

Scientific Literacy and Nature of Science as it Impacts on Students' Achievement in South
Trinidad

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Abstract

Many countries globally have embarked on reform efforts to their education system in an attempt to increase the scientific literacy of the population. Achieving scientific literacy, of which the Nature of Science is an important component, is vital for individuals to make informed scientific decisions and become more productive citizens. It has been observed by the researcher that students tend to perform well on high stakes examinations; however, their scientific literacy appears to be relatively low. Thus, this study examines the impact of a Unit of lessons infused with the Nature of Science on students' scientific literacy and achievement. The sample consisted of 34 boys of mixed ability between the ages of 11-12 years from an urban school in south Trinidad. Data obtained from the Nature of Science and scientific literacy surveys and the achievement test were analyzed statistically using the SPSS 17.0 program. The findings revealed that students' initial, moderate understanding of the Nature of Science became more non-traditional after the intervention. Their scientific literacy and achievement also increased after participating in the unit of lessons designed to change their views of the Nature of Science.

Keywords: scientific literacy, nature of science, students' views

Chapter I

Introduction

It has been observed by the researcher that the students of this school do not develop a holistic view of science but rather they resort to 'rote' learning or learning by memorization of selected information. They do not learn any additional material which they know will not be tested on their end of term, Caribbean Examination Council (CXC) or National Certificate of Secondary Education (NCSE) examinations. Consequently, learning at this school is driven by desire of the boys to perform well at these high stakes examinations. Students' academic achievement on these tests is often high but their scientific literacy (SL) appears to be relatively low. Additionally, these students depend heavily on the teacher for information as the teacher is viewed as the dispenser of knowledge. They also rely on the textbook to a large extent as a primary source of knowledge. Hence, the way in which the curriculum is delivered may be adding to this problem of low scientific literacy. In order to address this issue, science needs to be presented to the students in a more meaningful way so that it becomes relevant to their everyday life.

This school is considered by many individuals of the community as one of the 'prestige' schools located in the city of San Fernando. Consequently, there are high expectations that the boys will produce outstanding results at both the Caribbean Secondary Education Certificate (CSEC) and Caribbean Advanced Proficiency Examinations (CAPE). In essence, the success of the school is measured by the success of the students. That is, the number of scholarships attained by the boys is sometimes used as a measure of the performance of the school. The need for 'results' at CXC is often reinforced by administration during staff meetings, graduation ceremony and professional development sessions. Hence, teachers place more emphasis and

value on content knowledge rather than meaningful learning. Consequently, the students do not develop the life-long skills essential in becoming a productive citizen; one who is capable of contributing to the social and economic welfare of our society.

Interest in this topic was also generated after listening to a lunchtime conversation among several of my colleagues including a young, untrained science teacher. This teacher had given a class a science test earlier that day in which the students were required to name four scientists. One of the boys noted two scientists from the past but also included the names of two science teachers from the school whom he thought were scientists. To my surprise, the teacher laughed at the students' response and proceeded to share the boys' answer with other staff members implying that the answer was wrong. I was able to recognize that the child was indeed correct having studied the Nature of Science (NOS) in one of my courses as well as in the Diploma in Education Programme. This incident made me realize that the teacher's views of the NOS, or lack thereof, may be impacting upon the students and the way they learn science. Having not been trained in the field of education, the science teacher may possess a more non-traditional view of science which is being transferred to the students. Therefore, if we want our students to become scientifically literate we, as educators, need to present science in a more holistic way.

Furthermore, my interest in this topic was heightened as a result of the labor shortage in Trinidad and Tobago over the past few years. As such, the government made the decision to source workers from other parts of the world to supplement our local labor force. Ironically, most of these workers belonged to science related fields. For instance, in 2003 a group of eighty doctors and nurses arrived in Trinidad to begin their two-year contract in this country (Pickford-Gordon, 2003). This was in response to a shortage of doctors and nurses at our nation's hospitals. Similarly, in 2008 the government of Trinidad and Tobago contracted the Chinese company,

Shanghai Construction Group, to renovate the Prime Minister's residence at an estimated cost of US \$500 million dollars (Bagoo, 2010). This is the same company which received the multimillion dollar contracts to build the National Academy for the Performing Arts (NAPA) Centre in Port-of-Spain and the San Fernando Performing Arts Centre (Peters: \$300m Sando, 2010). Likewise, the construction of the multimillion dollar interchange in north Trinidad was completed by a French company called Vinci (Julien, 2010). The questions then beg, why is there such a need to outsource for labor. Do we not have local companies who can provide similar or better service to our country? Clearly, there is a dire need for citizens to enhance their scientific literacy so as to make a valuable contribution to society. As educators we need to take heed of these glaring issues that are affecting our learners and find possible ways in which to curb this problem.

