ABSTRACT

Title of Dissertation: A COMPARATIVE STUDY OF COMMUNITY COLLEGE AND UNIVERSITY STUDENTS' VIEWS ON SOCIO-SCIENTIFIC ISSUES AND SOCIAL AND CULTURAL ASPECTS OF THE NATURE OF SCIENCE

Sunday A. Iwalaiye, Ed.D. October 2019

Dissertation chaired by: Glenda Prime, Ph.D.

Dean of the School of Education and Urban Studies

The goals of this research are to determine the views of college students from three selected institutions, large suburban community college in the Northeast, large urban historical black college in the Northeast, and large Catholic university in the Northeast on the Nature of Science (NOS), and socio-scientific issues (SSIs), and to investigate whether there are statistically significant differences in the NOS and SSI views of students in these institutions. The study also explored the correlations between NOS and SSI views of these students. The NOS views of these students were measured with Student Understanding of Science and Scientific Inquiry (SUSSI) and the SSI views of these students were measured with Scientific Habits of Mind Survey (SHOMS).

This study employed quantitative methods using descriptive, causal-comparative, and correlation techniques. The independent variable is the institution type as represented by these three selected colleges and the dependent variables are

the scores of students on the NOS tenets and SSIs from the two instruments (SUSSI and SHOMS). The institution was used in this study as a proxy for race/culture since the populations in those schools are either majority white students or minority students.

The study's findings showed that there were no significant differences in the SSI means between students attending the three higher education institutions. There were significant differences in the NOS means between students attending the three higher education institutions. The t-test showed that the significant difference in the NOS means observed between the three groups of students was between the community college and historically black college. There were no correlations between the NOS and SSI views of students from either of the institutions.

A COMPARATIVE STUDY OF COMMUNITY COLLEGE AND UNIVERSITY STUDENTS' VIEWS ON SOCIO-SCIENTIFIC ISSUES AND SOCIAL AND CULTURAL ASPECTS OF THE NATURE OF SCIENCE

by

Sunday Adebayo Iwalaiye

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has been approved

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DISSERTATION COMMITTEE APPROVAL:

______________________, Chair
Glenda M. Prime, PhD

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Mark J. Hubley, PhD

____
Vanessa Dodo Seriki, PhD

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DEDICATION

First and foremost, I give honor and glory to God for his abundant grace in my life that saw me to the end of the most rigorous and challenging academic journey of my life to date. Secondly, I acknowledge the untiring support, words of encouragement, and personal sacrifice of my wife that allowed me to keep moving and pushing along despite all the odds on the way in this intellectual journey of my life and professional career.

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CHAPTER 1

Introduction

Background

One of the main goals of science education worldwide is to help students develop scientific literacy. The term scientific literacy includes foundational knowledge of scientific concepts, critical-thinking skills, problem-solving skills, understanding of current socio-scientific issues (SSIs), and knowledge of key tenets of the Nature of Science (NOS), (Program for International Student Assessment [PISA, 2015]. SSIs are controversial social issues that are connected to the scientific enterprise that include the risks and benefits of science and often do not have clear-cut single solutions. The inclusion of SSIs in the curriculum can serve as tools or strategies for the promotion of scientific literacy in science education (Zeiler & Nicols, 2009). SSIs expose science students to the real-world impacts and applications of science. These SSIs require students to use their scientific knowledge and moral reasoning to address them (Sadler, Barab, & Scott, 2007). Examples of current SSIs of our time include questions around genetic engineering, climate change, vaccines, animal testing for medical purposes, and oil drilling in national parks, among many others.

In the science education literature, one of the most studied aspects of scientific literacy is NOS. According to Lederman (1992), "NOS refers to the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent in scientific knowledge and its development" (p. 331). There is no one standard definition of NOS, but there is a consensus among science education researchers on the main tenets of NOS.

The American Association for the Advancement of Science (AAAS), in its highly regarded Project 2061 report of 1995 said that the Nature of Science includes a scientific world view, scientific methods of inquiry, and the nature of the scientific enterprise (Primack, 1990). The teaching of NOS concepts has been emphasized in major education reform efforts in K-12 science education in America through the Next Generation Science Standards (NGSS), as well as in other documents in many other countries around the world. Despite these reform efforts, some recent studies that examined the NOS views of undergraduate science and non-science majors still claim that undergraduate students have similar views with high school science students which are described as naïve views of the basic tenets of NOS. Research into NOS views of undergraduate students, particularly science majors is very limited

Many of the NOS studies have focused on K-12 teachers and students. Studies of NOS views of community college students are even fewer. Studies that evaluated the NOS views of minority students in a community college setting do not appear to exist in the science education literature. This dissertation is a comparative study of community college and university students' views on socio-scientific issues, and socio-cultural aspects of the Nature of Science.

Science is a human enterprise that is driven primarily by culture or cultural beliefs. Contrary to common belief, science never starts with neutral observations (Popper, 1992). The non-objective nature of scientific knowledge implies that scientific claims, scientific methods, and scientific findings that establish scientific knowledge are all influenced by the scientists' perspectives, values, community biases, and personal interests. Objectivity in the scientific enterprise is not possible. Human biases are part and parcel of scientific enterprise in real life. It is then reasonable to conclude that students from different cultures, social backgrounds, varied educational experiences, and demographics may have different views of the NOS and SSIs. Prior educational experiences of students can be a major factor in shaping their views of the NOS and SSIs. This study compared the NOS and SSI views of community college and university students. The community college sample for this study consisted of mainly minority students and the university sample was made up of White and minority students. Minority students include African-Americans and immigrants. This comparative study could address the factors that shape students' views of the NOS and SSIs since the two comparison groups seem likely to represent different cultural and demographic backgrounds. The findings of this study may also contribute new knowledge to the existing literature concerning the NOS and SSI views of minority students in particular, and White undergraduate students in general that enrolled in an introductory astronomy course.

I chose an introductory astronomy course for three reasons. Firstly, astronomy is a science course that comes early in the higher education academic programs and is taken by students with different academic majors and educational preparations (science and non-science), in order to meet the mandatory requirement of having a college course in science (See Appendix F). Secondly, students are fascinated with astronomy as one of the branches of science. Colleges do not require students to have any pre-requisite science courses in astronomy. It seems likely that students' prior cultural experiences and not prior science courses would likely be the strongest influence on the views of the students taking this course. This astronomy course is very likely to be influenced by students' experiences and not directly by other science courses. Thirdly, this type of science course may likely attract students who are fascinated by nature and its elements, such as, planets, stars, and galaxies.

I compared the NOS and SSI views of the students who enrolled in astronomy courses at a large suburban community college in the Northeast, large urban historical black university in the Northeast, and large Catholic university in the Northeast. There are fundamental differences in the admission requirements of students who attend community colleges and those who attend four-year colleges. This community college is a two-year institution that educates primarily minority and immigrant students and awards associate degrees. Admission to community colleges requires lower high school grade point average (GPA), American College Testing (ACT) and Scholastic Assessment Test (SAT) scores when compared to the four-year universities. The black historical college is a four-year university that educates mainly minority and international students, and the Catholic institution is a four-year private university that educates mainly White students. The Catholic university and black historical college award undergraduate and graduate degrees.

The Basic Tenets of Nature of Science

Beyond the general characterizations of NOS, there is no consensus at the moment that exists among philosophers and historians of science, scientists, and science educators on a specific definition of NOS (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). However, the main tenets of NOS that are generally accepted and used by science education researchers worldwide are the following:

1. Scientific knowledge is tentative and not absolute.
2. Not all scientific knowledge is based on experimentation (e.g., astronomy).
3. Scientific knowledge is based on empirical data.
4. Scientific knowledge is subjective in nature.

5. Creativity and imagination drive scientific innovation.

6. There is no one standard scientific method in the world.

7. The contributions to the development of scientific knowledge came from scientists worldwide.

8. Economics, politics, social issues, and culture drive the direction of science in every society.

9. The laws and theories of science are not the same and are not hierarchical.

10. Science (pure) and technology (applied science or engineering) are not the same thing.

11. Observation and inference are different (Lederman, Lederman, & Antink, 2013).

The basic tenets of NOS in detail are reflected as follows:

1. The history of science reveals both evolutionary and revolutionary changes. With new evidence and interpretation, old ideas are replaced or supplemented by newer ones. The tentative nature of scientific knowledge implies that scientific knowledge is not permanent. Scientific knowledge may be abandoned or modified in the light of new evidence, new technology, or reconceptualization of prior evidence, and knowledge. An example is the recent observation of Pluto with more advanced technology by the NASA space shuttle in 2015. The new technology has now given us a better understanding of this unique planet in our solar system. The NASA space

machine was equipped with new technology that took better pictures of Pluto leading to new insights about the geology, composition, and atmosphere of this dwarf planet.

2. Not all scientific knowledge is based on experimentation. For example, the scientific knowledge that is created in the fields of astronomy and quantum physics did not come from scientific experiments. The scientific knowledge in astronomy comes from the observation and measurement of the properties of celestial bodies using ground-based telescopes, and manned and unmanned space machines. Experimentation with uncontrolled variables is possible in astronomy. Scientific knowledge in quantum physics is based on the computer and mathematical modeling of the microscopic interactions between micro-particles at the atomic levels inside atoms.

3. Scientific knowledge is empirically-based, and it is derived from the observation of our physical or natural world. The data can be quantitative or qualitative. Quantitative data are collected through measurements and the use of tools and instruments. They are numerical in nature. Qualitative data are descriptions of the observations that are made.

4. Scientific knowledge is subjective in nature because it is theory-laden. The theory-ladeness of observations means that any observation that is made about our natural world by any scientist is normally based on the prior understanding of some existing theories and concepts. It will be difficult for another scientist to understand this observation if that scientist does not know about the theories and concepts that were employed for the observation or disagreed with those theories and concepts that were used. Science as a human enterprise is non-objective. The human biases of scientists are reflected in their observations of our natural world (Popper, 1992). The subjective

nature of scientific knowledge derives from the fact that findings reflect the scientists' viewpoints, personal interpretations given to those scientific findings, cultural influences, and areas of interest.

5. Scientific innovations, such as the methods for data collection, designing of experiments, analysis, and interpretation of data (human-invented explanations), are all based on the creativity and imagination of the scientists. Each scientist uses his or her imagination and creativity in the practice of science. The development of the first widely recognized Periodic Table of Elements in 1869 by the Russian chemist, Dimitri Mendeleyev is a good example of the use of imagination and creativity in the practice of science.

6. There is no rigid or a single universal step-by-step scientific method for doing science. Scientists share certain values in doing their work, such as reliance, observations, rational argument, inference, skepticism, peer review, and replicability of work. The scientific method that is employed in the practice of science is unique to the scientist that is involved. However, scientific findings should be replicable by other scientists (Lederman et al., 2013).

7. The history of science shows clearly that the major contributions to the development of science came from men and women all over the world. These men and women represent different races, cultures, languages, religions, and nationalities. Albert Einstein who developed the theory of relativity in physics was a Jew. Galileo Galilei, the father of experimental physics, was Italian.

8. Money that is needed to fund scientific enterprise and politics drive the direction of scientific research. Scientific work requires funding to get done. The money that is needed to practice science has to come from governments or private funding agencies.

The money that is released for scientific work is based on the priorities and interests of the funding agencies. For example, at the moment money is pouring into research worldwide that is focused on the cure of the disease HIV/AIDS and the prevention of terrorist attacks.

9. Laws and theories of science are two different types of scientific knowledge that are equally needed to explain scientific findings. Scientific theories are well-established, highly substantiated, and internally consistent systems of explanations (Suppe, 1977). Theories are formed to explain the hypotheses that have been tested again and again that continue to produce the same outcome. Theories are based on the available scientific evidence and they are tentative in nature. Theories could be modified to reflect new scientific evidence, or they could be discarded and then replaced with new theories. Scientific laws predict what will happen in nature when certain required conditions are met. Scientific laws are also tentative in nature and may change in the face of new scientific findings. For example, the inadequacies in Newton's laws of motion in physics at the microscopic level of matter were made adequate by Albert Einstein's law of relativity that was developed 100 years later.

10. While science and technology do impact each other, basic scientific research and scientific knowledge are not directly concerned with the practical outcomes, but rather with gaining an understanding of the natural world each for its own sake. Science is the creation of knowledge about our natural world and technology is the application of scientific knowledge to address the needs of humanity. The scientific knowledge of force and motion is used by engineers to build automobiles, bridges, tunnels, aircraft, rockets and space machines.

