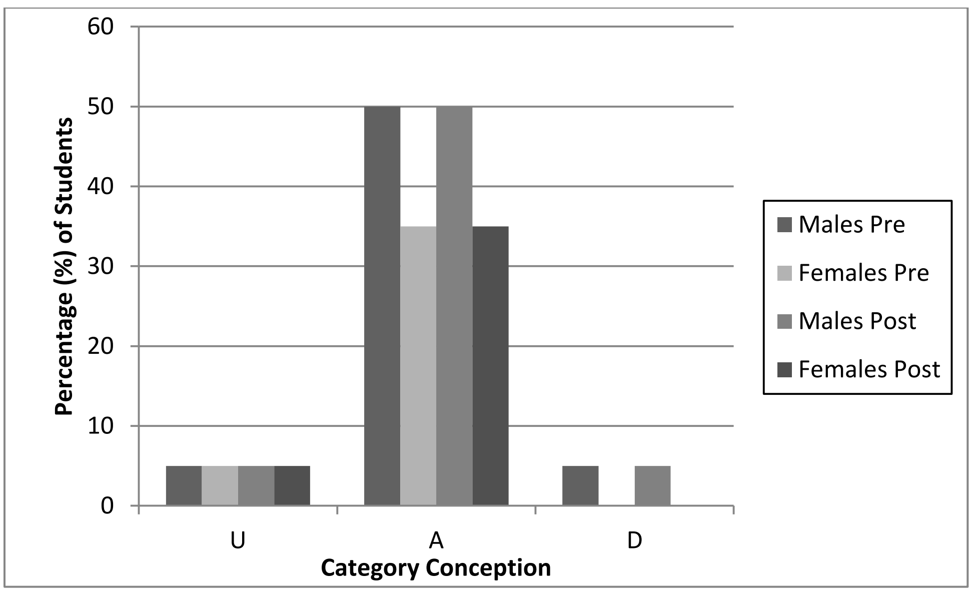

Figure 13. Percentage of students that selected each category conception on pre and post-course questionnaire for item 6, N=20.

VOSTS Item 8

VOSTS item 8 relates to the subtlety of the difference between invention and discovery; both terms are highly common in science and are often used interchangeably.

For this statement, assume that a gold miner "discovers gold" while an artist "invents" a sculpture. Some people think that scientists *discover* scientific HYPOTHESES. Others think that scientists *invent* them. What do you think?
Your position, basically: (Please read from A to I, and then choose one.)

Scientists discover an hypothesis:
U/1 A. because the idea was there all the time to be uncovered.
A/2 B. because it is based on experimental facts.
A/2 C. but scientists invent the methods to find the hypothesis.
A/2 D. Some scientists may stumble onto an hypothesis by chance, thus discovering it. But other scientists may invent the hypothesis from facts they already know.
D/3 E. Scientists invent an hypothesis:
U/1 F. because an hypothesis is an interpretation of experimental facts which scientists have discovered.
U/1 F. because inventions (hypotheses) come from the mind — we create them.
U/1 G. I don't understand.
U/1 H. I don't know enough about this topic to make a choice.
U/1 I. None of these choices fits my basic viewpoint

Figure 14. VOSTS item 8 with response choices and scoring scheme.

Answers were pretty evenly scattered between the three category conceptions across the board, from pre- to post-test (Table 12, Figure 15). There were small improvements in a few students' answers over the span of the course, meaning some students learned that scientists invent a hypothesis. The course text showed plenty of invention of hypotheses in the history of science such as Darwin hypothesizing about evolution and Newton developing hypotheses on gravitational motion (Gribbin, 2002).

Table 12.
Student response choices by category for item 8 on pre and post course questionnaire.

				Post 8		
				Undesirable	Acceptable	Desirable
				Count	Count	Count
Pre8	Undesirable	Gender	F	0	1	2
			M	4	0	1
	Acceptable	Gender	F	0	1	0
			M	1	2	0
	Desirable	Gender	F	1	1	4
			M	0	2	2

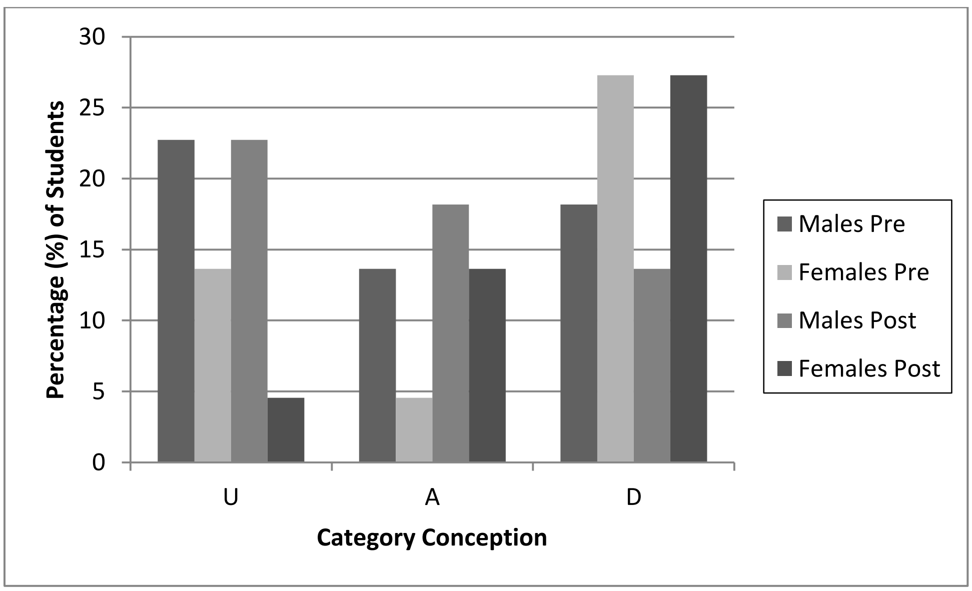

Figure 15. Percentage of students that selected each category conception on pre and post-course questionnaire for item 8, N=22.

VOSTS Item 10

VOSTS item 10 relates to students' perception of scientific theories. This question was intended to gauge students' understanding of scientific theories and how they come about.

For this statement, assume that a gold miner “discovers” gold while an artist “invents” a sculpture. Some people think that scientists *discover* scientific THEORIES. Others think that scientists *invent* them. What do you think?
Your position, basically: (Please read from A to I, and then choose one.)

Scientists discover a theory:
U/1 A. because the idea was there all the time to be uncovered.
U/1 B. because it is based on experimental facts.
U/1 C. but scientists invent the methods to find the theories.
A/2 D. Some scientists may stumble onto a theory by chance, thus discovering it. But other scientists may invent the theory from facts they already know.
Scientists invent a theory:
A/2 E. because a theory is an interpretation of experimental facts which scientists have discovered.
D/3 F. because inventions (theories) come from the mind — we create them.
U/1 G. I don’t understand.
U/1 H. I don’t know enough about this topic to make a choice.
U/1 I. None of these choices fits my basic viewpoint.

Figure 16. VOSTS item 10 with response choices and scoring scheme.

For this particular item, students mostly selected “Undesirable” or “Acceptable” choices on both the pre- and post-course survey. Again, here is an example when it calls for the student to distinguish between the words “discover” and “invent.” Females chose more “Desirable” choices in the post-test but not significantly over the males. Answer choices did improve over the span of the course, but not enough to verify a strong course impact.