Background to the Problem

Our society and economy are becoming more competitive today than in the past due to the advancement in technological innovations. Hence, there is an increasing demand for individuals to be scientifically literate in order to compete on the global market. All people, despite age, gender, ethnicity and culture, need to possess a certain amount of scientific knowledge and skill in this rapidly changing world to enable them to realize their personal and social aspects (Stefanova, Minevska & Evtimova, 2010). Consequently, there exists growing concerns regarding the current scientific literacy status of our population.

Every three years the Programme for International Student Assessment (PISA) evaluates the knowledge and skills of 15-year-old students in three subject areas (English, Mathematics, Science) from participating and Organization for Economic Co-operation and Development (OECD) countries. The main focus of PISA 2006 was on SL. This large-scale test does not focus

on how well students have mastered the curricular content but rather their ability to apply the knowledge and skills in real life situations (PISA, 2006). The findings revealed that while the majority of students were motivated to study science only 37% indicated that they would like to work in a science-related career.

The PISA 2009 results indicate that the students of Trinidad and Tobago possess a relatively low proficiency in science as measured on a scale of 1 to 6. Approximately seventy five percent of the students who participated in this test were at level two or lower (PISA, 2009). This means that they possess adequate scientific knowledge to provide explanations in familiar contexts but they are unable to apply this knowledge to different contexts (PISA, 2006). It is findings like this that has prompted numerous countries worldwide to reform its science education programme in order to increase the scientific literacy of its population.

Globally, there is much concern about the status of science education and the decreasing interest of our students in science-related fields. Analysis of research conducted by the OECD over the last decade indicates that even though more young people in Europe are attending university, they are choosing to study fields that are unrelated to science (Rocard, Csermely, Jorde, Lenzen, Walberg-Henriksson & Hemmo, 2007). This has led to the promotion of two innovative initiatives across Europe known as 'Pollen' and 'Sinus-Transfer'. Pollen currently operates in twelve countries in the European Union while Sinus has been extensively tested in Germany. These two projects adopt a more inquiry-based approach to teaching science (Rocard et al., 2007; Dillon, 2009). They both aim to develop students' interest in science and to generate excitement in this area. Interestingly, these projects have no intention of changing the curricula or its content but rather they propose an innovative pedagogical approach to science instruction.

Other countries including Turkey and the Netherlands have also reformed their science education program in an effort to increase scientific literacy. In 2003, Turkey implemented a new science curriculum for primary school so as to attain international standards of education similar to developed countries such as Europe, North America and East Asia (Dillon, 2009). This is because the scientific ability of Turkish students appears to be relatively low as compared to that of students of the other OECD countries. Data from PISA (2006), in which science literacy was the main focus, shows that Turkey students obtained a science score of 424 which was well below the OECD average of 500. Consequently, Turkey ranked 44 out of a total of 57 countries that participated in PISA for that year.

Similarly, in 1994 the Netherlands embarked on two initiatives aimed at enriching the science curriculum so as to encourage more students into the science field (Dillon 2009). Firstly, they implemented an entirely new subject called the General Natural Sciences for all secondary school students. They then introduced a specialized science-enriched secondary school with an enhanced science curriculum and greater focus on scientific research.

Regionally, several Caribbean countries including Barbados, Bermuda and Jamaica have undergone large scale education reform in an attempt to increase the interest, knowledge and skills of students in science education. Sweeney (2003) describes some of these reform efforts in his overview of science education in the Caribbean. In 1998, Barbados embarked on one of the most ambitious education policy initiatives in the region known as EduTech 2000. This seven year project aimed to increase the number of students contributing to the development of Barbados by emphasizing the use and application of information technology in education (Ministry of Education and Human Resource Development, 2011).

Alternatively, in 1997 Bermuda began to reform its entire education system by implementing a new set of curricula for all public schools. Thus, in 2001 the Bermuda Science Performance Standard (BSPS) was introduced to schools. Although the BSPS was developed using standards from other countries, it was unique to Bermuda in that the curriculum was tailored to the culture and context of Bermuda. Additionally, the Bermuda Schools' Science Enrichment program was designed to encourage students to develop an interest in science using practical scientific experience. It also aimed to provide free professional development for science teachers (Sweeney, 2003). Moreover, Bermuda is currently engaging in its five year Strategic Plan (2010-2015) for education reform in which it aims to "deliver a first class education of global standards ensuring students reach their full potential" (Government of Bermuda, 2010). Part of this reform initiative involves the adoption of the Cambridge curriculum.

Likewise, Jamaica has also reformed its science education program with the main focus being on early childhood education. In 1998, the Science Matters in Life Everyday (SMILE) programme was initiated for both young children between the ages 4-6 and teachers (Sweeney, 2003). It was expected that by making science more exciting through the use of low cost materials and teacher training, there would be a greater interest in the teaching and learning of science (Jules, Miller & Armstrong as cited in Sweeney, 2003).