11. Observations and inferences are different. Observation of our natural world is done with the use of our five human senses of seeing, hearing, smelling, tasting, and feeling. Our five human senses are not adequate to observe our natural world at the microscopic level or from extreme distances. Scientific tools such as microscopes and telescopes are employed to support our senses in the observation process. Observation is descriptive and measurable. Some observations are measurable by quantitative methods, while other phenomena must be described qualitatively. Inference in science is the meaning that is given to the observation. Inference in science is based on prior knowledge and experience of the observer. Different inferences may be made from the same observation by different observers. For example, two observers may describe what they see in the same object differently in terms of the object's physical attributes.

Hull (1998) stated that:

> An understanding of the critical distinction between observation and inference is precursor to making sense of a multitude of inferential and theoretical entities and terms that inhabit the world of science. Examples of such entities include atoms, molecular orbitals species, genes, photons, magnetic fields, and gravitational forces. (p. 146)

Science education researchers have reached a consensus on the main tenets of NOS, but continue to be divided on the best method that can be employed for assessing students' NOS views. This division on the assessment methods and their validity led science education researchers to develop different NOS instruments. The first assessment instruments were multiple choices in nature and the newer instruments are open-ended types.

Theoretical Framework

Science is part and parcel of the social and cultural traditions of societies. People from different cultures contribute to the development of scientific knowledge. As a human endeavor, the practice of science is guided by the society and culture in which science practitioners reside. Cultural values of each society determine how science is done, explained, and received. Science is not an objective field of human knowledge, but an enterprise that is driven by cultures and social experiences. Scientific investigations never start with neutral observations (Popper, 1992). Scientific claims, methods, and findings that translate into scientific knowledge are influenced by the perspectives, values, community biases, and personal interests of the scientists. It is reasonable to conclude that students of science from different cultures, social norms, and demographic groups will have different views of NOS and SSIs. The educational experiences of students of science can greatly influence their views of NOS and SSIs as well.

This study of the possible impact of cultural factors on NOS and SSI views of community college and university students is framed by the work of Lev Vygotsky. Vygotsky's theory of cognitive development suggests that sociocultural factors, especially language, are the main contributors to cognitive development.

Many socio-cultural theories exist in the field of education. Lev Vygotsky's sociocultural theory is a highly sought after theory in the field of cognitive development in psychology. Vygotsky saw language as the main tool for communications and shaping individual thought, (Lantolf, Thorne, & Poehner, 2015). Vygotsky's theory serves as the theoretical framework for this study.

Vygotsky's sociocultural theory looks at the important contributions that society makes to individual cognitive development. The theory stresses the interaction between people and the culture in which they live. Lev Vygotsky, a Russian social psychologist, was one of the pioneers of sociocultural theory (Lantolf, et al., 2015). In Vygotsky's sociocultural theory, the content of a person's knowledge is influenced by the culture, which includes language, beliefs that are important to that culture, and skills considered important in that culture, such as computer skills, communication skills, and collaboration skills.

Lev Vygotsky emphasizes that both culture and social aspects of life affect cognitive development. The social environment, according to Vygotsky, leads to social interactions, social relationships, and social artifacts, such as signs, symbols, and linguistic terms (Lantolf et al., 2015). Factors such as textbooks, teachers' beliefs, and tools can influence the learner's construction of knowledge. Artifacts shape and transform the learner's mental processes.

The idea that cognitive development and acquisition of new knowledge is shaped by one's cultural background and prior experiences provides support for this study, which seeks to explore differences in NOS and SSI views of students of presumably different cultural backgrounds.

Studies that evaluated the NOS views of undergraduate students exist in science education literature. But these studies did not look into the impacts that race, social settings, and cultures of these students had on their NOS views (Miller, Montplaisir, Offerdahl, Chang, & Ketterling, 2010; Pace & Farrugia, 2014). Research on the NOS views of minority students in a community college setting that considered the impacts of the social life and cultures of these students on their NOS views did not exist in science education literature. The students from these three institutions who were participants in this study differ culturally and demographically. The current demographics of the students from these three research sites are included in the appendix.

The Catholic university educates primarily white students. The term “white” refers to a person having origins in any of the original peoples of Europe, the Middle East, and North Africa. Each culture has its unique beliefs, fears, hopes, and prejudices (Kirmayer, Rousseau, & Lashley, 2007). White Americans have a specific unique set of beliefs, fears, hopes, and prejudices that reflect their cultural practices (Kirmayer et al., 2007). Culture has the power to shape or influence how we perceive ourselves and interact with the world. Culture is the primary lens through which we organize our cognitive reasoning and our emotional response (Kirmayer et al., 2007). The black historical college and suburban community college educate mainly minority students. Minority students are non-white, ethnic groups in America with partial or total ancestry from the black racial groups of Africa or foreign countries. The cultural beliefs, fears, hopes, and practices of the minority groups are quite different from those of white Americans. The understanding of the SSI and NOS views of these three samples from a socio-cultural perspective could create new knowledge in the field of science education.

Science is culturally driven and Vygotsky’s sociocultural theory emphasizes the impacts of culture and social setting on an individual’s cognitive development. Therefore, it is highly probable that the NOS and SSI views of students from the three research centers are shaped by their diverse cultures, social settings, and demographics. NOS and SSI are fundamental constructs in science education for the promotion of scientific literacy. There are two main rationales that I considered for looking at the correlation between NOS and SSI views of these students. Firstly, SSIs offer a way for students to explore the basic tenets of NOS in a deeper way than the traditional way of teaching science. Secondly, SSIs expose students to the deep connections between culture and the impacts of science on the society where science is practiced. Lev Vygotsky's sociocultural theory serves as the rationale for examining the differences between community college and university science students' views on socio-scientific issues, and the sociocultural aspect of the Nature of Science.

Instruments

Scales from two different instruments were combined for this study. The first instrument is the 2006 revised Student Understanding of Science and Scientific Inquiry (SUSSI). This version of SUSSI was created by Liang et al. (2006). The SUSSI was used to measure students' NOS views (See Appendix A). The items that were used from the SUSSI for this study came from section four of the instrument. Section four deals with the social and cultural part of the NOS tenets. This section has five Likert-type items and a free-response question. The SUSSI has a reliability value of 0.67 on Cronbach's Alpha for studies done in America. The consistency of the alpha values across the three samples (America, China, and Turkey) suggests that SUSSI can be used as a reliable assessment tool in different cultural settings (Liang et al., 2006). The second instrument for this study is the Scientific Habits of Mind Survey (SHOMS) developed by Gauld (2005). The SHOMS was used to measure students' SSI views (See Appendix B). It has thirty-two Likert-type items that cover the main socio-scientific issues of our time. Ten items from SHOMS were selected for this study. These ten selected items are related to the prevailing socio-scientific issues of the day in America. The internal reliability of the instrument based on Cronbach's alpha is 0.73 (Calik & Coll, 2012).

The SHOMS was validated by administering it to two cohorts of pre-service science teachers: primary science teachers with little science background or interest (n = 145), and secondary school science teachers (who also were science graduates) with stronger science knowledge (n = 145). Face validity was confirmed by the use of a panel of experts and a pilot study employing participants similar in demographics to the intended sample. Statistical data and other data gathered from interviews suggest that the SHOMS proved to be a useful tool for educators and researchers who wish to investigate the scientific habit of mind for a variety of participants. Face validity is the degree to which an instrument appears to measure what it is supposed to measure. Face validity is easy and quick to develop and use. It is also the weakest form of validation. The statistical data from interviews is a way of strengthening the face validity of SHOMS (Calik et al., 2012).

Statement of the Purpose

The purpose of this research was to determine the NOS and SSI views of students in the three selected institutions and to investigate whether there are statistically significant differences in the NOS and SSI views of students in these institutions. The study also explored the correlations between NOS and SSI scores for these students. The NOS views of these students were measured by SUSSI and the SSI views of these students were measured by SHOMS.

Significance of this Study

The understanding of NOS tenets by students will assist them in making informed decisions about the SSIs of our time in the development of scientific literacy, which is the primary objective of science education. This comparative study has the potential to reveal how students' racial backgrounds and educational experiences might be related to their views of NOS and SSIs. The study provides information on the relationship between NOS and SSIs which potentially could provide some indication about the possible usefulness of SSIs as a context for teaching NOS.

Research Questions

Comparative Research

(1.) Are there statistically significant differences in SSI scores of students attending the three higher education institutions?

(2.) Are there statistically significant differences in NOS scores of students attending the three higher education institutions?

Correlational Research

(3.) Is there a statistically significant relationship between SSI and NOS scores for students at the three higher education institutions?

Definition of Terms

1. Minority students are non-White, ethnic groups in America with partial or total ancestry from the Black racial groups of Africa or foreign countries.

2. White students are an ethnic group in America with European origin or ancestry.

3. International students are not American citizens, but foreign nationals studying in America's colleges and universities on a temporary student visa program.

Delimitations and Limitations

The study did not evaluate the students' views on all the main aspects of the NOS tenets. The NOS tenets for this study are limited to the social and cultural aspect of NOS since this is the aspect of NOS deemed most likely to be impacted by a student's cultural background. The two instruments for this study, SUSSI, and SHOMS have lower reliability because I extracted items from the original instruments.

CHAPTER II

Review of the Literature

Introduction

The purpose of this research was to determine the NOS and SSI views of students at the three selected institutions and to investigate whether there are statistically significant differences in the NOS and SSI views of students in these institutions. The study also explored the correlations between NOS and SSI scores for these students. The NOS views of these students were measured by SUSSI, and the SSI views of these students were measured by SHOMS. This chapter described studies that evaluated the NOS and SSI views of undergraduate science and non-science majors. The review covered the period from 2000 to 2017.

What the Research Says About College Students' Views of NOS Tenets

Research showed that there is no significant difference in the contemporary understanding of NOS tenets among undergraduate science and non-science majors. Views of the NOS held by undergraduate science and non-science majors have been categorized as naïve, transitional, and informed (Miller, Montplaisir, Offerdahl, Chang, & Ketterling, 2010; Pace & Farrugia, 2014). Students who possess naïve views of NOS have no knowledge of the basic tenets of NOS. The NOS views of students categorized as transitional are just forming or developing. Students with informed views of NOS have the basic knowledge of the main tenets of NOS (See Appendix G).

According to Miller et al. (2010), "Results from this study provide evidence that undergraduate students in Environmental Science (non-majors) and Biology (major) have similar views of NOS, ranging on average from naïve to somewhat informed" (p. 47). These studies show that greater exposure of students to science courses does not have any significant effect on students' views of NOS tenets. Students showed a poor understanding of the following NOS tenets: theory and law, social and cultural aspects of science, and how scientific knowledge is generated by scientists. The teaching of the concepts of NOS was never emphasized in high school science curricula in America until recently through the major education reform efforts in K-12 science education. This reform is now reflected in the Next Generation Science Standards (NGSS).

Generally speaking, university science courses tend to emphasize science content knowledge over NOS tenets. Science and non-science majors are both impacted by the undergraduate science curriculum that focuses on science content knowledge over NOS tenets. One of the NOS tenets that college students did poorly on is the social and cultural aspect of science (Miller et al., 2010). Science is a cultural enterprise that is driven by the culture of the society where science is practiced. It is reasonable to infer that the cultures and social norms of these undergraduate students may impact their views of NOS. My study investigated how culture may impact students' views of NOS. This issue was not addressed previously in their studies (Miller et al., 2010; Pace et al., 2014).

Research in science education showed that exposing students to courses on the history of science (HOS) did not necessarily raise their conceptions of NOS tenets in the absence of any explicit instructional approach to teaching science. Few and limited changes in the undergraduate students' views of the NOS tenets were seen for students that took and completed courses of history of science, (Abd-El-Khalick & Lederman, 2000). The study did not lend empirical support to the intuitively appealing assumption held by many science education researchers that coursework in HOS will enhance students' NOS views. The findings of (Abd-El-Khalick et al., 2000) agreed with other similar studies (Miller et al., 2010; Pace et al., 2014) that showed undergraduate students' views of NOS tenets are inadequate.

Undergraduate science majors demonstrated misconceptions and naïve views of NOS main tenets, such as scientific knowledge, laws, and theories. Students viewed science as a discipline that is based on data, designed to prove scientific facts, and believed that scientific knowledge that has survived the testing process, or has accumulated enough evidence, acquires the status of scientific law and is no longer a scientific theory. In their view, a scientific theory is inferior to a scientific law (Liang & Tsai, 2010; Parker, Krockover, Lasher-Trapp, & Eichinger, 2008; Samara, 2015). These studies agreed with the studies done by (Miller et al., 2010; Pace et al., 2014) that concluded undergraduate students have poor understanding and many misconceptions about the main concepts of NOS.