Table 13.
Student responses by category for item 10 on pre- and post-course questionnaire.

				Post 10		
				Undesirable	Acceptable	Desirable
				Count	Count	Count
Pre 10	Undesirable	Gender	F	1	2	0
			M	3	4	0
	Acceptable	Gender	F	0	6	1
			M	1	3	0
	Desirable	Gender	M	0	1	0

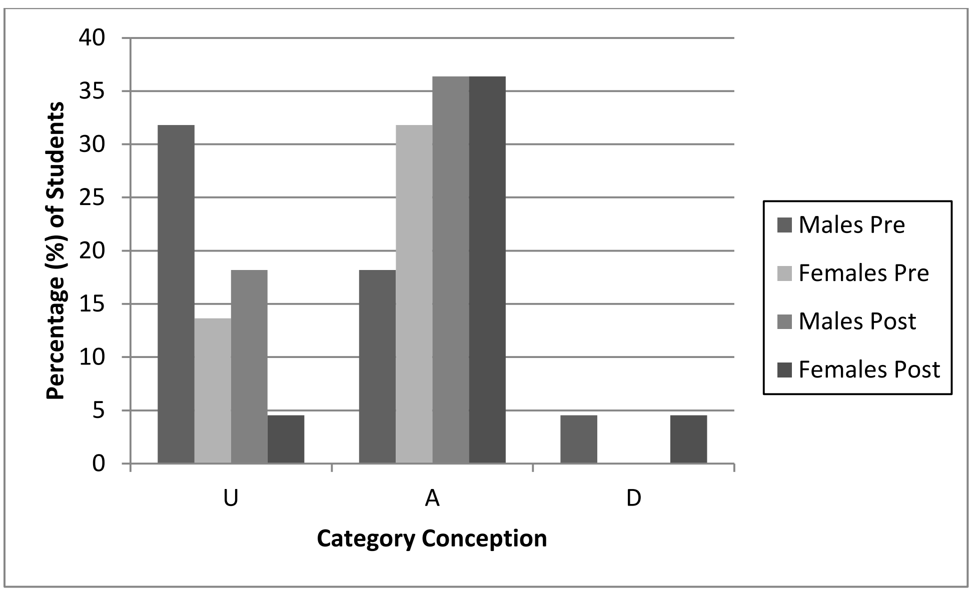

Figure 17. Percentage of students that selected each category on pre- and post- course questionnaire for item 10, N=22.

VOST Item 12

This question relates to McComas' (2004) core component: (7) science is a complex social activity. Politics and society are directly related to each other as politics depend on society. Society votes officials into office to make choices that affect the scientific community.

Politics affects scientists, because scientists are very much a part of society (that is, scientists are not isolated from society).
Your position, basically: (Please read from A to J, and then choose one.)

Scientists ARE affected by politics:
3/D A. because funding for science comes mainly from governments which control the way the money is spent.
Scientists sometimes have to lobby for funds.
3/D B. because governments not only give money for research, they set policy regarding new developments. This
policy directly affects the type of projects scientists will work on.
3/D C. because scientists are a part of society and are affected like everyone else.
2/A D. because scientists try to help society and thus they are closely tied to society.
Scientists are NOT affected by politics:
U/1 E. because the nature of a scientist's work prevents the scientist from becoming involved politically.
U/1 F. because scientists are isolated from society; their work receives no public media attention unless they make a spectacular discovery.
U/1 G. because it is a free country, and so scientists can work quite freely.
U/1 H. I don't understand.
U/1 I. I don't know enough about this subject to make a choice.
U/1 J. None of these choices fits my basic viewpoint.

Figure 18. VOSTS item 12 with response choices and scoring scheme.

Table 14.
Student response choices by category for item 12 on pre and post course questionnaire

				Post 12
				Desirable
				Count
Pre 12	Undesirable	Gender	F	1
	Desirable	Gender	F	9
			M	12

In the case of VOSTS item 12, students overwhelmingly picked desirable choices on both the pre- and post-course questionnaire. This shows students realize politics and science are very much related. The course also had little impact on student understanding of the relationship between science and politics according to the following category conception (Undesirable, Acceptable, and Desirable). But according to Figure 19, roughly the same percentage of students (whether male or female) chose D responses.

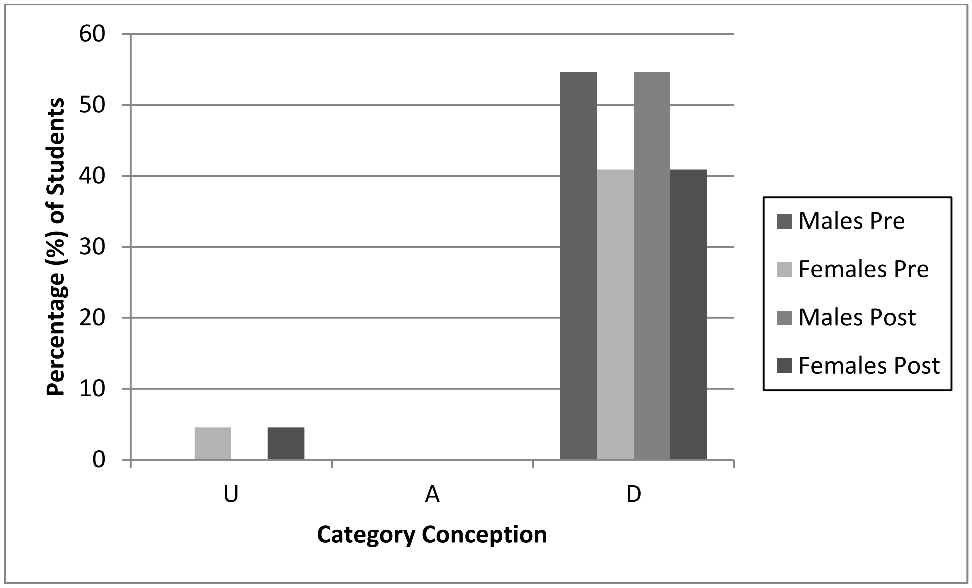

Figure 19. Percentage of students that selected each category conception on pre- and post-course questionnaire for item 12, N=22.

Discussion

Interpretation of Results

The results from this study provide a baseline for how the course “The Meaning and Nature of Science” influenced students’ overall view of the contemporary core components of the NOS (McComas, 2004). This course is taught from a historical perspective. Overall, from mid-term to final, scores did not improve. This suggests the course had little to no influence on certain components, such as the scientific method and the tentativeness of science, of the NOS. Also, the pre- and post-course survey showed no significant difference. This suggests the course had little to no impact on the student’s views on the NOS. Female and male students preformed at virtually the same level on the mid-term and final, as well as on the VOSTS survey. That is, males and females received similar scores on the mid-term as well as the final, and had comparable answers on the VOSTS survey. When discussing these results, percentages are out of the 22 students, unless otherwise designated.

Of the total 22 students, 45% entering “The Meaning and Nature of Science” course held a desirable conception about the definition of science (Table 8 and Figure 6). The result for this item is better than previous studies (Mackay, 1971; Meyling, 1997; Ryan & Aikenhead, 1992). It could be argued that this different outcome is due to a different scoring scheme, the coding scheme for this study was based on the conceptions of science educators and philosophers of science in place of a content biologist studies (Mackay, 1971; Meyling, 1997; Ryan & Aikenhead, 1992). It is possible that many of these students had some type of science or science education as their primary major. On the post-test, desirable conceptions dropped to 36%. The increased number of students selecting undesirable choices on the post-test most likely implies that more students identified with a wider definition of science (Table 8).