Trinidad and Tobago, though, is no exception to this global trend of education reform. We have recognized the need to develop an innovative population; one that consists of "highly skilled, well educated people" who are capable of being socially responsible and contributing to the economic development of the country (Multi-Sectoral Core Group, n.d., p. 19). The government of Trinidad and Tobago believes that through this reformed education system it will be able to achieve the goals as stated in its Vision 20/20 statement and hence, the country will be

well on its way towards attaining developed country status by the year 2020 (Ministry of Education, Trinidad and Tobago, n.d.).

Reform and modernization to its education system started in the 1990s and continues to be one of the primary goals in education (Republic of Trinidad & Tobago, Ministry of Education, 2004). This is evident by construction and refurbishment programmes at both the primary and secondary levels. At the secondary level these programmes are being conducted through the Secondary Education Modernization Programme (SEMP). In 1999 Trinidad and Tobago was granted a US \$100 million dollar loan from the Inter-American Development Bank for SEMP (Trinidad and Tobago, n.d.). This programme sought to improve the quality of education in a number of ways:

- A revised curriculum was initially introduced to the Forms 1-3 level which was “designed to ensure that all students cover a basic core of learning that will prepare them for further study and will give them the discipline required for entry to the world of work” (Ministry of Education, Trinidad and Tobago, n.d.,p.1). Additionally, training programmes were conducted for secondary school teachers in curriculum writing, school based management and administration in the preparation for the delivery of this modernized curriculum (Republic of Trinidad and Tobago, Ministry of Education, 2004).
- Construction of new secondary schools and upgrade of existing ones.
- Installation of computer labs in every secondary school. Many schools were supplied with laptops, desktop computers, printers and internet access in an effort to increase students’ proficiency in Information and Communication Technology (ICT). School libraries were also transformed into media centres to facilitate this process.

Theoretical Perspective

While researchers (Dawkins & Dickerson, 2003; Musante, 2005) who have conducted studies on the NOS and SL have adopted a more historical and philosophical approach to science education, this study will utilize the sociology of science as its conceptual framework to provide alternatives to science education. This framework represents a shift away from the traditional approaches to science education and has been largely overlooked in the past (Cunningham & Helm, 1998). However, Cunningham and Helm (1998, p. 484) advocate that “understandings from sociology of science can provide a powerful framework for making science education more authentic and more inclusive”. It can be used by educators to inform both the content and pedagogy of the science classroom.

The sociological framework utilized in this study assumes that science is a social enterprise (Driver, Learch, Millar & Scott, 1996). That is, the work of scientists and the generation of scientific knowledge are influenced by interactions amongst researchers and the wider community. Like scientists, students conduct experiments in order to test their hypotheses. They make observations and conduct replications of their study to verify their results. When conducting experiments, though, scientists may use their tacit knowledge or intuition to influence their results. Hence, this makes the replication process more difficult and controversial for other scientists as there is no rigid scientific method (Cunningham and Helm, 1998).

The construction of scientific knowledge is a long, gradual process which involves collaboration amongst scientists. In order for an idea to gain recognition, it must first be examined by other scientists (Cunningham & Helm, 1998). For instance, scientists must first persuade themselves then others in the wider community of their significant findings. They do

this by conducting research and publishing their finding in journal and books for their peers to review. This serves as a form of communication whereby scientists critique each other's work finding both strengths and weaknesses. Similarly, students operate as scientists by submitting a written report to the teacher upon completion of the experiment.

Furthermore, Cunningham & Helm (1998) suggests that the community plays an important role in the social nature of science. Many scientists form alliances and belong to various associations which provide a forum for the sharing of information. Such a setting allows scientists to collaborate on scientific ideas and keep abreast of the rapidly changing nature of science. This networking process may also be used by scientists as a means of procuring equipment, funding and other material needed for their research. It helps to generate support for scientists' and their research so that it is accepted by the wider community as new scientific knowledge. Likewise, students form small groups when conducting experiments in the laboratory in order to share ideas, advice and data. This allows them to produce more reliable results and to recognize that there may be many possible solutions to a given problem.

In his study Moss (2001) developed a model consisting of five criteria used to interpret students' perceptions of science. This model perceives science as a social activity which influences and responds to the social needs of society. For instance, science graduates may become journalists who report on new scientific discoveries or health officers informing the public about food safety practices (Ryder, Leach & Driver, 1997). A sound understanding of NOS is needed by these individuals in order to make informed, scientific decisions. Additionally, scientists are influenced by cultural factors such as funding or grants which are made available to them by governments, private companies and other institutions such as universities. These

groups may influence the direction of scientific research by funding some areas and not others. (Driver et al., 1996). Their work may also be influenced by their personal experience, family life, background and even feuds with other scientists.

Problem Statement:

Under high pressure to complete the syllabus in time for examinations, science teachers do not cater to students' interests. Hence, science is not being presented in a holistic way, resulting in students who engage in 'rote' learning. They perform well on high stakes examinations but yet they are not considered to be scientifically literate; capable of making rational and well educated scientific decisions.