According to Parker et al. (2008), "Activities in the laboratory that allow students to confirm scientific laws for themselves (such as Newton's laws or the ideal gas laws) may mislead students to believe that this is how science is performed" (p. 1686). The laboratory activities that allow students to verify scientific laws and theories may mislead students into misconceptions about NOS and to believe that scientific knowledge is not tentative in nature and that scientific laws and theories are set in stone.

The traditional laboratory experimental setup looks like a cookbook that explains how to prepare different meals by strictly following a set of rules. This traditional approach of doing laboratory experimentation in science overshadows the place of scientific imagination and creativity which are both needed in the practice of science. Traditional laboratory activities overlook various steps that are taken by scientists in the development of those theories and laws of science needed to explain different scientific findings. These scientific findings are never set in stone but can be reviewed and revised constantly in the face of new or contradicting scientific evidence. The concepts of using imagination and creativity to do science which is part of NOS are not addressed in the traditional laboratory activities in the college science curriculum.

Although religion is not explicitly one of the NOS tenets, the history of science shows that religious beliefs continue to be at loggerhead with scientific knowledge and its development. Religion is based on faith (set of beliefs), while science is based on physical evidence through observation, experimentation, and data analysis. The findings from a study showed clearly that half of the undergraduate biology majors understood the main difference between science and religion, but demonstrated naïve views of NOS (Karakas, 2008).

The publication from the National Academy of Sciences on Science, Evolution and, Creationism in (2008) supports the view that science and religion are independent:

> Science and religion are based on different aspects of human experience. In science, scientific explanations must be based on evidence drawn from examining the natural world. Scientifically based observations or experiments that conflict with an explanation always lead to the modification or abandonment of that explanation. Religious faith, in contrast, does not

> depend on empirical evidence, is not necessarily modified in the face of conflicting evidence, and typically involves supernatural forces or entities. Because they are not a part of nature, supernatural entities cannot be investigated by science. In this sense, science and religion are separate and address aspects of human understanding in different ways. Attempts to put science and religion against each other create controversy where none needs to exist. (p. 5)

Undergraduate physics and chemistry majors have less sophisticated beliefs in the theory-laden and cultural-dependent aspects of science than the non-science majors. Science majors might have been exposed to the instructional background where scientific knowledge was described as objective and universal (Eshach, Hwang, Wu, & Hsu, 2013; Liu & Tsai, 2008; Marchlewicz & Wink, 2011). The history of science shows clearly that the major contributions to the development of science came from men and women all over the world representing different cultures. Science is driven by the culture of the society where science is practiced as a human enterprise. Cultural beliefs, norms and practices all impact the direction of science and what scientists may decide to investigate or to study. This makes science not to be an objective discipline in nature, but subjective, and full of human biases. Undergraduate science curricula that do not address the roles and impacts of cultures in the development of scientific knowledge will not expose students to the theory-laden and cultural dependent aspects of scientific knowledge in its development.

Scientific investigations do not begin with neutral observations (Popper, 1992). Claims, methods, and findings in science that translate into scientific knowledge are always influenced by the perspectives, values, community biases, and personal interests of the scientists doing the science. It is reasonable to conclude that students of science from different cultures, varied social experiences, and demographic groups will have different views of NOS. The educational experiences of students of science can greatly influence their views of NOS, which my study investigated.

Science education worldwide focuses on how to help students develop scientific literacy. Poor understanding of scientific literacy by students directly impacts their understanding of NOS. Scientific literacy is made up of the knowledge of science, methods of science, and the nature of science (Bybee, McCrae, & Laurie, 2009). Age and level of the study did not change students' understanding of scientific literacy. Sex was found to have contributed most and significantly to the observed variations in the level of the scientific literacy of undergraduate chemistry majors (Garner-O'Neale, Maughan, & Ogunkola, 2013).

Science and science careers are still male-dominated fields. This may explain why a significant difference was observed in the understanding of scientific literacy by undergraduate chemistry majors. Countries with cultures where gender equality in science is not practiced will continue to put women at a disadvantage in the fields of science, science career, and in the understanding of scientific literacy, of which NOS is part and parcel. My study investigated how the cultural experiences of college students impact their views of NOS which is rare in science education research.

The impacts of the Undergraduate Science Curriculum on Students' SSI Views

Research showed that university undergraduate science curricula are not designed to encourage students to participate effectively in the investigation of SSIs that require students to use multiple reasoning modes and interdisciplinary thinking (Yao Liu, Shun Lin, & Tsai, 2010). Undergraduate science courses tend to emphasize science content knowledge over socio-scientific issues. The knowledge of science consists of facts, definitions, concepts, theories, and laws of science. The SSIs are the products and the impacts that science has made on humans and the environment, as well as the moral and social issues that are associated with the practice of science in different cultures around the world.

Undergraduate science students that took science courses that were taught with argument-based instructional approaches showed superior levels of argument on SSIs when compared with students who took similar science courses that were taught with the traditional approach of using lecture (Grooms, Simpsom, & Golden, 2014). The use of scientific argumentation promotes science literacy, critical-thinking skills, problem-solving skills, and students' views of ongoing SSIs. One of the effective strategies for promoting scientific literacy is the use of SSIs for instruction. Students use the content knowledge of science to address the social and moral issues that are associated with the use and practice of science.

Science and its practice are both woven in the cultural norms of the practitioners of science. One reasonable assumption to make is to believe that the cultures and social norms of the students of science will impact their views of the social and moral questions that surround the practice of science and the products of the scientific enterprise. Research that evaluated the SSI views of undergraduate students is rare in science education literature. Studies that evaluated SSI views of minority students are almost non-existent. This study was designed to address this perceived knowledge gap in science literature by evaluating the community college and university students' views on SSIs.

Results of Explicit and Implicit Approaches to the Teaching of College Science Courses

Research in science education showed that no single pedagogy or instructional design made undergraduate science students in the college biology laboratories better in their understanding of five selected NOS tenets. The five NOS tenets used in this study are tentativeness of scientific knowledge, observation and inference, creativity, the theory-laden NOS, and the scientific method. The research suggested that instructional approaches for teaching college science courses should be selected based on the desired NOS learning objectives to be addressed in any particular lesson (Schussler, Bautista, Link-Perez, Solomon, & Steinly, 2013).

The common pedagogical approaches that are employed by college instructors in the delivery of science instruction are the direct instruction or implicit instructional method. The direct instructional approach is very different from the explicit instructional method. Research shows that explicit instructional methods do increase students' understanding of NOS tenets. Explicit instruction in NOS is advocated by Lederman (1998) and other NOS researchers and has evidential support for its effectiveness. Not to be confused with direct instruction, in the explicit approach the NOS is used as a context for the generation and learning of scientific knowledge, permeating the curriculum (Rannikmae & Holbrook, 2006; Tuberty, Dass, & Windelspecht, 2011). It takes purposeful instructional planning, integration, and discussion of the interplay of the NOS along with the scientific knowledge or content to be learned.

Implicit teaching is the traditional lecture and laboratory approach to science instruction without directly addressing and reflecting upon the tenets of NOS. Explicit teaching of NOS refers to the purposeful design of lectures, activities, and laboratory work to directly address the main tenets of NOS. Explicit teaching of NOS must also include reflective discussions with students so that they can confront their misconceptions about the NOS tenets. Implicit teaching does not address the NOS tenets directly. The focus of implicit teaching is on the learning and understanding of scientific concepts.

The study by Bannikmae et al. (2006) showed consistency with the previous research findings on the effectiveness of using explicit instruction to incorporate NOS tenets into college science instruction. The implicit NOS approach to teaching science did not positively influence students' conceptions of the NOS tenets. The implicit instructional method implies that students will have a better understanding of the NOS tenets by doing science when it is incorporated with the traditional hands-on laboratory activities, and without directly referencing those NOS tenets.

Studies by (Rannikmae et al., 2006; Tuberty et al., 2011) showed that explicit instruction that included the discussion of NOS tenets in the science content helped to change the students' conception of NOS. The course impacted students negatively in some areas of NOS tenets, in others there was no impact, while in some other areas, the impact varied by the course instructor. These studies focused on evaluating the change in students' understanding of scientific hypotheses, theories, and laws. The view that science is both content-based and experimental was strong in both studies. The view that science is tentative in nature, imaginative and creative was poorly expressed by the students in both studies.

According to Rannikmae et al. (2006), “The course on the philosophy of science seemed to have little impact in changing students’ views on their way of thinking about the nature of science or how science should be presented to school students” (p. 83). Research shows that exposing students to science content knowledge does not translate directly into a better understanding of NOS tenets by the students. The teaching of science content knowledge only in science courses does not expose students to NOS tenets.

The goals of science content knowledge are different from those of the NOS tenets. Traditional science content courses do not normally include the philosophy, history, and epistemology of science. The philosophy course was given to the students in this study to expose them to contemporary science. The philosophy of science course in this study contained topics like knowledge and power, traditional and postmodern view, and positivist and postmodern interpretations of scientific progress. These concepts that were taken from the philosophy of science courses are not science content knowledge but can expose students to contemporary science. This is in line with the primary goals of science literacy worldwide.

The Instruments for Assessing the Views of NOS

The science education researchers initially developed many different types of standardized instruments for assessing the students’ views of the NOS main tenets. These instruments were composed of forced-choice items, such as agree/disagree, Likert-type, or multiple choice. The use of these standardized instruments faced serious criticism about their validity (Lederman et al., 2002). This development led to the creation of instruments that elicit, probe, and clarify the learners’ in-depth views of the basic tenets of NOS using open-ended questions and personal interviews. The ways that respondents answer any given NOS question or NOS statement in the open-ended instruments reveal their original thinking and ideas. The forced-choice item instruments force the respondents to answer the given questions in the manner that the researchers or the instrument developers expect the answers to be.

Some of the widely used open-ended instruments are the Views of Nature of Science (VNOS) created by (Lederman & O'Malley, 1990) with many different versions; Views of Science-Technology-Society (VOSTS) created by (Aikenhead, Fleming, & Ryan, 1987), Student Understanding of Science and Scientific Inquiry (SUSSI) developed by (Liang et al., 2008), Scientific Epistemological Views (SEV) created by (Tsai & Liu, 2005) and Views on Science and Education Questionnaire (VOSE) by Chen (2006). There are many versions of the original VNOS-A such as VNOS-B, VNOS-C, VNOS-D, and VNOS-E. These different variations and improvements on the original VNOS-A are described below.

The VNOS-A was created by Lederman et al. (1990) and it is used in conjunction with follow-up interviews to assess high school students' beliefs about science. The VNOS-A has seven open-ended items plus follow-up interviews. One example of an item from VNOS-A is this: After scientists have developed a theory (e.g., atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to learn about theories. Defend your answer with examples.

The VNOS-B was designed by Abd-El-Khalick, Bell, and Lederman (1998) to assess preservice elementary and secondary science teachers' views of the tentative, empirical, inferential, creative, and theory-laden NOS, and the functions of and relationship between theories and laws. The VNOS-B has seven open-ended items in which two items are context-specific questions in nature plus a follow-up interview. The VNOS-C is the modified and expanded version of VNOS-B, and it was developed by Abd-EI-Khalick (1998) to assess views of the social and cultural embeddedness of science, and the existence of a universal scientific method. The VNOS-C was administered to and validated with college undergraduates, graduates, and preservice secondary science teachers. The VNOS-C has ten open-ended items in which three of those items are contextual plus structured follow-up interviews. The VNOS-D was created by (Khishfe & Abd-El-Khalick, 2002) for the assessment of NOS views of students about the empirical, tentative, inferential, and creative and imaginative nature of science, as well as the distinction between observation and inference. The VNOS-D has seven open-ended items, in which three of those items are structured to be context-specific. The open-ended items are administered by interview or survey. The VNOS-E is the newest version, designed to assess the NOS views of young students (K-3) and for students that cannot read or write (Khishfe & Abd-EI-Khalick, 2002). The VNOS-E was modified by using language and examples in its tested items that can be easily understood by young (K-3) students.