When students were asked to select the way scientists classify nature, the majority of students picked a desirable choice, on both the pre- and post-course survey. Undesirable choices were completely eliminated after the pre-course survey, and only acceptable and desirable choices were picked on the post-course survey. This indicates students realized that all classification schemes in science are not set in stone. This is a positive trend in the overall conception of the NOS and different from that of previous studies, like that of Ryan and Aikenhead (1992). Again, this could be due to a different scoring scheme of the category conceptions (Mackay, 1971; Meyling, 1997; Ryan & Aikenhead, 1992).This positive trend could also be attributed to the fact that students encountered more examples of classification from different fields of science and saw how those classification systems changed over time.

Item 5 on the VOSTS survey seemed to gain mostly undesirable choices, at 77% in the pre-course survey and 64% in the post-course survey (Table 10). This question refers to the changing nature of scientific knowledge. Students went to the two extremes and either picked desirable or undesirable choices. It is surprising that more students did not pick desirable, or at the least acceptable choices when thinking back over the course considering science changed drastically over the course of history, and many of them attested to this on their mid-term and final exams. However, choices improved over the course but not enough to make a significant difference (Table 10 and Figure 11). It should be noted that there was only one desirable choice to pick among the choices in item 5 (Figure 10).

Item 6 on the VOSTS survey was an item of particular importance when considering the NOS. Item 6 referred to what the scientific method is. Students picked mostly acceptable choices, at 85% in both the pre- and post-course survey (Table 11 and Figure 13). In this particular question, the sample size deviated to 20 instead of 22 because two female students left this question blank. Students' acceptable choices are not surprising considering how varied their responses were on the mid-term and final. Students more often than not believed there was a certain way the scientific method had to be conducted, while few realized the scientific method could and sometimes would have to change. The scientific method was often a common topic in class, during both small-group and class-wide discussions. It should be noted that item 6 only included one desirable choice (Figure 12).

VOSTS survey item 8 deals with science's subjective element, and the difference between discovery and invention of a hypothesis. Students were pretty evenly divided among the three category conceptions. The pre-course survey yielded 8 undesirable choices, 4 acceptable choices, and 10 desirable choices. The post-course survey improved in six undesirable choices, seven acceptable choices, and nine desirable choices (Table 12). Again, there was no statistically significant difference between pre- and post-course surveys. These answer choices are not surprising to me in reference to student responses on their mid-term and final exams. Possible reasons for this include the fact that in class discussion students often used the terms "discovery" and "invention" interchangeably, which could have led to confusion on the true definition of the terms.

VOSTS survey item 10 identifies with McComas' (2004) core component about scientific laws and theories. Most answer choices in reference to this item were either undesirable or acceptable (Table 13). Again, there was only one desirable choice to pick

(Figure 16). Females did tend to pick more "Desirable" answers than males but not enough to be significant. Also, the answer choices did improve from pre to post course, but not enough to signify a strong course impact (Figure 17).

Survey item 12 related to sciences' relationship with politics. This can be exemplified in McComas (2004) nine core components in reference to science being a social activity. Students' choices were overwhelmingly desirable. Only 1 student picked an undesirable choice on the pre course survey with over 95% picking a desirable choice in the pre course survey, and 100% in the post-course survey, in opposition to previous findings (Aikenhead, Fleming & Ryan 1987) (Table 14). Students realized the impact science can have on a socio-political climate. This survey item shows students held correct opinions on the relationship between science and politics. The course could have confirmed what the students already knew in relation to science and politics. By the post-test, 100% of students held a "Desirable" opinion, suggesting the course changed at least one student's point of view.

In reference to the frequency of different categories of SOCS types, they stayed relatively the same from mid-term to final (Table 5). The only SOCS type that went up significantly was $SOCS_B$ by males from 8 at the mid-term and 14 at the final. $SOCS_C$ dropped overall from 22 total to 16. This drop in $SOCS_C$ possibly shows higher thought conception was not a product of course impact. Perhaps the SOCS conceptions changed because students focused more on connections rather than implications. Since the scoring value of the three different types of SOCS was the same, in reference to grades, there was no benefit to students in writing type C SOCS and they may have found it easier to write about relationships and connections (type B SOCS) that were obvious within the text, than to write implications that would have involved more original thinking on their part as opposed to quoting the textbook alone.

Though the scores on the mid-term and final were not significantly different, and the progression from $SOCS_A$ to $SOCS_C$ was not significant, evaluation of mid-term and final responses showed clear progression of thought in some students. For example, a female student on the mid-term said this about the scientific method:

> *By comparing the practice of the scientific method by the first true scientists, Gilbert and Galileo, it is evident that they set the standard on how to conduct science in an appropriate fashion. They demonstrated the need for experiments to be verifiable, repeatable, and testable by others. Both Gilbert and Galileo set the stage for future scientists to explore their studies in a more reliable fashion rather than simply relying on logic and reason as was previously done* (Gribbin, 2002).

Clear thought progression can be seen on her opinion of the scientific method on the final:

> *Science is constantly evolving and changing with the discovery of new information and ideas through the use of the scientific method to conduct experiments and make observations. When new information surfaces through the use of the scientific method, the previously accepted understanding is reevaluated and refined if necessary in light of new understandings. For example, the scientific method was used to study the model of the atom and it slowly developed and formed over many years due to the works and experiments of many scientists such as Thomson, Rutherford, and Bohr. The atomic structure model started with a very simple understanding and slowly progressed into how we view it today, the Bohr Model* (Gribbin, 2002).

It seems the teachings of the course influenced how this student viewed the impact of the scientific method. In the mid-term, she explains why the scientific method is important to scientific development yet in the final she goes on to explain the importance and role of the scientific method in discovering new scientific information. The progression of thought is clear by her realization that the scientific method could change scientific discoveries.

Another student, a male, reflected on the relationship between science and technology:

> *While reading the book, we have talked about the impact of technology on science and the scientific method. One part of science that has greatly been impacted is the science of chemistry. The lack of findings in early chemistry was not due to the inability of scientist's minds but the lack of technology. The author clearly states this when talking about the advancement of chemistry saying, "They [scientists] simply lacked the tools for the job." (242) The author hits it right on the head with this statement. When we look at the other sciences, they can be observed without needing instruments to perform an experiment, if instruments were needed they were very simple. This need for technology impacted the scientific method as well because one needs accurate data to understand if their hypothesis is correct or not as well as understand their data.*

This statement clearly shows that the student is aware of McComas (2004) core component that science and technology are related but not the same. But his perspective improves further after the final when he said this:

> *The knowledge gained through use of the scientific method can change. Like stated earlier, it seems that it changes with the inventions of new technologies but this does*

not mean that the prior knowledge is invaluable. There had to be a starting point for everything in science. I think that we see this starting point a lot in the book, specifically the predictions many scientist made. The best example of this is in astronomy and physics. Urbain Leverrier used calculations to accurately predict, "…the presence of Neptune on the basis of Newton's laws and the way in which the orbits of other planets were being perturbed by an unseen gravitational influence." (475) Then in physics, Dirac presented a wave equation for the electron and then realized the equation, "…was actually predicting the existence of a previously unknown particle, with the same mass as an electron but positive charge." (521) Although these are two very different predictions, they can be looked at as very similar. Scientists at the time lacked technology to see either of these things. Neptune was too far to see with the best telescope and a positron was too small to see with the best microscope. Both men used the scientific method in different ways but concluded that there was something out there that could not be seen. Of course with better technology their predictions were found to be correct, but I think it's important to note that jumping off point that starts the scientific method. The starting point is very important to science and the knowledge gained should not be forgotten even if it changes.