Purpose of Study

The purpose of this quantitative study is to examine students' views of NOS and whether these views change, becoming more non-traditional after participating in a unit of NOS-infused lessons. This action research will also evaluate students' SL level and the extent to which it changes after the intervention. The impact of students' SL and views of the NOS on their achievement will be assessed statistically. This study will test the theory of the social perspective of science of a purposive group of Form One boys in South Trinidad. In this case NOS "refers to the values and assumptions inherent to scientific knowledge and the development of scientific knowledge" (Lederman & Lederman, 2004, p.36). SL, though, is defined as the ability of students to use their scientific knowledge and skills in different areas and in different life situations (PISA, 2006). Students' achievement will be measured by their academic performance on a test designed to assess their NOS views and SL skills.

Research Questions

This empirical study is guided by a single overarching question and three sub-questions:

Overarching question. What impact would a Unit of Lessons on Matter, infused with the Nature of Science, have on Form One students' scientific literacy and academic achievement in a boys' secondary school in South Trinidad?

Sub-questions. 1. How do students view the NOS?

2. Is there a significant change in students' NOS scores following participation in an intervention designed to change their views of science from traditional to more non-traditional?
3. Does the intervention have an impact on students' scientific literacy scores?
4. Is there a significant change in students' performance scores following participation in an intervention designed to increase their scientific literacy?

Statement of Hypotheses

Hypothesis testing was conducted to investigate the extent to which a unit of lessons infused with the NOS impacts on students' SL and achievement. The hypotheses included:

1. H_0 : There is no significant change, at the .05 alpha level, in students' traditional and non-traditional views of NOS after being taught a unit of lessons infused with the NOS.
2. H_0 : There is no significant change, at the .05 alpha level, in students' SL level after participating in an intervention designed to change their NOS views.
3. H_0 : There is no significant relationship, at the .05 alpha level, among students' views of NOS, SL level and their achievement.

Significance of the Study

This study is significant as both the NOS and SL have not been extensively researched in Trinidad and Tobago or in the Caribbean. Thus, it may serve as pioneering research in these fields in a local context. Additionally, the study will contribute to the existing body of knowledge on SL and students' views of the NOS. Moreover, the findings of this action research may be significant to various stakeholders including students, teachers and policy makers. Students may develop a greater interest in science resulting from their enhanced understanding of the NOS. Consequently, they may engage more frequently in science-related activities and careers.

The results of this study may also be used to enact change in teachers' pedagogy and policy documents. Having recognized the benefits of NOS-infused lessons, teachers may become more motivated to modify their traditional teaching strategies to explicitly incorporate the NOS so that science is presented to students in a more holistic way. This study will also generate awareness amongst all stakeholders as it highlights the importance and urgency of integrating NOS into the science curricula at the secondary level. The findings will provide policy makers with initial data regarding the impact of the NOS on students' scientific literacy and achievement. It may be used by these stakeholders in their efforts to reform science education in Trinidad and Tobago.

Scientific Literacy

Many countries around the world have recognized the need to increase the scientific literacy of its people in order to prepare them to become productive citizens who are capable of competing on an international level. Since the introduction of the term "scientific literacy" in 1952 (Kemp, 2000), it has gained much popularity among educators and has become a primary

goal of science education curricula in many countries (Ozdem, Cavas, Cavas, Cakiroglu & Ertepinar, 2010). However, since then the concept has not been well defined and as such, it is not well understood (Preczewski, Mittler & Tillotson, 2009). There appears to be no consensus on its meaning or content (Ozdem et al, 2010). Hence, there is no universally accepted definition of scientific literacy (Liu, 2009). Many researchers and educational organizations, though, have attempted to define this concept. Preczewski et al. (2009, p.247) defines scientific literacy as “the ability of a citizen to make rational and well-educated choices about scientific encounters as adults”. The National Science Education Standards (National Research Council, 1996, p. 22) gives the following definition of scientific literacy:

Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed...Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments.

PISA, though, defines SL as the ability of students to use their scientific knowledge and skills in different areas and in different life situations (PISA, 2006).

Additionally, many researchers have proposed varying components or elements of scientific literacy. However, there are aspects of scientific literacy that are common to all of them.

Understanding the NOS remains a key dimension by which students' scientific literacy can be

enhanced (Preczewski et al., 2009). Shen (as cited in Liu, 2009) identified six elements of scientific literacy to be: (a) understanding basic science concepts, (b) understanding nature of science, (c) understanding ethics guiding scientists' work, (d) understanding interrelationships between science and society, (e) understanding interrelationships between science and humanities and (f) understanding the relationships and differences between science and technology. In his analysis of the Lebanese science curriculum, though, BouJaoude (2002) developed and used a framework which was composed of four aspects of scientific literacy. These included: (a) knowledge of science, (b) the investigative nature of science, (c) science as a way of knowing and (d) the interaction of science, technology and society. The framework developed by BouJaoude (2002) will be used in this study.