VOSTS survey is a tool that was developed by (Aikenhead, Fleming, & Ryan, 1987). The instrument evaluates high school students' beliefs about science, technology, and society. The VOSTS describes students' views of the social nature of science and how science is conducted, what science and technology are, how society influences science and technology, how science and technology influences society, how science as taught in school influences society, what characterizes scientists, how scientific knowledge comes about, and the nature of scientific knowledge. The VOSTS is made up of 114 multiple choice questions with three standard options under each item. The VOSTS items were developed by producing choices empirically derived from students' writing and from a sequence of interviews. The VOSTS reflects students' ideas, not numbers. The VOSTS items were not derived from a theoretical or researcher-based viewpoint but came from the realm of student viewpoints. The student responses to VOSTS are qualitative data in nature.

The VOSE was developed by Chen (2006) to evaluate pre-teachers, in-service teachers, and college students' NOS views on tentativeness of scientific knowledge, nature of observation, scientific method, hypotheses, theories and laws, imagination, validation of scientific knowledge, and objectivity and subjectivity in science. VOSE can also evaluate respondents' attitudes toward the teaching of NOS. The VOSE is available in both English and Chinese. It focuses on seven aspects of NOS that are particularly relevant to K-12 science education and can be used to perform comparison studies that yield data useful for inferential statistics. The VOSE is made up of sixty-nine questions that are empirically derived from the learners' perspectives. Each question has five-point Likert statements. The 69 questions are grouped into thirteen items. The two of the items out of the thirteen items on VOSE are related to science education.

In recent years, science education researchers in Asia have developed their own instruments, such as Scientific Epistemological Views (SEV) and Student Understanding of Science and Scientific Inquiry (SUSSI). The SEV was developed by (Tsai & Liu, 2005) to evaluate the students' NOS views on social negotiation, scientific inventions, and creativity, the tentativeness of scientific knowledge, and cultural impacts on science. The SEV has nineteen items and each item has five options that are each on a Likert scale. The SUSSI was developed by (Liang et al., 2008). It is designed to assess the students' NOS views on observation and inference, change in scientific theories and laws, social-cultural influences in science, imagination and creativity in science, and methodology of scientific investigation. The SUSSI has 24 items. Each item has five-Likert type statements. The 24 items are grouped into six categories that included an invitation to explain responses with examples per item. The six categories are observations and inferences, tentative nature of scientific theories, scientific laws versus theories, social and cultural influence on science, imagination and creativity in scientific investigations, and methodology in scientific investigations.

Conclusion

Research in science education concluded that undergraduate science majors and non-science majors continue to exhibit naïve views of the main NOS tenets with no significant difference between the two groups of students (Miller et al., 2010; Pace et al., 2014). Depending on the aspect of NOS tenets under consideration, students can have either naïve views, transitional and/or moderate views, or informed views of the NOS tenets. The naïve view of a NOS tenet means that a student has no knowledge or understanding of the concept. A transitional view of NOS tenet means that a student's knowledge of the concept is just forming or developing. The moderate or informed view of a NOS tenet means that a student has basic knowledge of the concept. Exposure to more science content courses did not significantly increase students' understanding of NOS tenets. Additionally, traditional laboratory activities did not raise students' understanding of NOS tenets (Liang et al., 2010; Parker et al., 2008; Samara, 2015).

These studies evaluated the NOS views of undergraduate students but did not consider the impacts that the social settings and cultures of these students had played in shaping their views of NOS and SSIs. This study is designed to fill this gap in research. The participants in this study from the three institutions differ culturally. The evaluation of the SSI and NOS views of these students from the sociocultural perspective point of view could create new knowledge in the NOS and SSI views of college students in the sub-field of minority studies in science education.

Vygotsky's sociocultural theory serves as the theoretical framework for this study. This theory was used as a tool to investigate and evaluate how the interaction between the participants and the cultures in which they were born or lived has affected their individual cognitive development as well as their views of NOS and SSIs. The sociocultural theory states that knowledge is influenced by the culture, which includes the language, and beliefs that are important to that culture, and the skills that are equally important in that culture (like computer skills, communication skills, collaboration skills). The sociocultural theory says that the social environment provides the learner with social interaction, social relationship, and social artifacts, such as signs, symbols, and linguistic terms (Lantolf et al., 2015). Factors such as textbooks, teachers' beliefs, and tools can influence the learner's construction of knowledge. Artifacts shape and transform learners' mental processes. Lev Vygotsky's sociocultural theory serves as the lens for examining the differences between community college and university science students' views on socio-scientific issues, and the sociocultural aspect of the Nature of Science. Vygotsky's theory will be used to provide a framework or foundation for this study.

CHAPTER III

Methodology

Research Design

This study employed quantitative research methods using descriptive causal-comparative and correlation techniques.

Research Questions

(1.) Are there statistically significant differences in SSI scores of students attending the three higher education institutions?

(2.) Are there statistically significant differences in NOS scores of students attending the three higher education institutions?

(3.) Is there a statistically significant relationship between SSI and NOS scores for students at the three higher education institutions?

This study employed quantitative methods using descriptive causal-comparative and correlation techniques. The independent variable is the institution type as represented by three selected institutions and the dependent variables are the scores of students on the NOS tenets and SSIs from the two instruments (SUSSI and SHOMS). The institution was used in this study as a proxy for the race since the populations in those schools are either majority white students or minority students. The findings from this study may contribute to an understanding of the factors that influence students' views of the NOS and SSIs. The analytical techniques that were used in this comparative study were descriptive and inferential statistics. These descriptive and inferential statistics of the students' scores from the two instruments

(SUSSI and SHOMS) in the three research sites were used to answer the three research questions.

The descriptive statistics included measures of central tendency (mean, median, and mode) and variation (standard deviation). The inferential statistics employed analysis of variance (ANOVA) and correlational statistics.

Research Question One

Are there statistically significant differences in SSI scores of students attending the three higher education institutions?

The independent variable is the institution type as represented by these three selected institutions and the dependent variables are the scores of the students on the SSI survey from the instrument (SHOMS). The SHOMS has ten Likert-type items. Each Likert-type item has four possible responses. The responses are strongly disagreed, disagree, agree, and strongly agree. The strongly agree will be assigned four points, agree is three points, disagree is two points, and strongly disagree is one point. Scores from the students' responses from the SHOMS will be analyzed using ANOVA the institution as the main effect. The null hypothesis for an ANOVA is that there is no significant difference among the three groups. The alternative hypothesis assumes that there is at least one significant difference between the three groups.

Research Question Two

Are there statistically significant differences in NOS scores of students attending the three higher education institutions?

The independent variable is the institution type as represented by the three selected institutions and the dependent variable is the scores of the students on the

NOS tenets from the instrument (SUSSI). The SUSSI has five Likert-type items and a free-response question. Each Likert-type item has five possible responses. The responses are strongly disagreed, disagree, neither agree nor disagree, agree and strongly agree. The strongly agree will be assigned five points, agree is four points, neither agree nor disagree is three points, disagree is two points, and strongly disagree is one point. Scores from the students' responses from the SUSSI will be analyzed with ANOVA. The null hypothesis for an ANOVA is that there is no significant difference among the three groups. The alternative hypothesis assumes that there is at least one significant difference between the three groups. The responses of the students to the one free-response question on SUSSI were summarized.

Research Question Three

Is there a statistically significant relationship between SSI and NOS scores for students at the three higher education institutions?

Pearson r correlation was used to determine if a correlation exists between students' views of SSIs and the socio-cultural aspect of the NOS tenet between students at the three research sites. Pearson r correlation is a statistical technique that is used to measure and describe the strength and direction of the relationship between two variables (NOS and SSI scores). Pearson r correlation requires two scores from the same individuals. Pearson r correlation is the most widely used correlation statistic to measure the degree of the relationship between linearly related variables. Pearson's correlation coefficient is commonly represented by the letter r and may be referred to as the sample correlation coefficient or the sample Pearson correlation coefficient. The correlation r between two variables is given by the following equation below:

$$\text{(i)}\quad r = [1 / (n - 1)] * \Sigma \{ [(xi - \bar{x}) / sx] * [(yi - \bar{y}) / sy] \}$$

where n is the number of observations in the sample, Σ is the summation symbol, xi is the x value for observation i, $\bar{x}$ is the sample mean of x, yi is the y value for observation i, $\bar{y}$ is the sample mean of y, sx is the sample standard deviation of x, and sy is the sample standard deviation of y. The correlation coefficient, r, ranges from -1 to +1. The value for the r interpretation as follows: 1.0 is a perfect correlation, 0 to 1 means that the two variables tend to increase or decrease together, 0.0 implies that the two variables do not vary together at all, and -1 to 0 means that one variable increases as the other decreases. The r value of -1.0 is a perfect negative or inverse correlation. If r is far from zero, there are four possible explanations:

- Changes in the x variable cause a change in the value of the y variable.
- Changes in the y variable cause a change in the value of the x variable.
- Changes in another variable influence both x and y.
- x and y do not really correlate at all.

Correlational studies help researchers to explore the relationships between two or more variables. Correlational studies provide a numerical estimate of the relationship between the two variables, which is known as the correlation coefficient. This helps researchers to determine if any statistically significant relationship exists between any two variables that are studied (Goodwin, 2009).

The greatest limitation of correlational research is that it cannot determine causation. Correlation assesses the extent to which two variables co-vary. The correlational part of this study helped me to determine the type of correlation coefficient that exists between the two independent variables (NOS and SSI) of each group and the three groups.

Population and Sample

The population was the students that enrolled in the introductory astronomy course at the three selected institutions. All these students have a high school diploma, GED or equivalent. The students at the suburban community college and black historical college are mainly minority by race or ethnicity (See Appendixes C and D). The students from the Catholic university are mainly white by race or ethnicity (See Appendix E). The sample size for the study was 249 students (33 students from community college, 44 from historically black university, and 172 from Catholic university).

Instrumentation

Description

Two different instruments were used in this study. The first instrument is the 2006 revised Student Understanding of Science and Scientific Inquiry (SUSSI). This version of SUSSI was created by (Liang et al., 2005). The items that were used from the SUSSI for this study came from section four, which deals with the social and cultural influence in science. The section has five Likert-type items and a free-response question. The second instrument for this study is the Scientific Habits of Mind Survey (SHOMS) developed by (Gauld, 2005). It has thirty-two Likert-type items that cover the main socio-scientific issues of our time. Ten items from SHOMS were related to the prevailing socio-scientific issues in America and the social and cultural experiences of these three groups of students.

Reliability and Validity

The SUSSI has a reliability coefficient value of 0.67 on the Cronbach's Alpha for studies done in America. The consistency of the alpha values across the three samples (America, China, and Turkey) suggests that SUSSI can be used as a reliable assessment tool in different cultural settings (Liang et al., 2006). The internal reliability of the SHOMS based on Cronbach's alpha is 0.73 (Calik & Coll, 2012). The SHOM was validated by the administration to two cohorts of pre-service science teachers: primary science teachers with little science background or interest (n = 145), and secondary school science teachers (who also were science graduates) with stronger science knowledge (n = 145). Face validity was confirmed using a panel of experts and a pilot study employing participants similar in demographics to the intended sample. Statistical data and other data gathered from interviews suggest that the SHOMS is a useful tool for educators and researchers who wish to investigate scientific habit of mind for a variety of participants (Calik et al., 2012)

Procedures for Data Collection

The collection of data for this study began around the middle of the spring Semester of 2018 at the three research sites simultaneously. The college instructors that taught astronomy in these three institutions administered the paper survey. The informed consent form was provided to the students decided to participate in this study. The informed consent form explained the purpose of this study to the participants and explained that it was voluntary. The time for completing the survey was about twenty-five minutes. The survey was administered during class time to give students enough time to complete all the items on the survey. The data collection process lasted for about two weeks: 249 astronomy students from the three institutions were surveyed for this study. The data analysis commenced immediately after the completion of the survey. This research was completed in the summer of 2018.

Methods of Data Analysis

Analysis of the Comparative Data

The analytical techniques that were used for this study included descriptive and inferential statistics. The descriptive statistics included the central tendency (mean, median, and mode), and variation (standard deviation). The inferential statistics employed the analysis of variance (ANOVA). The ANOVA was used to determine whether there are any statistically significant differences between the means of two or more independent (unrelated) groups. ANOVA was employed to determine if any statistical differences exist between the means of these three independent groups of students from the three institutions.

Analysis of the Correlational Data

Pearson r correlation was used to determine if a correlation exists between students' views of SSIs and the socio-cultural aspect of the NOS tenet between students that attended the three institutions. Pearson r correlation is a statistical technique that is used to measure, describe the strength and direction of the relationship between two variables (NOS and SSI scores).