This student's response on the final, links technology further to science by linking it to the scientific method and its processes, showing clear progression of thought and the huge impact that technology has on science.

Though the scores on the mid-term and final exam, the SOCS category changes, and the VOSTS changes do not show it, thought progression and a clearer idea of what the NOS is all about can be seen in the improvement of student reflection between the mid-term and final responses.

Limitations and Future Directions

The outcomes of this study are important as they provide a good starting point for the conduct of future studies about the NOS. This study does have limitations. The total number of students participating in this study was only 22, making statistical power low. Working with human subjects also has distinctive challenges, as it is difficult to control participants' involvement with outside sources providing scientific information, such as other courses and the media. Also, attendance at the "Meaning and Nature of Science" class was not always at 100%. Discussions about the core components of the NOS cannot affect students if they are not present to hear them. It also should be noted that there is evidence that there is possible grading bias among teachers, both conscious and subconscious (Malouff, 2008). For example, if a student confided in a professor that he or she was under some sort of stress, such as financial or personal issues, a professor may be more lenient when considering this student's test response. In addition to personal student issues, a professor may have many papers to be graded, which could contribute to grade variations such as unintentional mistakes due to fatigue. These factors could be a contributing aspect in mid-term and final exam grades. In the future, it may be useful to have students use a different anonymous way of submitting their responses to discount any grading bias.

The lack of significant difference in male and female scores and VOSTS survey responses could be due to the low sample size, or the fact that males and females do not learn differently from one another, or not enough to make a statistically significant distinction (Nankervis, 2010). Studies suggest females have an edge when considering the written word, while males perform better with numerical information due to slight brain differences. Though differences were seen, the gender differences are not dependent on gender learning differences (Nankervis, 2010). There were other differences present that were not fully examined in this study. Since this course was cross-listed as a General Science course and an Honors course, the main differences could lie in the fact that some students were honors students. Many different majors were represented throughout the two semesters of this course. Students' choice of major study could have easily influenced perceptions on the mid-term, final, and the VOSTS survey. Also, other factors could account for larger differences such as race, socioeconomic status, or even age.

In the future, it would be useful to see if a larger sample size would detect any differences in course impact on gender. It would be beneficial to repeat this study with a larger sample size and combine it with these results, in order to see if any differences were to emerge. Also, it may be beneficial to examine the other differences such as race, socioeconomic status, or major, in students enrolled in the "Meaning and Nature of Science" course.

Although this study revealed no significant differences over the time period of the course and between genders, it was still useful. Learning how students come to understand the NOS and how they represent that knowledge on their mid-term and progressively on their final exam, as well as their VOSTS survey responses can shape the way the course is taught in the future.

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APPENDIX A

STUDENT INFORMED CONSENT

Consent to Participate in a Research Study within GS 4404 course

Title of the Research Project: Understanding Science through the History of Science

You are invited to participate in a research study about **how students' understanding of the nature of science develops when they study the history of science, as will be done during this GS 4404 course.**

If you agree to be part of the research study, you will be asked to **respond to the *Views On Science-Technology-Society* questionnaire at the beginning and end of this semester (as pre- and post-test). Your responses on the pre-test will be compared to those on the post-test to determine how studying the history of science in this course (GS 4404) may have influenced your understanding of various components of the nature of science.**

Participating in this study is completely voluntary. There are no risks, benefits, and rewards for participation in the study, except that by participating you will contribute to the knowledge base of how people's understanding of science changes when they study the history of science. Even if you decide to participate now, you may change your mind and stop at any time. You may choose not to **respond to any specific items on the questionnaire** for any reason, without the risk of any penalty.

If you have questions about this research study, you may contact **Ms. Sarah McNeill mcneillsc1@appstate.edu or Dr. P. M. Dass dasspm@appstate.edu**.

The ASU Institutional Review has determined that this study is exempt from IRB oversight. *I agree to participate in the study.*

______________________________________ ______________________

Student Signature Date

____

Student Name (Printed)

APPENDIX B

IRB

Exemption Request for Research with Human Participants

Instructions: ***Complete and send the request form electronically to irb@appstate.edu***.
Note: *checkboxes can be checked by putting an "x" in the box.*

Research activities are not exempt if prisoners, fetuses, or pregnant women are **targeted** for participation; if participants will be exposed to more than minimal risk; or if the research involves deception of the participant.

Section I: Study Description

1. Study Title: Understanding Science through the History of Science

2. Principal Investigator (PI) and responsible faculty member if student is the PI:
PI: Sarah McNeill
Responsible Faculty: Pradeep M. Dass
Department(s): Biology

3. Summary of research: *Please describe briefly the purpose of the research, and research question.*

This research will investigate development of undergraduate students' understanding of the nature of science as they explore the history of science in *The Meaning & Nature of Science* course (GS 4404 and HON 3515-104). Since the course is dual-listed for the Science Education Program in the Biology department and the University Honors Program (Honors College), the research focus will be on a comparison of change in understanding of the nature of science between biology secondary education students and the non-biology major honors students. The research question, therefore, is:

How does an exploration of the history of science impact science majors vs. non-science majors in shaping their understanding of the nature of science?

4. By submitting this request, the PI (and responsible faculty member if PI is a student) accepts responsibility for ensuring that all members of the research team: 1) complete the required CITI training and any other necessary training to fulfill their study responsibilities, 2) follow the study procedures as described in the IRB approved application and comply with *Appalachian's Guidelines for the Review of Research Involving Human Subjects* and all IRB communication and 3) uphold the rights and welfare of all study participants.

The parties (i.e., the IRB and the PI and responsible faculty member if PI is a student) have agreed to conduct this application process by electronic means, and this application is signed electronically by the Principal Investigator and by the responsible faculty member if a student is the PI.

My name and email address together constitute the symbol and/or process I have adopted with the intent to sign this application, and my name and email address, set out below, thus constitute my electronic signature to this application.

Sarah McNeill — PI Name

mcneillsc1@appstate.edu — PI Email address

Pradeep M. Dass — Responsible Faculty Name if PI is a student

dasspm@appstate.edu — Responsible Faculty Email address if PI is a student

5. Dissemination of Results

[*] I plan to publish (thesis, dissertation, journal, book, etc.)
[*] I plan to present off campus (conferences, etc.)
[*] I plan to present on campus (Celebration of Student Research, Capstone, etc.)
[ ] I will not publish or present outside of class assignment
[ ] Other: describe

6. Type of research, check all that apply:

[ ] Faculty Research
[*] Dissertation/Thesis/Honor's Thes
[ ] Product of Learning/ Capstone Research
[ ] Class Project – Course Number:
[ ] Other: describe

7. Source of Funding:

[**] Not Funded
[ ] Funds Awarded
[ ] Funds Pending
[ ] Federally Funded
[ ] University Funded: describe

If funds awarded/pending, provide sponsor name, Sponsored Programs number:
Attach a copy of the contract/grant/agreement.