The Infusion Approach

The infusion approach is more commonly associated with the works of Swartz and Perkins. It represents a natural strategy in which critical and creative thinking skills are integrated into content instruction. According to Swartz and Parks (1994) the infusion approach is "based on the natural fusion of information that is taught in the content areas with forms of skillful thinking" used in our everyday life. Infusion involves the *teaching of thinking* by direct instruction in which students learn how to use explicit thinking strategies which are guided by the teacher. Additionally, it incorporates *teaching for thinking* whereby students develop a deeper understanding of the content using graphic organizers, cooperative learning and even higher order questioning.

Every infusion lesson utilizes collaborative thinking activities and involves four main stages (Swartz, Fisher & Parks, 1998; Swartz & Parks, 1994; Swartz, Whipple, Blaisdell & Kiser, 1999). These include: (a) the lesson introduction, (b) thinking actively, (c) thinking about

scientific thinking and (d) applying the thinking. In the first stage the students are introduced to the objectives of the lesson, the content and the NOS. These components of the lesson are explicitly stated to show students the importance of this type of thinking and to engage them in the process. The second part of the lesson involves students following the thinking map or graphic organizer created for the specific type of thinking. The students may work collaboratively during the thinking activity.

In the next stage, the teacher engages the students in metacognition or reflection on how they were thinking during the lesson. This is done using oral questions or a metacognitive log to guide the students. Finally, the students engage in transfer activities where they apply their knowledge and thinking skills to their everyday life and other real world contexts. Transfer activities may be of two types: near transfer and far transfer. In near transfer the students apply the thinking process to content similar to the initial activity within the same class session. However, in far transfer the students apply the thinking process to content different from the initial activity.

The Nature of Science (NOS)

The inclusion of the NOS in science education originated in the works of Ernest Mach of the late nineteenth century and that of John Dewey of the early twentieth century (Bell, Abd-El-Khalick, Lederman, McComas, & Matthews, 2001). Since the 1960's the concept of the nature of science (NOS) has assumed a more prominent role in the scientific community and curriculum reform (Rudolph, 2000) as science educators have recognised that NOS is a central component in achieving scientific literacy (Muslu & Akgul, 2006). However, the term NOS remains multifaceted and complex in nature (Abd-El-Khalick, Waters & Le, 2008) as there exists no universally agreed upon definition (Muslu & Akgul, 2006). Also known as the epistemology of

science, the NOS includes aspects of history, philosophy and sociology of science (Bell et al., 2001). Consequently, many definitions of the NOS exist depending on how researchers interpret this concept. Lederman and Lederman (2004, p.36) suggest, though, that NOS “refers to the values and assumptions inherent to scientific knowledge and the development of scientific knowledge.”

Similarly, researchers and educators often present different aspects of the NOS based on the assumptions that they make about the NOS. Despite their disagreements concerning the tenets of the NOS, many researchers (Abd-El-Khalick et al., 2008; Colburn, 2004; Lederman & Lederman, 2004; Irez, 2008) still share common ideas regarding the components of the NOS. These include the tentativeness of science and the lack of a single, universal scientific method. In their study, Lederman and Lederman (2004) identified seven NOS components which they believe have been generally agreed upon and essential for all citizens to know. These include: (a) the distinction between observation and inference, (b) the distinction between laws and theories, (c) scientific knowledge is empirically based and involves human imagination, (d) scientific knowledge is partially subjective, (e) science is socially and culturally embedded and (f) scientific knowledge is tentative. Abd-El-Khalick et al. (2008), though, focused their attention on the following ten aspects of the NOS: (a) empirical, (b) inferential, (c) creative, (d) theory-driven, (e) tentative, (f) myth of “The Scientific Method”, (g) scientific theories, (h) scientific laws, (i) social dimensions of science and (j) social and cultural embeddedness of science. For the purpose of this study the unit of lessons will focus on the ten aspects of the NOS science as outlined by Abd-El-Khalick et al. (2008).

Many students today, though, still possess naïve views of the NOS or very little understanding of this concept. This has led to students developing a more traditional view of science in which they regard science as consisting of facts and laws that cannot change. Students' naïve views of science often result from the way in which science is presented to them by teachers as well as the curricula and practices associated with pre-service and in-service science teacher education (Abd-El-Khalick et al., 2008). Like the students, teachers' views of the NOS are generally not consistent (Cochrane, 2003). Also, if these NOS components are not included in the curriculum documents, to which many science teachers adhere to, then it will more than likely be omitted from science education. Furthermore, Abd-El-Khalick et al. (2008) believe that students' views of the NOS are a result of the way in which it is presented in many science textbooks.