Analysis of Free Response Question

The responses of the students from the three research sites to the one free-response question from the instrument (SUSSI) generated qualitative data on the students' views of the social and cultural aspects of the NOS. The responses of these students were summarized.

The free-response question is below:

Explain how society and culture affect OR do not affect scientific research, and provide examples to support your answer.

I used the inductive approach to analyze the qualitative data from SUSSI. I read all the students' responses to the free-response question from SUSSI. I looked for similar themes and patterns in students' responses that aligned with the tenets of the socio-cultural aspect of the NOS tenet. Responses to the open-ended question were manually coded. This was followed by the creation of themes that summarized the responses of students from the three institutions. A comparison of themes was made between the students from the three institutions. I divided these themes into four different categories.

CHAPTER IV

Analysis and Interpretation of Data

Introduction

The collection of data for this study with the two instruments (SUSSI and SHOMS) was completed in the middle of the spring semester of 2018 at the three research sites. Table 1 shows that 172 students responded to the SHOMS survey from a Catholic university, 44 from black historical college, and 33 from a suburban community college. Table 2 shows that 164 students responded to the SUSSI survey from a Catholic university, 29 from black historical college, and 28 from a suburban community college. The students who were surveyed in this study were science and non-science majors in the introductory to astronomy courses.

The goal of this research was to determine the NOS and SSI views of students in the three selected institutions and to investigate whether there are statistically significant differences in the NOS and SSI views of students in these institutions. The study explored the correlations between NOS and SSI scores for these students. The NOS views of these students were measured with SUSSI and the SSI views of these students were measured with SHOMS.

This study employed quantitative methods that used descriptive, causal-comparative, and correlation techniques. The independent variable for this study is the institution type as represented by the three institutions and the dependent variables were the scores of students on the NOS tenets and SSIs from the two instruments (SUSSI and SHOMS). The institution was used in this study as a proxy for race/culture since the populations in those schools are either majority white students or minority students. The findings contribute to an understanding of the factors that influence students' views of the NOS and SSIs. The analytical techniques that were used in this comparative study were descriptive and inferential statistics. Data gleaned from the two instruments (SUSSI and SHOMS) in the three research sites were used to answer these three research questions:

Research Questions

(1.) Are there statistically significant differences in SSI scores of students attending the three higher education institutions?

(2.) Are there statistically significant differences in NOS scores of students attending the three higher education institutions?

(3.) Is there a statistically significant relationship between SSI and NOS scores for students at the three higher education institutions?

Analysis of Free Response Question

The responses of the students from the three research sites to the one free-response question from the instrument (SUSSI) generated qualitative data on their perceptions of the social and cultural aspects of the NOS. The responses of these students were summarized.

The free-response question is below:

Explain how society and culture affect OR do not affect scientific research, and provide examples to support your answer.

Descriptive Statistics

Results

Table 1

Descriptive Statistics of the SSI Scores from the Three Research Sites

Groups	*N*	*Sum*	*Mean*	*Variance*	*Median*	*Mode*	*SD*
Community College	*33*	*890*	*26.97*	*20.84*	*28*	*30*	*4.56*
Black Historical University	*44*	*1206*	*27.41*	*19.74*	*27*	*27*	*4.44*
Catholic University	*172*	*4671*	*27.16*	*18.92*	*28*	*29*	*4.35*

Table 2

Descriptive Statistics of the NOS Scores from the Three Research Sites

Groups	*N*	*Sum*	*Mean*	*Variance*	*Median*	*Mode*	*SD*
Community College	28	406	14.4	15.00	14	12	2.84
Black Historical University	29	481	16.6	6.96	16	17	2.64
Catholic University	164	2574	15.7	10.32	16	16	3.21

SSI Means and Standard Deviation

Table 1 shows that the average SSI score for a community college was 26.97 (*SD* = 4.56), the black historical university was 27.41 (*SD* = 4.44), and Catholic university was 27.16 (*SD* = 4.35)

NOS Means and Standard Deviation

Table 2 shows that the average NOS score for a community college was 14.50 (*SD* = 3.87), the historically black university was 16.59 (*SD* = 2.64), and Catholic university was 15.70 (*SD* = 2.31).

Distribution of NOS Scores for the three institutions

Table 3

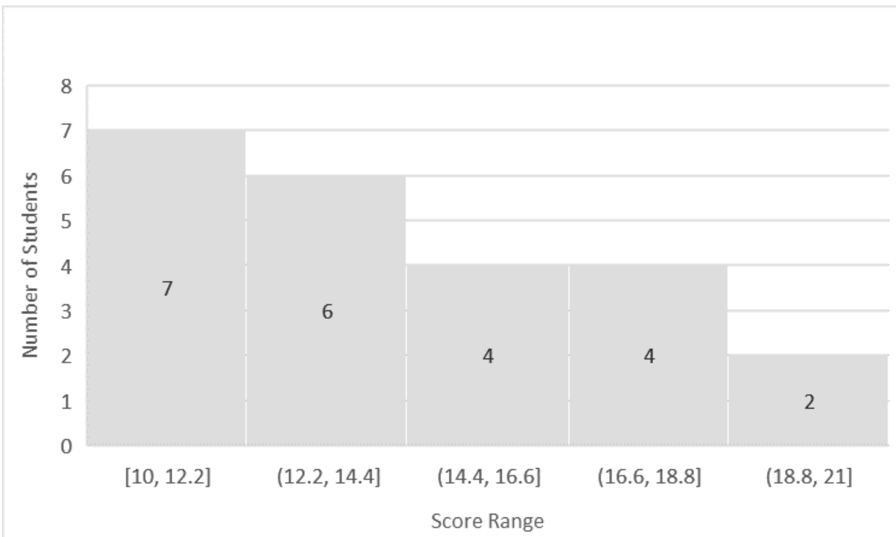

Table 3 shows the NOS scores distribution for community college. The NOS scores are moderately skewed, with skewness of 0.71 and kurtosis of 0.14. Most students scored less than the NOS mean value of 14.5 for the group. The NOS scores lack outliers. The community college has a NOS score range of 11.

Table 4

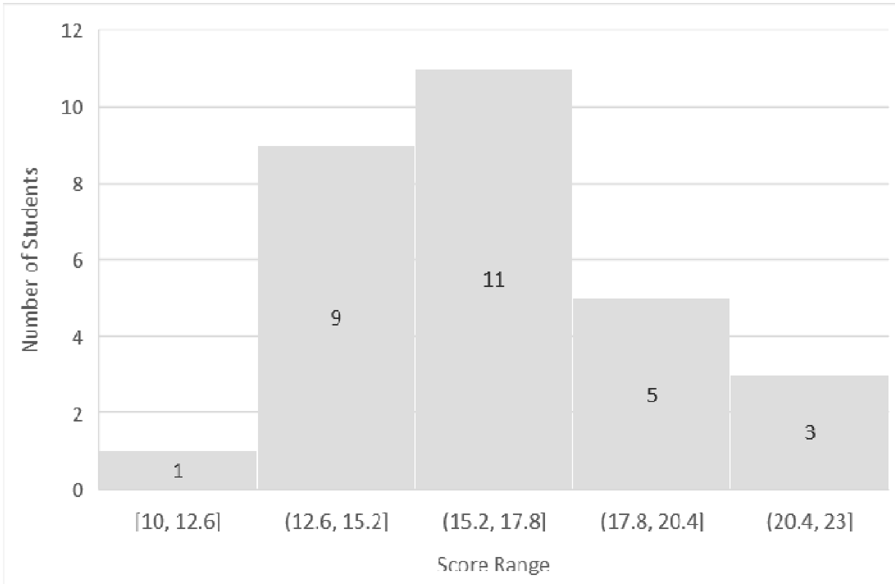

Table 4 shows the NOS scores distribution for the historically black university. The NOS scores are fairly symmetrical, with skewness of 0.38 and kurtosis of 1.37. Most students scored less than the NOS mean value of 16.6 for the group. The NOS scores lack outliers. The historically black university has a NOS score range of 13.

Table 5

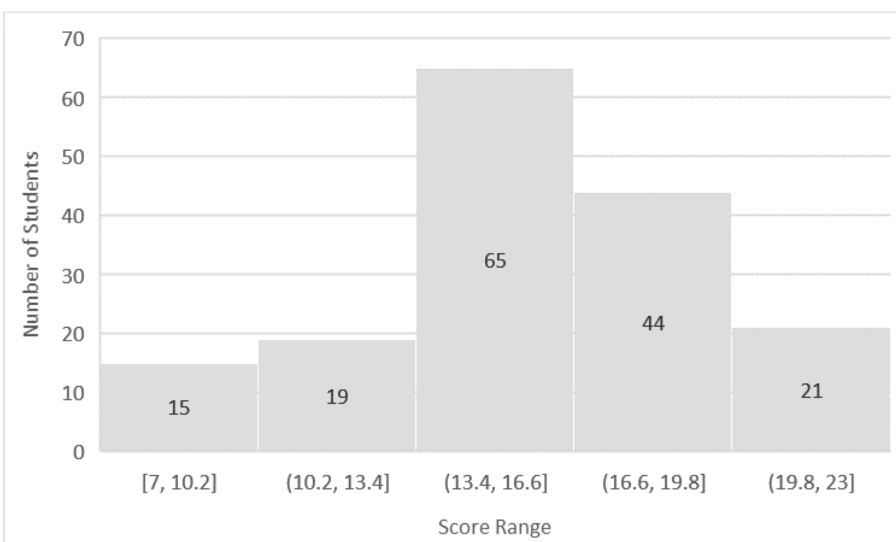

Table 5 shows the NOS scores' distribution for the Catholic university. The NOS scores are fairly symmetrical, with skewness of -0.37 and kurtosis of -0.11. Most students scored more than the NOS mean value of 15.7 for the group. The NOS scores lack outliers. The Catholic university has a NOS score range of 16.

Distribution of SSI Scores for the three institutions

Table 6

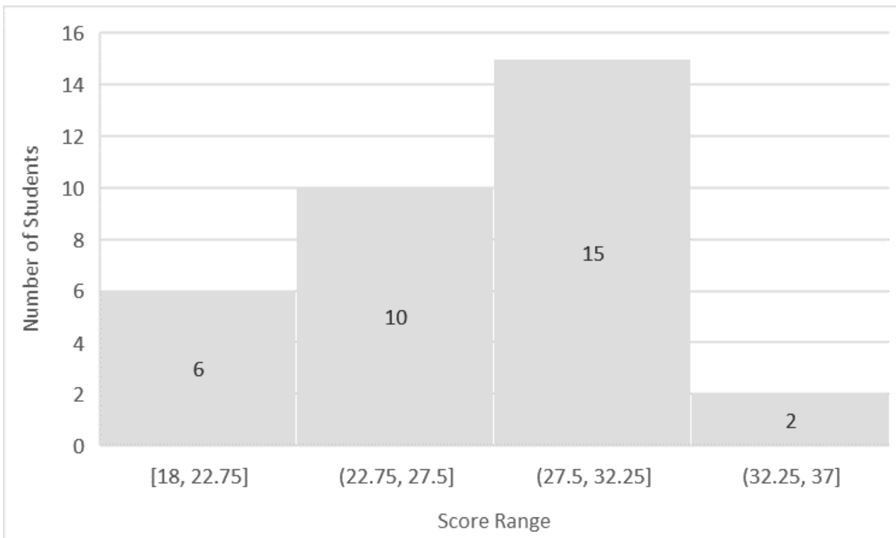

Table 6 shows the SSI score distribution for the community college. The SSI scores are fairly symmetrical, with skewness of -0.30 and kurtosis of -0.20. Most students scored more than the group SSI mean score of 26.97. The data set lacks outliers. The community college has an SSI score range of 19.