8. What, if any, relationship exists between the researcher(s) and agencies (e.g., schools, hospitals, homes) involved in the research? *Attach appropriate approvals (e.g., letter of agreement) from agencies involved in the research.* N/A

Section II: Research Personnel

1. Enter each team member (including PI) in the table below. All members of the team must complete the required CITI training.

(Note: Personnel changes can be submitted via email with the information below. If you need additional room, add rows by: right click, insert, and then insert rows below)

Name	**Role** (e.g., PI, co-I, Research Assistant, Research Coord., Faculty Advisor, etc.)	**Receive IRB Correspondence** (Y/N)? If yes, provide preferred email address.
Sarah McNeill	PI	mcneillsc1@appstate.edu
Pradeep M. Dass	Faculty Advisor	dasspm@appstate.edu

2. Are there any known or potential conflicts of interest related to this research?

Conflict of interest relates to situations in which financial or other personal considerations may compromise or have the appearance of compromising an employee's objectivity in meeting University responsibilities.

[*] No [ ] Yes If yes, describe and explain how participants will be protected from

*		the influence of competing interests:

Section III: Participant Population and Recruitment

1. Number of participants sought: 20

2. Targeted Participant Population (check all that apply):

	Adults (>= 18 yrs old)	**	College Students (only 18 or older)
	Minors (< 18 yrs old) Age range:		College Students (under 18 may participate)
	Minorities		Cognitively or emotionally impaired
	Inpatient participants		Non-English speaking
	Outpatient participants		Employees of a profit or non-profit organization
	International research		

Section IV: Risk

Minimal risk means that the probability and magnitude of harm or discomfort anticipated in the research are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.

Assessment of level of risk:

**	This study contains no more than minimal risk.
	This study contains risks that are more than minimal.

Section V: Exempt Categories

1. **Briefly describe research procedures as they relate to participants.** *Include a summary of recruitment, type of data collected, how data will be stored and destroyed.*
2.

All students in the course will be given a survey questionnaire as pre-post test. Data is in the form of numerical responses. Survey results will be stored locked in the faculty advisor's research lab and the survey response sheets will be shredded upon the completion of research.

3. Please select the category or categories most applicable to your research and answer the question(s) associated with any selected categories:

**	**Normal Educational Practices and Settings (1)**

Research conducted in established or commonly accepted educational settings, involving normal education practices, such as (a) research on regular and special education instructional strategies, or (b) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

1a. Explain why the research procedures are normal educational practices in a commonly accepted educational setting:

The impact of the course is being assessed using a survey questionnaire.

☐ **Educational Tests, Surveys, Interviews, or Observations (2)**
Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), surveys, interviews or observation of public behavior, unless: (i) information obtained is recorded in such a manne that participants can be identified, directly or through identifiers linked to the subjects; and (ii) any disclos of an individual's response(s) outside of the research setting could reasonably place the subject at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation. [**Note:** Surveys or interviews which include minors as subjects are not included in this exempt category.]

2a. Can the information collected be linked (directly or indirectly) to participants? ☐ Yes ☐ No
2b. If the answer to 2a is yes, would an accidental disclosure of the information damage a participant's reputation, employability or financial standing? ☐ Yes ☐ No

☐ **Identifiable Subjects in Special Circumstances (Public Officials or Federal Statutes) (3)**
Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), surveys, interviews, or observations of public behavior that are not exempt under (2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) require(s) without exception that the confidentiality of the personal identifiable information will be maintained throughout the research and thereafter.

3a. Explain why the research applies to this category:

☐ **Collection or Study of Existing Data (4)**
Research involving the collection or analysis of existing data, documents, records, pathological specimer or diagnostic specimens, if such sources are a matter of public record or if the information is recorded by investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to th subjects.

4a. All of the data/specimens involved in the study have already been collected: ☐ Yes ☐ No
4b. The investigators will not record any information that can be linked directly or indirectly to participants
☐ True ☐ False

☐ **Public Benefit or Service Programs (5)**
Research and demonstration projects which are conducted by or subject to the approval of, department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under such programs; (iii) possible changes in or alternatives to such programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under such programs.

5a. Explain why the research applies to this category:

☐ **Taste and Food Evaluation and Acceptance Studies (6)**

Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U. S. Department of Agriculture.

6a. Explain why the research applies to this category:

Section VI: Informed Consent

1. Consent to participate in the research will be sought by providing (please check all that apply):

**	A statement of the purpose of the research.
**	An explanation of the procedures of the study.
**	If there are foreseeable risks, benefits to the participant, or compensation, they are explained.
**	An explanation that participation is voluntary and that there are no consequences if the subject refuses participate or decide to discontinue participation (at any time).
**	Contact information for the investigator and faculty advisor if the investigator is a student.

If any of the consent items above are not checked, please explain why it is impractical to explain this information to participants:

2. Will participants sign an informed consent? [**] Yes [ ] No

Please **send an electronic Word attachment (not scanned) of this application and any accompanying materials (e.g., informed consent, surveys, interview questions) to** **irb@appstate.edu**. Thank you for taking your time to promote ethical human participant research at Appalachian!

APPENDIX C

Views On Science Technology and Society (VOSTS) Survey

Views on Science, Technology, & Society (VOSTS) Questionnaire

1. Defining science is difficult because science is complex and does many things. But MAINLY science is:

Your position, basically: (Please read from A to K, and then choose one.)

A. a study of fields such as biology, chemistry and physics.
B. a body of knowledge, such as principles, laws and theories, which explain the world around us (matter, energy and life).
C. exploring the unknown and discovering new things about our world and universe and how they work.
D. carrying out experiments to solve problems of interest about the world around us.
E. inventing or designing things (for example, artificial hearts, computers, space vehicles).
F. finding and using knowledge to make this world a better place to live in (for example, curing diseases, solving pollution and improving agriculture).
G. an organization of people(called scientists) who have ideas and techniques for discovering new knowledge.
H. No one can define science

I. I don't understand.
J. I don't know enough about this subject to make a choice.
K. None of these choices fits my basic viewpoint.

2. Most American scientists are motivated to work hard. The MAIN reason behind their *personal* motivation for doing science is:

Your position, basically: (Please read from A to K, and then choose one.)

A. earning recognition, otherwise their work would not be accepted.
B. earning money, because society pressures scientists to strive after financial rewards.
C. acquiring a bit of fame, fortune and power, because scientists are like anyone else.
D. satisfying their curiosity about the natural world, because they like to learn more all the time and solve mysteries of the physical and biological universe.
E. solving curious problems for personal knowledge, AND discovering new ideas or inventing new things that **benefit society** (for example, medical cures, answers to pollution, etc.). Together these represent the main personal motivation of most scientists.
F. unselfishly inventing and discovering new things for technology
G. discovering new ideas or inventing new things that benefit society (for example, medical cures, answers to pollution, etc.).
H. It's not possible to generalize because the main personal motivation of scientists varies from scientist to scientist.

I. I don't understand.
J. I don't know enough about this subject to make a choice.
K. None of these choices fits my basic viewpoint.

3. The best scientists are always very open-minded, logical, unbiased and objective in their work. These personal characteristics are needed for doing the best science.
Your position, basically: (Please read from A to I, and then choose one.)