It is important to recognize that effective science teaching does not only result from the learning of facts and theories. In order to convey the NOS to students, teachers themselves need to understand the attitudes, behaviours and worldview of scientists (Matson & Parsons, as cited in McComas, 1998). Thus, they should possess a comprehensive understanding of the NOS and be able to effectively communicate this understanding to their students using various instructional strategies. Researchers (Allchin, 2004; Mc Donald, 2010; Musante, 2005) have identified that the best approach to the teaching and learning of the NOS is through the use of explicit, reflective instruction. That is, engaging in discussion, questioning and reflection on the content and processes of scientific knowledge. Additionally, Book Review (2010) and McDonald (2010) suggest that the most promising approach to teaching the NOS is by integrating it into the science curriculum using a context method rather than as an auxiliary learning outcome. Separating the learning objectives may result in the replacement of science

objectives. Such an approach will require careful planning in order to make the implementation process successful.

Assumption

- It is assumed that the students will interpret the items on the NOS questionnaire in the same way as the researcher.

Limitations

The findings of this study may be limited by the following factors:

- Participants may have attended extra ‘lessons’ which may have influenced their views of the NOS and impacted on their SL. Therefore, their responses to the questionnaires may not be a true reflection of the impact of the intervention on their views of NOS and SL.
- The instrument used to measure students’ NOS views was closed ended and did not contain any open-ended items for students to elaborate on or clarify their responses. Hence, the researcher was unable to obtain an in-depth understanding of students’ views of the NOS.
- The unit of NOS-infused lessons did not focus on students’ cultural beliefs and indigenous knowledge. Thus, this aspect of NOS could not be measured adequately and as a result, they were omitted from the data analysis.
- Other factors which were not controlled for in this study may have impacted on students’ achievement. These included students’ socio-economic status, age, primary school attended and whether they attended science ‘lessons’ in primary school.
- This study was conducted over a period of five weeks. Such a short period of time may be insufficient to make any significant change in students’ views of NOS which would

have taken them years to establish. Given a longer period of time the intervention may have had a greater effect on students' views of science, their SL and achievement.

- In her study Pomeroy (1993) used a 50-item Likert-scale questionnaire to measure scientists, secondary and primary school teachers' views of the NOS. In this study, though, a modified version of this questionnaire was used to measure secondary students' views of the NOS. These students may not have interpreted the items in the same way as those participants of the Pomeroy study.

Delimitations

The following factors served to define the boundary of this study:

- The study is limited to one Form One class in a denominational school who were purposely selected for participation. The sample consists of boys who are mostly of East Indian descent. Therefore, the findings of the study cannot be generalized to all Form One students, boys and girls, in government, private and denominational schools.
- Most of the students at this school and thus, participants in this study, are of an average or above average ability. Consequently, this sample may not reflect the ability of all Form One students.

Definition of Terms

Operational definitions are provided for three terms in this study:

1. SPSS: Statistical Package for the Social Sciences is a computer program used for statistical analysis of data.
2. Traditional views science: This refers to beliefs of the NOS in which many myths of science are embedded.

3. Non-traditional views of science: This is a contemporary view of the knowledge and processes of science. That is, the individual believes in dynamic nature of the scientific enterprise.

Organization of Rest of Paper

This paper is divided into five chapters. In Chapter 2 the researcher critically and analytically reviews the experiences, design, method, data analysis and findings of empirical studies conducted by researchers who attempted to contribute a solution to a problem similar to that identified in this study. It also gives a justification for the focus and approach of this study. The methodology is presented in Chapter 3. It describes the type and design of study, research questions and the procedure used to conduct the study. It also includes explicit descriptions of the instruments used to collect data, the sample and the sampling procedure. Additionally, the methods of data collection and analysis will be described thoroughly. The data analysis and findings of the study are presented in Chapter 4. This chapter describes the results in relation to each research question. Chapter 5 discusses any similar findings between this study and the literature review. Additionally, conclusions are drawn and recommendations are made for future studies. Furthermore, this chapter outlines the implications of the findings of this study to the various stakeholders.

Chapter II

Literature Review

Introduction

In this chapter the researcher will critically analyze the empirical experiences, design, method, data analysis, results and findings of studies conducted by other researchers that are similar or related to this study. Both the strengths and the weaknesses of these studies will be highlighted in order to evaluate the validity of the findings. The content will be organized into sections according to the research questions and any significant relationships amongst the variables being investigated. Furthermore, the studies reviewed will be presented in a systematic and logical way.

Students' views of the NOS. Research conducted on elementary students indicates that they primarily possess an inadequate and traditional view of the NOS. Muslu and Akgul (2006) conducted a qualitative research study in which they sought to identify 8th-grade students' understanding about science, scientists and the scientific process. The sample consisted of 26 (15 males, 11 females) students who were randomly selected from an elementary school in Istanbul. The researchers chose a qualitative design for this study as they believed that this method would generate more open, in-depth and detailed data due to a lack of predetermined categories. Hence, data was collected using student-generated artifacts and open-ended questions. The findings revealed that the participants hold traditional views about science, scientists and the scientific process.