Table 7

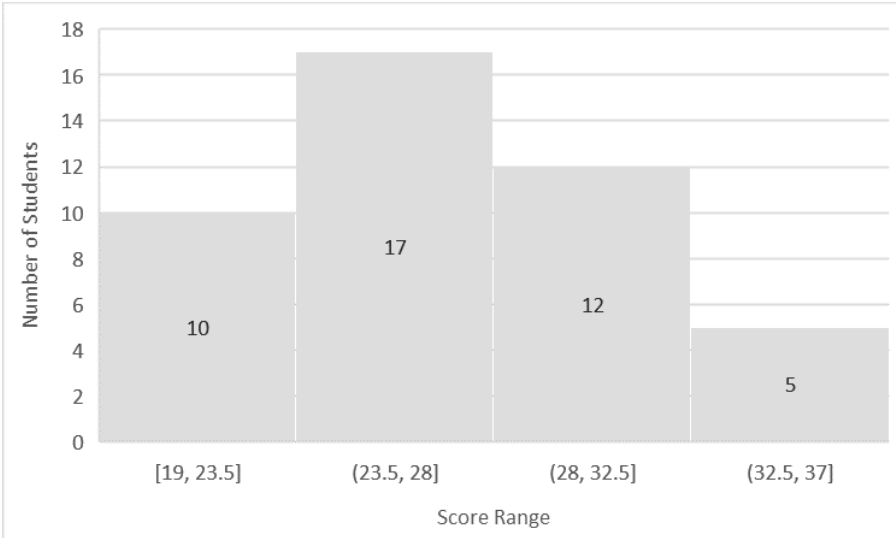

Table 7 shows the SSI scores' distribution for the historically black university. The SSI scores are fairly symmetrical, with skewness of -0.01 and kurtosis of -0.45. Most students scored more than the SSI mean value of 27.41 for the group. The SSI scores lack outliers. The historically black university has an SSI score range of 18.

Table 8

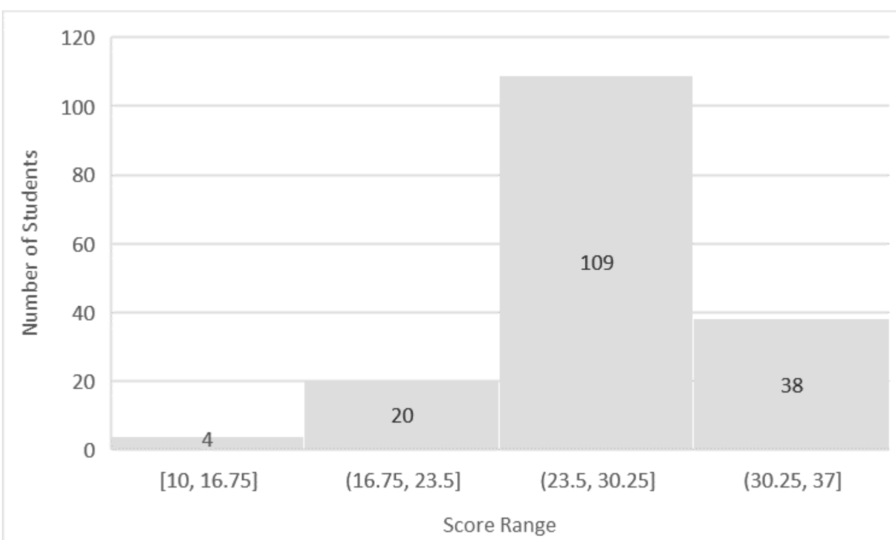

Table 8 shows the SSI scores distribution for the Catholic university. The SSI scores are moderately skewed, with skewness of -1.00 and kurtosis of 1.87. Most students scored more than the SSI mean value of 27.16 for the group. The SSI scores lack outliers. The Catholic university has an SSI score range of 27.

Inferential Statistics

Research Question One

Are there statistically significant differences in SSI scores of students attending the three higher education institutions?

Table 9 presents the results of a one-way ANOVA using the institution as the main effect.

Table 9

One-Way ANOVA Analysis of SSI Scores from the Three Research Centers

Source of Variation	*SS*	*df*	*MS*	*F-Statistics*	*P-value*	*F-critical value*
Between Groups	3.8572111	2	1.928605543	0.086665162	0.91701207	3.032511609
Within Groups	5474.3677	246	22.25352719			
Total	5478.2249	248				

Note $p = 0.05$

Results of the ANOVA given in Table 9 indicate that there were no significant differences in the SSI means between students attending the three higher education institutions $F(2, 246) = 0.09$, $p = .917$. The result is not significant at $p < .05$. Therefore, we accept the null hypothesis and say that there is no significant difference in the SSI means of the three independent groups.

Research Question 2

Are there statistically significant differences in NOS scores of students attending the three higher education institutions?

Table 10 presents the results of a one-way ANOVA using the institution as the main effect.

Table 10

One-Way ANOVA Analysis of NOS Scores from the Three Research Centers

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F-critical value*
Between Groups	*62.7569*	*2*	*31.3785*	*3.26548*	*0.040054*	*3.0325111609*
Within Groups	*2094.7906*	*218*	*9.6091*			
Total	*2157.5475*	*220*				

Note p = 0.05

Results of the ANOVA in Table 10 indicated that there were significant differences in the NOS means between students attending the three higher education institutions $F(2, 218) = 3.27$, $p = .040$. The result is significant at $p < .05$. Therefore, we have evidence to reject the null hypothesis and say that there is a significant difference in the NOS means of the three independent groups.

T-tests

The Bonferroni approach and post-hoc tests were used to determine where the differences lay. The post-hoc test is a t-test that assumes that two samples have equal variances. The result of the independent sample t-test on Table 11 indicated that there was a significant difference in the NOS means between community college and historically black college, $t(55) = -2.88$, $p = .01$. The result is significant at $p = .05$.

The result of the independent sample t-test shown in Table 12 indicated that there was no significant difference in the NOS means of historically black college and Catholic university, t(191) = 1.41, $p = .16$. The result is not significant at $p = .05$. The result of the independent sample t-test shown in Table 13 indicates that there was no significant difference in the NOS means of community college and Catholic university, t(190) = -1.84, $p = .066$. The result is not significant at $p = .05$.

Table 11

T-Test: Two-Sample Assuming Equal Variances

	Community College	Historical Black University
	NOS	*NOS*
Mean	14.5	16.5862069
Variance	8.037037037	6.965517241
Observations	28	29
Pooled Variance	7.49153605	
Hypothesized Mean Difference	0	
df	55	
t Stat	-2.876818923	
P(T<=t) one-tail	0.002853385	
t Critical one-tail	1.673033965	
P(T<=t) two-tail	0.005706769	
t Critical two-tail	2.004044783	

Note p =.05

Table 12

T-Test: Two-Sample Assuming Equal Variances

	Historical Black University	Catholic University
	NOS	*NOS*
Mean	16.5862069	15.69512195
Variance	6.965517241	10.32365704
Observations	29	164
Pooled Variance	9.831364295	
Hypothesized Mean Difference	0	
df	191	
t Stat	1.410764363	
P(T<=t) one-tail	0.07997037	
t Critical one-tail	1.652870547	
P(T<=t) two-tail	0.15994074	
t Critical two-tail	1.97246199	

Note p = .05

Table 13

T-Test: Two-Sample Assuming Equal Variances

	Community College	Catholic University
	NOS	*NOS*
Mean	14.5	15.69512195
Variance	8.037037037	10.32365704
Observations	28	164
Pooled Variance	9.998716303	
Hypothesized Mean Difference	0	
df	190	
t Stat	-1.848376446	
P(T<=t) one-tail	0.033051012	
t Critical one-tail	1.652912949	
P(T<=t) two-tail	0.066102024	
t Critical two-tail	1.972528182	

Note p = .05

Effect Size for Statistically Significant Difference in the NOS Means

The effect size allowed me to see the difference between statistical significance and practical significance. Statistical significance is a function of sample size. Statistical significance indicates that the difference in the NOS means of the three groups did not occur by chance. Practical significance is the standardized measurement between the sample and the null hypothesis. Practical significance removes the influence of sample size. Practical significance means that the difference in the NOS means of the three groups has both practical and clinical usefulness in the real world.

As the sample size increases, small differences may be statistically significant. One way of measuring the effect size for one-way ANOVA is called the partial eta squared. It works the same way as a t-test for two samples assuming equal variances. The partial eta squared calculates how much proportion of the variability between the three groups is due to the between-group difference.

The eta squared, which represents the strength of association and measures the percentage of variance in the dependent variable that can be accounted for by the independent variable, is often biased. The partial eta squared is unbiased and is a correction to eta squared. This was used to calculate the percentage of variance in the dependent variable (NOS scores) that is accounted for by the independent variable (institution type).

$$\eta_p{}^2 = \frac{SS_{effect}}{SS_{effect} + SS_{error}}$$

Using the data in Table 10 to calculate the partial eta squared:

Partial eta squared = 66.7569/66.7569 +2094.7900

Partial eta squared = 0.03 or 3%.

Results indicate that 3% of the variability in the NOS means between the three groups is explained by the independent variable (institution type). The Partial Eta Squared of 3% is a small effect size. Ninety-seven percent of what is responsible for the difference in the NOS means of the three groups is unknown.

Correlational Analysis

Research Question Three

Is there a statistically significant relationship between SSI and NOS scores for students at the three higher education institutions?

The correlational analysis of research question three using the Pearson Correlation Coefficient is shown in Tables 14, 15, and 16 respectively. The coefficient of determination (R^2), the square of the correlation coefficient was calculated. This is used to determine how much of the variation in one of the variables is associated with variation in the other. This explains the effect size.

Table 14

The Pearson Correlation Coefficient for Community College (NOS and SSI Scores)

Correlation Coefficient	-0.08
p-value (2-tailed)	0.68
Degree of Freedom	26
Number of Observation	28

p = .05

There was a weak negative correlation between the NOS and SSI scores of students of the community college as shown in Table 8, $r(26) = -.08$, $p = 0.68$. The coefficient of determination was 0.0064 and the effect size was 0.64%.

Table 15

The Pearson Correlation Coefficient for Historical Black University (NOS and SSI Scores)

Correlation Coefficient	0.19
p-value (2-tailed)	0.33
Degree of Freedom	26
Number of Observation	28

$p = .05$

There was a weak positive correlation between the NOS and SSI scores of students of the historically black college, $r(26) = .19$, $p = 0.33$. The coefficient of determination was 0.0361 and the effect size was 3.61%.

Table 16

T*he Pearson Correlation Coefficient for Catholic University (NOS and SSI Scores)*

Correlation Coefficient	0.00
p-value (2-tailed)	0.99
Degree of Freedom	160
Number of Observation	162

$p = .05$

There was no correlation between the NOS and SSI scores of students from a Catholic university, r(160) = .00, $p = 0.99$. The coefficient of determination was 0.00 and the effect size was 0.00%.

Analysis of Free Response Question

The responses of the students from the three research sites to the one free-response question from the instrument (SUSSI) generated qualitative data on the social and cultural aspects of the NOS. The responses of these students were summarized.

The free-response question is below:

Explain how society and culture affect OR do not affect scientific research, and provide examples to support your answer.

The analysis of the responses from the students generated four different themes. The themes are funding of scientific research, types of scientific research, regulation of scientific practice, and bias in scientific research. There were no distinct differences in responses according to the institution in my findings.

Meaning of the Themes

Funding for Scientific Research

Science cannot be practiced without money. The money that is needed to fund most scientific research does not come from scientists. The money for scientific work comes from government agencies and privately-owned corporations that are part and parcel of the society, and its prevailing cultural norms. Scientists are also part of society and its cultural beliefs. One participant responded to this free response question by saying “Society and culture determine whether science is done or not. Society controls the money that is needed to do science. Taxpayers can weigh in on the issue of scientific funding.” Another participant said that “Many scientific researchers will not receive funding if they do not reflect the values of the culture of such society in the practice of science.”

Types of Scientific Research

This is the specific type of scientific research that is embarked upon by scientists due to the direct influence of the society and culture on these scientific practitioners. Society prioritizes the type of science that it supports or accepts. Society supports science that is in line with its cultural norms, social practices, and can solve real-life problems that affect that society. One participant responded that “Harmful scientific experimentation that destroys our environment will not be allowed by society, like unregulated nuclear testing." Another participant wrote, "Society and culture determine the scientific findings that will be accepted. An example is a controversial debate on the status of the planet Pluto which is now reclassified by scientists as a dwarf planet."

Regulation of Scientific Practice

The practice of science is regulated by society and culture where scientists reside to practice their expertise. Science cannot be practiced in isolation by scientists from the culture and society they reside in. Society uses its government agencies to monitor and regulate scientific practice. Proposals for any scientific research must go through these government regulatory bodies to be approved, modified or rejected. One participant wrote, "Science and culture affect the practice of science. Testing of animals must meet certain standards set by the society." Another participant responded that "Society and culture control science and determine what humane and inhumane practices are in the practice of science." One participant put it this way: "History shows that science is influenced by society, like the concept of phrenology that creates a false case that Africans are less intelligent than the white race."