A. The best scientists display these characteristics otherwise science will suffer.
B. The best scientists display these characteristics because the more of these characteristics you have, the better you'll do at science.
C. These characteristics are not enough. The best scientists also need other personal traits such as imagination, intelligence and honesty.

The best scientists do NOT necessarily display these personal characteristics:
D. because the best scientists sometimes become so deeply involved, interested or trained in their field, that they can be closed-minded, biased, subjective and not always logical in their work.
E. because it depends on the individual scientist. Some are always open-minded, objective, etc. in their work; while others can be come closed-minded, subjective, etc. in their work.

F. The **best** scientists do NOT display these personal characteristics **any more than** the average scientist. These characteristics are NOT necessary for doing good science.

G. I don't understand.
H. I don't know enough about this subject to make a choice.
I. None of these choices fits my basic viewpoint.

4. A scientist's religious views will NOT make a difference to the scientific discoveries he or she makes.
Your position, basically: (Please read from A to G, and then choose one.)

A. Religious views do **not** make a difference. Scientists make discoveries based on scientific theories and experimental methods, not on religious beliefs. Religious beliefs are outside the domain of science.
B. It depends on the particular religion itself, and on the strength or importance of an individual's religious views.

Religious views do make a difference:
C. because religious views will determine how you **judge** science ideas.
D. because sometimes religious views may affect what scientists do or what problems they choose to work on.

E. I don't understand.
F. I don't know enough about this subject to make a choice.
G. None of these choices fits my basic viewpoint.

5. Loyalties affect how scientists do their work. When scientists work together for a company, *their loyalty to the ideals of science* (open-mindedness, honesty, sharing results with others, etc.) is replaced by a *loyalty to the company* (for example, the company is always right).
Your position, basically: (Please read from A to J, and then choose one.)

Loyalty to the ideals of science is **replaced** by a loyalty to the company:
A. because most scientists are affected by the politics involved in doing science, such as conforming to a company's viewpoint.
B. because most scientists want to keep their jobs.
C. because most scientists want the company to get ahead so they can personally make more money and get promoted.
D. because company loyalty helps most scientists work together better and achieve more success.

E. It depends on the personal qualities of a scientist. One scientist will follow the ideals of science, while the other will put the interests of the company first.

Loyalty to the ideals of science is NOT affected by a loyalty to the company:
F. because by putting the ideals of science ahead of the company, a scientist is more likely to contribute to society or achieve personal success.
G. because most scientists do research to find the real facts, even though the facts may show that the company is wrong.

H. I don't understand.
I. I don't know enough about this subject to make a choice.
J. None of these choices fits my basic viewpoint.

6. When scientists disagree on an issue (for example, whether or not low-level radiation is harmful), they disagree mostly because they do not have all the facts. Such scientific opinion has NOTHING to do with moral values (right or wrong conduct) or with personal motives (personal recognition, pleasing employers, or pleasing funding agencies).

Your position, basically: (Please read from A to J, and then choose one.)

Disagreements among scientists can occur:
A. because not all the facts have been discovered. Scientific opinion is based entirely on observable facts and scientific understanding.
B. because different scientists are aware of different facts. Scientific opinion is based entirely on a **scientist's awareness** of the facts.
C. when different scientists **interpret** the facts differently (or interpret the significance of the facts differently). This happens because of different scientific theories, NOT because of moral values or personal motives.
D. **mostly** because of different or incomplete facts, **but partly** because of scientists' different personal opinions, moral values, or personal motives.
E. for a number of reasons — any combination of the following: lack of facts, misinformation, different theories, personal opinions, moral values, public recognition, and pressure from companies or governments.
F. When different scientists **interpret** the facts differently (or interpret the significance of the facts differently). This happens **mostly** because of personal opinions, moral values, personal priorities, or politics. (Often the disagreement is over possible risks and benefits to society.)
G. because they have been influenced by companies or governments.
H. I don't understand.
I. I don't know enough about this subject to make a choice.
J. None of these choices fits my basic viewpoint.

7. Scientists publish their discoveries in scientific journals. They do this mainly to achieve credibility in the eyes of other scientists and funding agencies; thus, helping their own careers to advance.

Your position, basically: (Please read from A to J, and then choose one.)

Scientists publish their discoveries:
A. mainly to get credit for their achievements, to become better known, or to profit from any financial success. If scientists were denied these personal benefits, science would come to a standstill.
B. **both** to benefit personally from any credit, fame or fortune that a discovery may bring; **and** to advance science and technology by sharing ideas, and thus building upon each other's work.
C. mainly to advance science and technology. By sharing their ideas publicly, scientists build upon each other's work. Without this open communication, science would come to a standstill.
D. mainly for other scientists to evaluate the discovery. This criticism and checking ensure that science will advance on the basis of true results.
E. to share ideas publicly, **and** to have the discovery evaluated by other scientists.

F. mainly to help other scientists in all parts of the world. Good communication prevents wasteful duplication of effort and consequently speeds the advance of science.
G. to advance science and technology through open communication, **and** to inform the general public about the latest discoveries.
H. I don't understand.
I. I don't know enough about this subject to make a choice.
J. None of these choices fits my basic viewpoint.

8. Scientists compete for research funds and for who will be the first to make a discovery. Sometimes fierce competition causes scientists to act in secrecy, lift ideas from other scientists, and lobby for money. In other words, sometimes scientists break the rules of science (rules such as sharing results, honesty, independence, etc.).

Your position, basically: (Please read from A to H, and then choose one.)

Sometimes scientists break the rules of science:
A. because this is the way they achieve success in a competitive situation. Competition pushes scientists to work harder.
B. in order to achieve personal and financial rewards. When scientists compete for something they really want, they'll do whatever they can to get it.
C. in order to find the answer. As long as their answer works **in the end,** it doesn't matter how they got there.
D. It depends. Science is no different from other professions. Some will break the rules of science to get ahead and others will not.
E. Most scientists do **not** compete. The way they really work, and the best way to succeed, is through **cooperation** and by following the rules of science.
F. I don't understand.
G. I don't know enough about this subject to make a choice.
H. None of these choices fits my basic viewpoint.

9. A scientist may play tennis, go to parties, or attend conferences with other people. Because these social contacts can influence the scientist's work, these social contacts can influence the content of the scientific knowledge he or she discovers.

Your position, basically: (Please read from A to H, and then choose one.)

Social contacts influence the content of what is discovered:
A. because scientists can be helped by the ideas, experiences, or enthusiasm of the people with whom they socialize.
B. because social contacts can serve as a refreshing or relaxing break from work; thus revitalizing a scientist.
C. because scientists can be encouraged by people to apply or change their research to a new area relevant to the needs of society.
D. because social contacts allow scientists to observe human behavior and other scientific phenomena.

E. Social contacts do NOT influence the content of what is discovered because a scientist's work is unrelated to socializing.
F. I don't understand.
G. I don't know enough about this subject to make a choice.
H. None of these choices fits my basic viewpoint.

10. With the same background knowledge, two scientists can develop the same theory independently of each other. The scientist's individuality does NOT influence the content of a theory.

Your position, basically: (Please read from A to I, and then choose one.)

The scientist's individuality will NOT influence the content of a theory:
A. because this content is based on facts and the scientific method, which are not influenced by the individual.