Likewise, Akerson and Abd-El-Khalick (2005) investigated elementary students' views of the NOS in the United States of America (USA) over a period of one year. A sample of 23 Grade 4 students (10 male and 13 female) participated in this study. Students' conceptions of the

NOS were measured using a modified version of an open-ended questionnaire, Views of Nature of Science- Form B (VNOS-B), developed by Lederman, Abd-El-Khalick, Bell and Schwartz in 2002. Additionally, interviews were used to provide additional data about students' views of science. The results of this study indicated that the fourth grade students held misconceptions about various aspects of the NOS including the distinction between observation and inference, creativity and imagination and the tentativeness of science.

In their study Kang, Scharmann and Noh (2004) also investigated students' views of the NOS across grades 6, 8 and 10 in Seoul, Korea. This was done using a large scale survey consisting of 5 multiple choice items adapted from the Views on Science-Technology-Society (VOSTS) developed by Aikenhead, Ryan and Fleming and an instrument designed by Solomon et al. Additionally, students' were asked to respond to an open-ended section in order to provide rationales for their choices on the survey. The survey was administered to 1702 students who were randomly selected from five school districts. The results indicated that the majority of Korean students possessed an absolutist/empiricist perspective of the NOS. That is, they do not hold contemporary views of science. Also, it was found that there was no clear difference in the distribution of 6th, 7th and 8th graders' views on the NOS.

Alternatively, Haidar and Balfakih (1999) investigated high school students' views of the epistemology of science. Approximately sixteen hundred 11th and 12th grade students were randomly selected from 22 schools from the seven Emirates that constitute the United Arab Emirates. The average age of these students was 17.5 years. Data of students' views of science was collected using a multiple choice questionnaire which was modified from Aikenhead and Ryan in 1992. Students' responses to open-ended questions were categorized and used to develop the choices to the questions on the questionnaire. This was done in order to avoid the

shortcomings of closed-ended questions and to provide the researchers with a deeper understanding of the responses. The interview technique, though, was not feasible in this case due to the large sample size. The results indicated that most students (9-70%) held uninformed or traditional views of science while a smaller percentage of students (3-59%) possessed a more constructivist view of science. Additionally, the results showed that students' cultural background influence their views of the epistemology of science.

In an attempt to obtain a more global perspective of students' views of the NOS, Griffiths and Barman (1992) conducted a multinational study of secondary school students' views of the NOS. Thirty two students of varying ability and interest in science were randomly selected from each of the countries Canada, the USA and Australia. However, due to varying grading systems among the countries, students' ability was not a constant parameter. Each student was interviewed individually and was asked a series of open-ended questions in order to elicit their views of science. The researchers selected the interview method as opposed to a written instrument such as a questionnaire as they believed that an interview would generate responses and understandings which would not normally be obtained from tests. These interviews were transcribed and students' statements were summarized. The results indicated that the students of these countries possessed relatively vague views of the NOS.

Similarly, Dogan (2010) conducted a study to investigate the views of NOS of 11th-grade students from three different high schools in Turkey. This study is based on research which has indicated that both teachers and students do not have an adequate understanding of the NOS. Consequently, the scientific literacy of students in Turkey is below that of students in Western countries. A total of 117 students from the three schools participated in this study. Data of students' understanding of the NOS was collected using the Perspectives of Scientific

Epistemology (POSE) questionnaire which was developed by Abd-El-Khalick in 2002.

Comparison among the three schools was possible as they all had a common curriculum with only minor differences. The findings revealed that most of the students have misconceptions of the NOS. They hold positivist views on the producing of scientific knowledge, theory and law, and the effects of socio-cultural on science and scientists. Also, the students held naïve views regarding some aspects of the NOS such as creativity and imaginations, scientific knowledge and scientific opinion. Furthermore, students' views of the NOS did not show significant differences among the three schools.

Additionally, Moss (2001) examined the conceptions of 5 high school students from Northern USA over a period of one year. Purposeful sampling was utilized to select these 5 participants of mixed ability based on their willingness to participate in the study, gender and their achievement. Students' conceptions of the NOS were measured using various qualitative data sources; the main one being formal semi-structured interviews. Each participant was interviewed a total of 6 times over the course of the school year. Other data sources included students' work and notes acquired during participant observations which were used to corroborate statements made during the interviews. The findings of this study revealed that students began the school year with either a partial or full understanding of many of the tenets of the NOS and their beliefs remained consistent throughout the study.