Bias in Scientific Research

The biases of scientific practitioners affect the way science is practiced worldwide. Biases are introduced into the practice and interpretation of scientific findings due to the impacts of societies and cultures on the scientists. Scientific observation does not start on neutral ground (Popper, 2002). Scientists bring their social and cultural biases in their work. Research and interpretation of scientific findings reflect the biases of scientists that are involved. One participant wrote, "Society and culture influence science. Every scientist is a product of culture and has the biases that are associated with the culture and the practice of science within the same culture." Another participant said, "Science is affected by society and culture. All humans follow what their cultures and societies teach them. Some scientists are religious and do not believe in the Big Bang Theory. But are influenced by their experiences, the cultures they come from and personal values that come from their societies. Scientific research will always be biased." One participant wrote that "scientists are not trained to be unbiased. Their religious beliefs can affect what is studied."

Reliability of the Instruments

The study did not evaluate the students' views on all the main aspects of the NOS tenets. The NOS tenet for this study was limited to the social and cultural aspect of NOS since this is the aspect of NOS deemed most likely to be impacted by a student's cultural background. The two instruments for this study, SUSSI, and SHOMS have lower reliability because items were extracted from the original instruments. For this study, the calculated Cronbach's alpha for SUSSI was 0.62 and Cronbach's alpha for SHOMS was 0.66. The original SUSSI has a reliability coefficient value of 0.67 on the Cronbach's Alpha for studies done in America. The consistency of the alpha values across the three samples (America, China, and Turkey) suggests that SUSSI can be used as a reliable assessment tool in different cultural settings (Liang et al., 2006). The internal reliability of the SHOMS based on Cronbach's alpha is 0.73 (Calik, et al., 2012). The SHOM was validated by the administration to two cohorts of pre-service science teachers: primary science teachers with little science background or interest (n = 145), and secondary school science teachers (who also were science graduates) with stronger science knowledge (n = 145).

CHAPTER V

Summary and Conclusion

Introduction

The goal of this research was to determine the NOS and SSI views of students in the three selected institutions and to investigate whether there are statistically significant differences in the NOS and SSI views of students in these institutions. The study explored the correlations between NOS and SSI scores for these students. The NOS views of these students were measured by SUSSI and the SSI views of these students were measured by SHOMS.

This study employed quantitative methods using descriptive, causal-comparative, and correlation techniques. The independent variable is institution type as represented by the three institutions and the dependent variable is the scores of students on the NOS tenets and SSIs from the two instruments (SUSSI and SHOMS). The institution was used in this study as a proxy for race/culture since the populations in those schools are either majority white students or minority students. These institutions have different populations in terms of admission requirements and socioeconomic status (SES). The differences in the populations of the three institutions could be regarded as constituting differences in their cultures if institution type is used as a proxy for culture. The use of another variable as a proxy for culture is not without precedent in the science education literature. Liang et al. (2006) used the nationality or country of origin of the participants as the proxy for culture in a study that evaluated the NOS views of preservice teachers from America, China, and Turkey.

The analytical techniques that were used in this comparative study are descriptive and inferential statistics. Descriptive and inferential statistics were used to analyze the students' scores from the two instruments (SUSSI and SHOMS) in order to answer the three research questions. This chapter also contains a discussion of the meaning of the research findings and future research possibilities.

Summary of Findings

Institutional Impacts on Students' SSI Views

This study's findings for the SSI views of undergraduate students from the three higher education institutions showed that there is no significant difference in their SSI views. Lev Vygotsky's sociocultural theory that serves as the theoretical framework for this study suggests that the content of a person's knowledge in relation to meaning-making in life is influenced or shaped by the culture which includes language, beliefs that are important to that culture, and skills considered important in that culture, such as, computer skills, communication skills, and collaboration skills (Lantolf, et al., 2015). The three educational institutions used in this study are different and represent different institutional cultures, demographics, and admission criteria. In this study, the institution type served as a proxy for culture. On the basis of Vygotsky's theory of cognitive development which provided a framework for this study. I expected the SSI views of students from these three institutions to be different. In the absence of data to implicate college curriculum experiences in determining students' SSI views, it may be conjectured that other factors, possibly prior educational experiences in high schools or science classroom experiences are more influential in shaping their SSI views. However, the design of this study and the absence of data on these variables do not allow for such conclusions. The use of institution type as a proxy for culture in this study may not be the best way to evaluate the way the SSI views of these college students will be impacted by their cultures and social experiences in life.

The introduction to the astronomy course that was taken by these three groups of students that participated in this study was taught using the traditional approach of lecture and laboratory activities. The literature in science education research showed that undergraduate students who took science courses that were taught with argument-based instructional approach showed a superior level of argument on SSIs when compared with students who took similar courses that were taught with the traditional approach of using lecture and laboratory activities (Grooms et al., 2014). This traditional approach of using lecture and laboratory activities to teach college science courses may likely be one of the factors that account for the lack of any significant differences in the SSI means of these college students who participated in this study.

The curricula of the Introduction to Astronomy courses taken by these college students emphasized science content knowledge over socio-scientific issues. Science content knowledge consists of facts, definitions, concepts, theories, and laws of science. The SSIs are the products and the impacts that science has made on humans and the environment, as well as the moral and social issues that are associated with the practice of science in different cultures around the world. Research showed that university undergraduate science curricula are not designed to encourage students to participate effectively in the investigation of SSIs that require students to use multiple reasoning modes and interdisciplinary thinking (Yao Liu et al., 2010). The curricula of the astronomy courses taken by the students from these three institutions focused on science content knowledge over socio-scientific issues. This may have contributed to the fact that there were no significant differences observed in the SSI scores of these participants.

Institutional Impacts on Students' NOS Views

There were significant differences in the NOS means between students attending the three higher education institutions. I expected the biggest difference in the students' NOS views to be between the community college and Catholic university because of demographic differences and varied college admission requirements. The significant difference in the NOS means was between community college and historically black university. The similarity in the demographics composition of these two institutions suggests similarity in their cultures, yet they exhibited a significant difference in their NOS views. This lends support for the idea that prior educational experiences might be a more important factor in the determination of their NOS views. These two institutions have varying different admission criteria and therefore drawn from a poll of students who may have had vastly different high school experiences. The NOS mean for a community college was 14.5 and the NOS mean for the historically black university was 16.6. From these three independent groups, it seems to me that students from community college and historically black college would be the most similar in terms of demographics and based on the idea that white students and black students have different cultural experiences and social norms in life (Kirmayer et al., 2007). However, it is between these two groups (community college and historically black college) that I found the only significant difference in their NOS means. Vygotsky's sociocultural theory says a person's culture influences how they make meaning about issues of life.

The observed significant difference in the NOS means between community college and historically black university that represents minority students with similar demographics may be explained further by pointing to the fundamental differences in the admission requirements of students who attend community colleges and four-year colleges. The community college is a two-year college that educates primarily minority and immigrant students and awards associate degrees. Admission to community colleges allows lower high school grade point average (GPA), Scholastic Assessment Test (SAT) scores and American College Testing (ACT) scores when compared to the four-year universities. Most of the students that are admitted to community college have high school GPAs of less than 3.0, lower SAT, and ACT scores. Students that are admitted with a high school GPA of less than 3.0 are given the school-administered alternative placement test in math and reading in place of these colleges standardized admission tests (SAT and ACT). MSU admits students with higher high school GPA, SAT, and ACT scores. According to the 2017 report of the National Center for Education Statistics (NCES), the historically black university attracts and accepts students with an average high school GPA of 2.65 and high school grades of "C^{+}". Catholic university attracts and accepts high school students with an average high school GPA of 3.45 and high school grades of "B^{+}". The SAT scores and high school GPAs required for admission to this community college were not reported by NCES.

Relationship Between NOS and SSI Views of the Students

The teaching of NOS helps students in the understanding of SSI. Both concepts are used by science educators to help students of science to become more scientifically literate. The correlational analysis of the NOS and SSI views of these students from the three educational institutions showed that there were no correlational relationships between their NOS and SSI means. The small sample size might be responsible for the lack of correlation between the NOS and SSI scores of students who took the Introductory to Astronomy courses in these three research sites. A large sample will be needed to be sure that the sample is an accurate reflection of the population. The sample size used for community college and the historically black university was smaller compared to the sample from a Catholic university. The extracted pieces of the two instruments (SUSSI and SHOMS) used for this study may have also contributed to the lack of correlation that was observed. The correlation results are inconclusive.

Research that evaluated the SSI views of undergraduate students is rare literature. Studies that evaluated the SSI views of minority students do not exist. Studies that evaluated the correlation between SSI and NOS views of undergraduate students are non-existent in science education literature. Studies showed that university undergraduate science curricula are not designed to encourage students to participate effectively in the investigation of SSIs that require students to use multiple reasoning modes and interdisciplinary thinking (Yao Liu et al., 2010). Research that evaluated how cultural experiences of college students impact their NOS views is rare in science education research.

SSI and NOS are two different concepts that are used for the promotion of scientific literacy. Scientific literacy is one of the main goals of science education worldwide. The SSIs address the moral and social issues associated with the practice of science in different cultures and social norms. The NOS focuses on the history, epistemology, and sociology of science as a way of knowing. A good grasp of the

SSIs by undergraduate students can help them to better understand the basic tenets of NOS which most college students' still exhibit naïve views of NOS.

Discussion

Students' Views of Nature of Science

The mean scores of the students across the three research sites in the socio-cultural aspect of NOS that this study evaluated showed that these students have naïve/transitional views of the sociocultural aspect of NOS tenet. Students with naïve views of NOS have no knowledge of the basic tenets of NOS. The NOS views of students that are categorized as transitional are just forming or developing. These findings agreed with research that showed that college students exhibited a poor understanding of the NOS tenets, theory, and law, social and cultural aspect of science, and how scientific knowledge is generated by scientists ((Miller et al., 2010; Pace et al., 2014). Research showed further that greater exposure of students to science courses does not have any significant effect on students' views of NOS tenets (Miller et al., 2010; Pace et al., 2014). The teaching of the concepts of NOS was never emphasized in the high school science curriculum in America until recently through the major education reform efforts in K-12 science education. This reform is now reflected in the Next Generation Science Standards (NGSS). According to the study done by Miller et al. (2010), "Results from this study provide evidence that undergraduate students in Environmental Science (non-majors) and Biology (major) have similar views of NOS, ranging on average from naïve to somewhat informed" (p. 47).

Existing studies of the NOS views of undergraduate students did not look specifically at the differences in the NOS views of undergraduate students based on demographics, social settings, and cultures of these students (Miller et al., 2010; Pace et al., 2014). This study addressed this gap in the literature by evaluating the roles that cultures and social experiences of college students may have played in shaping the NOS views of these students who enrolled in the Introductory to Astronomy courses using the institution as a proxy for culture.

The findings of this study showed that there were significant differences in the NOS views of the students from the three institutions. This is inconsistent with Lev Vygotsky's sociocultural theory that emphasizes the impacts of both culture and social aspects of life on a person's cognitive development. Social environment according to Vygotsky leads to social interaction, social relationship and social artifacts, such as signs, symbols and linguistic terms (Lantolf et al., 2015). Factors such as textbooks, teachers' beliefs, and tools can influence the learner's construction of knowledge. Artifacts shape and transform learners' mental processes. The prior students' educational experiences of these college students may likely be the factors that were responsible for the significant differences observed in their NOS scores based on the findings of this study**.**

Students' Views of the Sociocultural Aspect of NOS

The responses of the students from the three research sites to the one free-response question from the instrument (SUSSI) generated qualitative data on the social and cultural aspects of the NOS. The responses of these students were summarized.

The free-response question is below:

Explain how society and culture affect OR do not affect scientific research, and provide examples to support your answer.

There are no differences in the responses of the students from the three research sites on the question of how society/culture may affect how science is practiced. Students across the three higher institutions believed that a scientist's societal norms and cultural beliefs determine how science is done. The findings from the responses of these participants agreed with one of the main tenets of NOS that says that social issues and cultures drive the direction of science in every society (Lederman et al., 2002). The analysis of the responses of students from the three research sites generated four different themes. The themes: are funding of scientific research, types of scientific research, regulation of scientific practice, and bias in scientific research. These themes are consistent with the main tenets of NOS that are generally accepted and used by science education researchers worldwide (Lederman, et al., 2013). The theme of the bias in scientific research agreed with the studies that showed that human biases of scientists are reflected in their observations of our natural world (Popper, 1992). The subjective nature of scientific knowledge derives from the fact that scientific findings reflect the scientists' viewpoints and personal interpretations that are given to those scientific findings, as a result of their cultural influences and varied areas of interest.