B. because this content is based on facts. Facts are not influenced by the individual. However, the way a scientist **conducts an experiment** will be influenced by his or her individuality.
C. because this content is based on facts. The way a scientist **interprets the facts** will, however, be influenced by his or her individuality.

A scientist's individuality WILL influence the content of a theory:
D. because different scientists conduct research differently (for example, probe deeper or ask slightly different questions). Therefore they will obtain different results. These results then influence the content of a theory.
E. because different scientists will **think** differently and will have slightly different ideas or viewpoints.
F. because a theory's content may be influenced by what a scientist **wants** to believe. Bias has an influence.
G. I don't understand.
H. I don't know enough about this subject to make a choice.
I. None of these choices fits my basic viewpoint.

11. Scientists trained in different countries have different ways of looking at a scientific problem. This means that a country's education system or culture can influence the conclusions which scientists reach.

Your position, basically: (Please read from A to I, and then choose one.)

The country DOES make a difference:
A. because education and culture **affect all aspects** of life, including the training think about a scientific problem.
B. because each country has a different system for teaching science. The way scientists are **taught to solve** problems makes a difference to the conclusions scientists reach.
C. because a country's government and industry will only fund science projects that meet their needs. This affects what a scientist will study.
D. It depends. The way a country trains its scientists might make a difference to some scientists. BUT other scientists look at problems in their own individual way based on personal views.

The country does NOT make a difference:
E. because scientists look at problems in their own **individual** way regardless of what country they were trained in.
F. because scientists all over the world use the same scientific method which leads to similar conclusions.
G. I don't understand.
H. I don't know enough about this subject to make a choice.
I. None of these choices fits my basic viewpoint.

12. BACKGROUND: A team of scientists worked together "in private" in their lab for 3 years and developed a new theory. The team will present their theory to a group of scientists at a science conference and the team will write a scientific journal article explaining their theory (that is, the team will work "in public" with other scientists). The following statement compares *private* and *public* science.

STATEMENT: When scientists do their *private* science (for example, when they work in a lab), their thinking is open-minded, logical, unbiased and objective; just as it is when they do their *public* science (for example, when they write an article for presentation).
Your position, basically: (Please read from A to J, and then choose one.)

A. Private science is basically the same as public science. A scientist's thinking is most often open-minded, logical, unbiased and objective, in private as well as in public.
B. It depends on the individual scientist. Some scientists act differently in their private work than in their public work, while other scientists act the same.

C. In their **private** work, scientists are NOT necessarily open-minded, logical, etc. because they become very involved in their work and become sure about their ideas. Thus, private science can be different from public science.
D. In their **public** work, scientists are NOT necessarily open-minded, logical, etc. because by the time scientists go public their minds are pretty well made up, or else they need to persuade other scientists. Thus, private science can be different from public science.
E. The process of publicly discussing a presentation with other scientists makes a scientist's conclusions more objective etc., since biases will be modified by the views of other scientists. Thus, private science is different from public science.
F. Natural biases or jealousies of scientists are brought out **more** when they are in public than in private. Thus, private science is different from public science.
G. In public science there is much more pressure to follow "the rules" of public science (to appear to be open-minded, logical, unbiased and objective).
H. I don't understand.
I. I don't know enough about this subject to make a choice.
J. None of these choices fits my basic viewpoint.

13. Scientific observations made by competent scientists will usually be different if the scientists believe different theories.

Your position, basically: (Please read from A to H, and then choose one.)

A. Yes, because scientists will **experiment** in different ways and will notice different things.
B. Yes, because scientists will **think** differently and this will **alter their observations.**
C. Scientific observations will **not differ** very much even though scientists believe different theories. If the scientists are indeed **competent** their observations will be similar.
D. No, because observations are as exact as possible. This is how science has been able to advance.
E. No, observations are exactly what we see and nothing more; they are the facts.
F. I don't understand.
G. I don't know enough about this subject to make a choice.
H. None of these choices fits my basic viewpoint.

14. Many scientific models used in research laboratories (such as the model of heat, the neuron, DNA, or the atom) are copies of reality.

Your position, basically: (Please read from A to J, and then choose one.)

Scientific models ARE copies of reality:
A. because scientists say they are true, so they must be true.
B. because much scientific evidence has proven them true.
C. because they are true to life. Their purpose is to show us reality or teach us something about it.
D. Scientific models come close to being copies of reality, because they are based on scientific observations and research.

Scientific models are NOT copies of reality:
E. because they are simply helpful for learning and explaining, within their limitations.
F. because they change with time and with the state of our knowledge, like theories do.
G. because these models must be ideas or educated guesses, since you can't actually see the real thing.
H. I don't understand.
I. I don't know enough about this subject to make a choice.
J. None of these choices fits my basic viewpoint.

14. When scientists classify something (for example, a plant according to its species, an element according to the periodic table, energy according to its source, or a star according to its size), scientists are classifying nature according to *the way nature really is;* any other way would simply be wrong.

Your position, basically: (Please read from A to I, and the choose one.)

A. Classifications match the way nature really is, since scientists have proven them over many years of work.
B. Classifications match the way nature really is, since scientists use observable characteristics when they classify.
C. Scientists classify nature in the most simple and logical way, but their way isn't necessarily the only way.
D. There are many ways to classify nature, but agreeing on one universal system allows scientists to avoid confusion in their work.
E. There could be other correct ways to classify nature, because science is liable to change and new discoveries may lead to different classifications.
F. Nobody knows the way nature really is. Scientists classify nature according to their perceptions or theories. Science is never exact, and nature is so diverse. Thus, scientists could correctly use more than one classification scheme.
G. I don't understand.
H. I don't know enough about this subject to make a choice.
I. None of these choices fits my basic viewpoint.

15. Even when scientific investigations are done correctly, the knowledge that scientists discover from those investigations may change in the future.

Your position, basically: (Please read from A to G, and then choose one.)

Scientific knowledge changes:
A. because new scientists **disprove** the theories or discoveries of old scientists. Scientists do this by using new techniques or improved instruments, by finding new factors overlooked before, or by detecting errors in the original "correct" investigation.
B. because the old knowledge is **reinterpreted** in light of new discoveries. Scientific facts can change.

C. Scientific knowledge APPEARS to change because the **interpretation** or the application of the old facts can change. Correctly done experiments yield unchangeable facts.
D. Scientific knowledge APPEARS to change because new knowledge is **added on to** old knowledge; the old knowledge doesn't change.
E. I don't understand.
F. I don't know enough about this subject to make a choice.
G. None of these choices fits my basic viewpoint.

16. Scientific ideas develop from *hypotheses* to *theories,* and finally, if they are good enough, to being scientific *laws.*

Your position, basically: (Please read from A to H, and then choose one.)

Hypotheses can lead to theories which can lead to laws:
A. because an hypothesis is tested by experiments, if it **proves** correct, it becomes a theory. After a theory has been **proven** true many times by different people and has been around for a long time, it becomes a law.
B. because an hypothesis is tested by experiments, if there is **supporting evidence,** it's a theory. After a theory has been tested many times and seems to be **essentially correct**, it's good enough to become a law.
C. because it is a logical way for scientific ideas to develop.