Funding for Scientific Research

Students' responses from the three research sites agreed that society and culture affect the practice of science when it comes to the issue of funding for scientific research. Most scientists do not have the money that is needed to fund their expensive research work. Scientists in many instances do not work independently. The main employers of scientists are government agencies and private corporations. The funding of scientific research comes from government agencies and private corporations that are directly the offshoots of the societies and cultures where they are. The decision-makers in these organizations have cultural values and social norms that affect their decision making when deciding to fund any scientific research.

Government agencies and corporations will normally fund scientific research that benefits their societies or can solve any ongoing societal problems. Examples of funded scientific researches are the search to find the medical cure for HIV/AIDS, and research for the development of alternative energy sources to replace the fossil fuels that impact the environment negatively and leads to climate change.

Types of Scientific Research

Students from the three independent groups in their responses agreed that society and culture have an overwhelming influence on the types of scientific research that can be done. Harmful scientific experimentation that threatens humans and their environment will not be supported by the society where scientists reside and practice their trade. Society and culture determine the scientific findings that should be accepted, like the controversial debate on whether the planet Pluto should be considered as a standard planet or a dwarf planet. The majority of scientists eventually decided to classify Pluto as a dwarf planet putting an end to the long debate.

People may not easily accept scientific findings that contradict their cultural beliefs and practices. What is normally considered to be important to society is what science research will focus on. The choice of scientific experimentation is impacted by society and culture where science is practiced. Countries that practice religious beliefs that teach creationism may not support the teaching of evolution in their schools or support any scientific research into the concept of evolution.

Regulation of Scientific Practice

Students from the three institutions said that society and culture regulate scientific enterprise. A science that goes against the cultural values and social norms of the society is always opposed by the society and culture where the scientists reside and practice their profession. Society may oppose scientific research that is inhumane to animals or destructive to the environment, like the testing of new drugs for the treatment of human diseases on domesticated and wild animals in which their side effects may not be easily known. Testing of the nuclear bomb on the land, oceans, and atmosphere with radioactive effects on the environment is opposed and rejected worldwide. Scientific findings that go against the popular opinion of the society are always controversial or rejected. Social and cultural beliefs of scientists may reflect in the presentation of their findings to conform to their societal popular mainstream opinions.

Bias in Scientific Research

Students from the three independent groups agreed that scientific enterprise is culturally driven. Every scientist belongs to a society and culture that influence his or her thinking. Scientists are humans with their own unique cultures. Scientists' personal beliefs are reflective of their cultural norms which then affect the practice of science. The influence that society and culture have on the practice of science gives rise to biases in science. Scientists use their scientific research and findings to justify some of their cultural beliefs. For example, some scientists concluded that black people are inferior beings to justify the practice of racism and slavery by their societies.

Scientists are influenced by their experiences, academic backgrounds, cultural norms, and social values that come from society and culture. This makes scientific research, scientific findings, and scientific interpretation of research outcomes to be laced with some biases. These biases come from society and culture. Society and culture determine how we live, how our government functions, and how science is practiced as a profession. Biases are part and parcel of science because scientists who do science are influenced by their own societal values and cultural norms.

The qualitative data from this study elicited students' views of the sociocultural aspect of NOS tenets than the quantitative data from the two instruments (SUSSI and SHOMS). The qualitative data of the NOS views of the students who participated in this study from the three research centers agreed with the main tenets of NOS that are accepted and used by science education researchers worldwide. The use of a qualitative research approach that elicits the thoughts of the participants and allows them to express their original ideas in the written forms may be a better way to look at the differences in the NOS views of students from these three institutions.

The differences in the NOS and SSI mean scores of the students from these three research centers were too small to make a conclusion about the impact of the institution on these students' NOS and SSI views. The use of institutions as a proxy for culture may not be the best way for evaluating the impacts of culture and social norms on the NOS and SSI views of these participants in this study. There may be a better way of measuring the impacts of culture on the NOS and SSI views of these students which may require a new type of research design. This exploratory and comparative study did not look at the other ways of evaluating the impacts that the cultures of these participants have on their NOS and SSI without using the institution as a proxy for culture.

Implications for Policy and Practice

1. The main goal of science education worldwide is to make students of science become scientifically literate. The SSI is one of the main constructs that is employed by science educators worldwide to promote scientific literacy. The college science curricula are not designed to encourage students to participate effectively in the investigation of SSIs that require students to use multiple reasoning modes and interdisciplinary thinking (Yao Liu, et al., 2010). Studies showed that college science courses that were taught using the argument-based instructional approach impacted college students' SSI views more significantly than the traditional lecture or direct instruction. Research showed that explicit attention to NOS tenets increased students' understanding of NOS tenets more than the traditional approach of using lecture and laboratory activities (Liang et al., 2010; Parker et al., 2008 & Samara, 2008). A deeper understanding of SSIs by college students would serve as an effective tool for increasing their NOS views. These research findings showed that there were no significant differences in the SSI views of college students that took the Introductory to Astronomy courses that were taught with the traditional approach of using a lecture or direct instruction from the three research sites. The use of the argument-based instructional approach for teaching college science courses by college faculty appears to be a better way to promote college students' views and understanding of SSI in particular and to promote scientific literacy in general. College science faculty

should be trained to use an argument-based instructional approach and explicit methods to teach science courses which research showed increased the SSI and NOS views of college students.

2. Research showed that science curricula that directly address NOS tenets promote students' understanding of NOS tenets. College science faculty should be trained on the use of an open-ended instrument in the designing and development of NOS based science curriculum. This teaching strategy is a better way to elicit and to probe their students' in-depth views of the basic tenets of NOS. This approach if used by college science faculty may benefit college students in particular, and the sub-groups of this population, especially the minority students in community colleges that are still heavily underrepresented in science education studies.

3. The use of institutional type as a proxy for race/culture in this study may not be the best way to look at the impact of cultures and social norms on the SSI and NOS views of college students from different cultures and varied social settings. The findings from this study showed that a significant difference in the NOS views of two groups of students (community college and historically black university) was observed even though the two groups have similar demographics. This finding from the NOS views of two very similar minority groups (community college and historically black university) contributes new knowledge to the existing literature concerning the NOS views of community college and undergraduate students that enrolled in the college Introductory Astronomy courses. The significant difference observed in the NOS means of these two institutions (community college and historically black university) with similar demographics showed that only 3% of the variability can be explained by the institution. Students' prior experiences and educational preparations appeared to

be more important than culture. The prior knowledge of these students in science appeared here to be more important than the culture.

Suggestions for Future Research

1. Overall, this study was exploratory in nature. It raises more questions in its findings. Other factors that impact college students' views of NOS and SSI apart from race/culture should be explored for future research.
2. Instructional strategies for teaching science to college students apart from an explicit teaching approach that would result in the development of NOS views among college students should be explored for future studies.
3. A better way of measuring the impacts of race/culture on the NOS and SSI views of college students without using the institution as a proxy for race/culture should be investigated for future research.

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APPENDIX A

Student Understanding of Science and Scientific Inquiry (SUSSI)

SD = Strongly Agree, **D** = Disagree, **U** = Unlikely,

A = Agree, **SA** = Strongly Agree.

Social and Cultural Influence of Science

A. Scientists who conduct scientific research are influenced by their culture and society.	SD	D	U	A	SA
B. The values and expectations of the culture determine what science is conducted, interpreted, and accepted.	SD	D	U	A	SA
C. The values and expectations of the culture determine how science is conducted, interpreted, and accepted.	SD	D	U	A	SA
D. Scientists are trained to conduct "pure", unbiased research; therefore their work is not affected by culture and society.	SD	D	U	A	SA
E. The purpose of scientific research is to find the absolute truth without the influence of the society and culture.	SD	D	U	A	SA

Please explain how society and culture affect science or explain why science is not affected by society and culture. Use examples to illustrate your answer.

APPENDIX B

The Scientific Habits of Mind Survey (SHOMS)

Directions: Please indicate the answer you think most closely represents your opinion about the following statements. It is important to understand that there is no right or wrong answer.

Demographics data (for data analysis purpose only). Please tick ALL that apply to you;

Male_____ **Female**_____ **Ethnicity** (please specify)__________________

Science Undergraduate________ **Social Science/Arts Undergraduate**________

1 = Almost Certainly true, 2 = Quite likely to be true, 3 = Quite likely to be untrue, 4 = Almost certainly untrue.

	1	2	3	4
1.Because the National Radiation Research Institute, reports that the radiation emitted by digital cell phones is not hazardous, we should believe this.				
2. The Ministry of Health should be believed when it says that the benefits of mass public vaccination programs outweigh individual risks of side effects.				
3. The National Association of Dentists should be believed when it says that the use of fluoride in municipal water improves dental health.				
4. If scientific research revealed a relationship between overhead power lines and increased rates of cancer, it is sensible to consider living away from power lines.				
5. It is reasonable to reconsider concerns about climate change if new scientific studies reported that long-term average global temperatures have both increased and decreased at various times.				
6. Reducing human-produced carbon dioxide is probably a a good way to prevent the potential effects of global warming, but there are so many factors to be considered we need more scientific studies before we consider changing our environmental or business practices				
7. A higher concentration of atmospheric carbon dioxide may affect the biological systems of the oceans, because oceans may become more acidic as a result of absorbing additional carbon dioxide.				
8. Early studies indicate that the use of cellphones may cause brain tumors; however, we don't know enough to be sure.				
9. We do not know enough to be sure that greenhouse gas emissions play a key role in climate change.				
10. It is a waste of money doing research about other planets and star systems.				

APPENDIX C

Community College Demographics for 2019

Students at Suburban Community College are mostly Black with a smaller. Hispanic population. The school has low racial diversity.

RACE	PERCENT OF STUDENTS
White	5%
Black	72%
Hispanic	11%
Asian	4%
American Indian / Alaskan	2%
Hawaiian / Pacific Islander	0%
Two or more races	0%
International	2%
Race Unknown	5%

The primary data source is from the National Center for Education Statistics (NCES).

APPENDIX D

Historical Black University Demographics for 2019

Students at Historically Black University are mostly Black with a small foreign resident population. The school has very low racial diversity.

RACE	PERCENT OF STUDENTS
White	2%
Black	83%
Hispanic	4%
Asian	1%
American Indian / Alaskan	0%
Hawaiian / Pacific Islander	0%
Two or more races	3%
International	7%
Race Unknown	1%

The primary data source is from the National Center for Education Statistics (NCES).

APPENDIX E

Catholic University Demographics for 2019

Students at this Catholic University are mostly White with a small Hispanic population. The school has low racial diversity.

RACE	PERCENT OF STUDENTS
White	78%
Black	6%
Hispanic	9%
Asian	4%
American Indian / Alaskan	0%
Hawaiian / Pacific Islander	0%
Two or more races	2%
International	0%
Race Unknown	0%

The primary data source is from the National Center for Education Statistics (NCES).

APPENDIX F

The Curricula for Astronomy Courses at the three institutions

Historical Black University

PHYS 102: Astronomy (2 Credits) – Two hours lecture; this is a study of heavenly bodies, constellations, time, celestial navigation, and astrophysics (spring semester only).

Community College

PSC-1010 Introduction to Astronomy (3 Credits): For nonscience majors. Introduction to the extraterrestrial environment, including astronomical concepts and theories. Science general education class. Honors: (Honors version available). Prerequisite(s): Reading proficiency.

Catholic University

PH 120 - Introduction to the Universe (3 Credits): A survey of the history of astronomy and the current state of this science. A look at the probabilities of, and search for, extraterrestrial life. A study of our solar system, stars and their evolution, our galaxy, and other galaxies, supernovas, pulsars, black holes, quasars. Fulfills one math/science core requirement. Closed to students who have taken PH 140 or PH 141.

APPENDIX G

Scoring Rubric Students'/Teachers' views of NOS aspects are categorized into naïve, transitional, or informed based on the following criteria (Liang et al., 2008):

Naïve: Student's/Teacher's response is not consistent with any part of the NOS aspect and full of misconceptions or contradicting statements.

Transitional: Student's/Teacher's response is consistent with some, but not all, parts of the NOS aspect and responses do not provide reasons or examples to justify their statements on NOS tenets.

Informed: Student's/Teacher's response is consistent and addresses all parts of the NOS aspect.