D. Theories can't become laws because they both are different types of ideas. Theories are based on scientific ideas which are less than 100% certain, and so theories **can't** be proven true. Laws, however, are based on facts only and are 100% sure.
E. Theories can't become laws because they both are different types of ideas. Laws **describe** things in general. Theories **explain** these laws. However, with supporting evidence, hypotheses may become theories (explanations) **or** laws (descriptions).
F. I don't understand.
G. I don't know enough about this subject to make a choice.
H. None of these choices fits my basic viewpoint.

17. When scientists investigate, it is said that they follow the scientific method. The scientific method is:

Your position, basically: (Please read from A to M, and then choose one.)

A. the lab procedures or techniques; often written in a book or journal, and usually by a scientist.
B. recording your results carefully.
C. controlling experimental variables carefully, leaving no room for interpretation.
D. getting facts, theories or hypotheses efficiently.
E. testing and retesting — proving something true or false in a valid way.
F. postulating a theory then creating an experiment to prove it.
G. questioning, hypothesizing, collecting data and concluding.
H. a logical and widely accepted approach to problem solving.
I. an attitude that guides scientists in their work.
J. Considering what scientists actually do, there really is no such thing as the scientific method.
K. I don't understand.
L. I don't know enough about this subject to make a choice.
M. None of these choices fits my basic viewpoint.

18. Even when making predictions based on accurate knowledge, scientists and engineers can tell us only what *probably* might happen. They cannot tell what will happen for certain.

Your position basically: (Please read from A to H, and then choose one.)

Predictions are NEVER certain:
A. because there is always room for error and unforeseen events which will affect a result. No one can predict the future for certain.
B. because accurate knowledge changes as new discoveries are made, and therefore predictions will always change.
C. because a prediction is not a statement of fact. It is an educated guess.
D. because scientists **never** have all the facts. Some data are always missing.

E. It depends. Predictions are certain, only as long as there is accurate knowledge and enough information.
F. I don't understand.
G. I don't know enough about this subject to make a choice.
H. None of these choices fits my basic viewpoint.

19. If scientists find that people working with asbestos have twice as much chance of getting lung cancer as the average person, this must mean that asbestos causes lung cancer.

Your position, basically: (Please read from A to H, and then choose one.)
A. The facts obviously prove that asbestos causes lung cancer. If asbestos workers have a greater chance of getting lung cancer, then asbestos is the cause.

The facts do NOT necessarily mean that asbestos causes lung cancer:
B. because **more research** is needed to find out whether it is asbestos or some other substance that causes the lung cancer.
C. because asbestos might work **in combination with** other things, or may work indirectly (for example, weakening your resistance to other things which cause you to get lung cancer).
D. because if it did, **all** asbestos workers would have developed lung cancer.
E. Asbestos **cannot** be the cause of lung cancer because many people who don't work with asbestos also get lung cancer.
F. I don't understand.
G. I don't know enough about this subject to make a choice.
H. None of these choices fits my basic viewpoint.

20. Science rests on the assumption that the natural world can *not* be altered by a supernatural being (for example, a deity).

Your position, basically: (Please read from A to H, and then choose one.)

Scientists assume that a supernatural being will NOT alter the natural world:
A. because the supernatural is beyond scientific proof. Other views, outside the realm of science, may assume that a supernatural being can alter the natural world.
B. because if a supernatural being did exist, scientific facts could change in the wink of an eye. BUT scientists repeatedly get consistent results.

C. It depends. What scientists assume about a supernatural being is up to the individual scientist.
D. Anything is possible. Science does not know everything about nature. Therefore, science must be openminded to the possibility that a supernatural being could alter the natural world.
E. Science can investigate the supernatural and can possibly explain it. Therefore, science can assume the existence of supernatural beings.
F. I don't understand.
G. I don't know enough about this topic to make a choice.
H. None of these choices fits my basic viewpoint.

21. For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists *discover* scientific LAWS. Others think that scientists *invent* them. What do you think?

Your position, basically: (Please read from A to H, and then choose one.)

Scientists **discover** scientific laws:
A. because the laws are out there in nature and scientists just have to find them.
B. because laws are based on experimental **facts**.
C. but scientists invent the **methods** to find those laws.

D. Some scientists may stumble onto a law by chance, thus discovering it. But other scientists may invent the law from facts they already know.
E. Scientists **invent** laws, because scientists interpret the experimental facts which they discover. Scientists don't invent what nature does, but they do invent the laws which **describe** what nature does.
F. I don't understand.
G. I don't know enough about this topic to make a choice.
H. None of these choices fits my basic viewpoint.

22. For this statement, assume that a gold miner "discovers gold" while an artist "invents" a sculpture. Some people think that scientists *discover* scientific HYPOTHESES. Others think that scientists *invent* them. What do you think?

Your position, basically: (Please read from A to I, and then choose one.)

Scientists **discover** an hypothesis:
A. because the idea was there all the time to be uncovered.
B. because it is based on experimental **facts**.
C. but scientists invent the **methods** to find the hypothesis.

D. Some scientists may stumble onto an hypothesis by chance, thus discovering it. But other scientists may invent the hypothesis from facts they already know.

Scientists **invent** an hypothesis:
F. because an hypothesis is an interpretation of experimental **facts** which scientists have discovered.
F. because inventions (hypotheses) come from the mind — we create them.
G. I don't understand.
H. I don't know enough about this topic to make a choice.
I. None of these choices fits my basic viewpoint.

23. For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists *discover* scientific THEORIES. Others think that scientists *invent* them. What do you think?
Your position, basically: (Please read from A to I, and then choose one.)

Scientists **discover** a theory:
A. because the idea was there all the time to be uncovered.
B. because it is based on experimental **facts**.
C. but scientists invent the **methods** to find the theories.

D. Some scientists may stumble onto a theory by chance, thus discovering it. But other scientists may invent the theory from facts they already know.

Scientists **invent** a theory:
E. because a theory is an interpretation of experimental **facts** which scientists have discovered.
F. because inventions (theories) come from the mind — we create them.
G. I don't understand.
H. I don't know enough about this topic to make a choice.
I. None of these choices fits my basic viewpoint.

24. Scientists in different fields look at the same thing from very different points of view (for example, H^+ causes chemists to think of acidity and physicists to think oI protons). This makes it difficult for scientists in different fields to understand each others' work.
Your position, basically: (Please read from A to H, and then choose one.)

It is difficult for scientists in different fields to understand each other:
A. because scientific ideas depend on the scientist's **viewpoint** or on what the scientist is used to.
B. because scientists must make an effort to understand the language of other fields which overlap with their own field.

It is fairly **easy** for scientists in different fields to understand each other:
C. because scientists are intelligent and so they can find ways to learn the different languages and points of view of another field.
D. because they have likely studied the various fields at one time.
E. because scientific ideas overlap from field to field. Facts are facts no matter what the scientific field is.
F. I don't understand.
G. I don't know enough about this topic to make a choice.
H. None of these choices fits my basic viewpoint.

Vita

Sarah Catherine McNeill was born in Chapel Hill, North Carolina in 1988, and her parents are Harold and Rhonda McNeill of Sanford, North Carolina. She attended Broadway Elementary School, East Lee Middle School, and graduated from Lee Senior High School in 2006. She attended East Carolina University where she obtained her Bachelor of Science degree in Biology in December 2009. In the fall of 2010, she was accepted to Appalachian State University to begin Master of Science degree in Biology. Her MS was awarded in August of 2013.