Sutherland and Dennick (2002) also conducted a study in North America which explored First Nations (Cree) and Euro-Canadian students' perceptions of science based on their culture and language. Seventy two students (34 females and 38 males) from a high school located in Manitoba, Canada were selected to participate in this study. Their views of science were measured using two different approaches. Firstly, a questionnaire consisting of both qualitative

and quantitative elements was administered to students. The qualitative part comprised of eleven open-ended questions while the Likert scale section was a modified version of the Nature of Scientific Knowledge Scale (NSKS) questionnaire developed by Rubba and Andersen in 1978. Secondly, semi-structured interviews were conducted with the Aboriginal students as this was deemed by the researcher as a more culturally appropriate method of obtaining their perceptions of science. It was found that these two groups of students differed significantly in some of the tenets in the NSKS questionnaire. However, no difference was found in their NSKS scores between language groups.

Furthermore, Dawkins and Dickerson (2003) explored the ideas of high school students regarding the nature and role of scientific theories, an aspect of the NOS. The participants included 641 students in grades 9-12 who were enrolled in high schools located in North Carolina, USA. Data about students' views was collected using a closed-ended 10 item instrument in which students were required to respond to two opposing statements. Additionally, participants were asked to explain their choices in a brief open-ended response. Data from the study indicated that these students hold vague notions about the nature of theories.

Studies conducted with students at the tertiary level of education show similar results to primary and secondary students regarding their inadequate conceptions of the NOS. Ryder, Leach and Driver (1997) examined the images of science held by 11 final-year, undergraduate university students in England. The sample comprised of students of mixed ability and gender. Each student was interviewed on three separate occasions. The first and last interviews contained discussions about five open-ended questions which were designed by the researchers to elicit students' images of science. The questions were piloted with two students before being administered to the sample group to determine its effectiveness in encouraging students to talk

about science. The findings revealed that students' viewed knowledge claims as provable solely on empirical grounds while their image of scientists working as a community were underrepresented in their discussions.

Likewise, Parker, Krockover, Lasher-Trapp and Eichinger (2008) explored undergraduate atmospheric science students' ideas of the NOS. The sample group comprised of 17 students (10 male and 7 female) who consented to participate in the study. Their views of the NOS were measured using an open-ended instrument, the Views of the Nature of Science questionnaire, which was developed by Lederman et al. in 2002. This questionnaire was designed to assess students' views of seven key components of the NOS. Additional demographic data was also collected from the students using a closed-ended survey determine any relationships between the characteristics of the participants and their responses. Analysis of the results revealed that students viewed science as a discipline based on data. They believed that science is primarily concerned with "proving" ideas. Although most of the participants believed that creativity is an essential component of science, many of them still felt that experiments were used to test and confirm scientific ideas.

Students' changing views of NOS. Research conducted on elementary students show that, like secondary and tertiary students, they too possess naïve views of the NOS. Khishfe and Abd-El- Khalick (2002) explored the influence of an explicit and reflective inquiry-oriented approach compared to an implicit one on 6th-grade students' understandings of the NOS over a period of 2.5 months in Lebanon. The intervention group which was taught using explicit, reflective NOS strategies was composed of 33 students (16 female and 17 male). Alternatively, the comparison or implicit group which was taught using the same inquiry activities minus the NOS discussions comprised of 29 students (12 female, 17 male). Participants' views of the NOS

were assessed using a six-item open-ended questionnaire which was adopted from Abd-El-Khalick in 1998. Semi-structured individual interviews were also used to validate the NOS questionnaire and generate in-depth responses on students' views of the NOS. Findings of the study showed that the majority of the participants in both groups possessed naïve views of the outlined aspects of the NOS. At the conclusion of the study, the views of the implicit group participants did not change. However, the students of the explicit group developed more informed views of one or more of the target NOS aspects after the intervention. This suggested that an explicit and reflective inquiry-oriented approach was more effective in promoting students' conceptions of NOS than an implicit inquiry-oriented approach.

More specifically, Sharkawy (2009) investigated how stories about scientists influenced first-grade students' views of the social nature of scientific work. The participants in this study comprised of 11 first grade students (4 males, 7 females) from a low socioeconomic, multiethnic school located in an urban city in Ontario, Canada. Multiple data collection methods were used to elicit students' views. These included semi-structured interviews before and after the intervention, drawings depicting scientists at work, stories about scientists as told by the students, fieldnotes and students' journal entries. With the exception of one student, no other evidence of the social context of scientific work was evident at the beginning of the study. However, after the intervention there was some evidence which supported students' awareness of the social nature of scientific work.

Moreover, Akerson and Donnelly (2010) explored the influence of a 6-week Saturday science program that used explicit reflective instruction on K-2 students' views of the NOS and how these views change at the end of the program. The sample comprised of 18 kindergarden, grade 1 and grade 2 students of which 14 were male and 4 female. The students were taught a

variety of topics using an inquiry-based approach. Their views of the NOS were determined using multiple sources including the Views of Nature of Science Form D (VNOS-D), group discussions, copies of students' work and interviews at the end of the program. As expected by the researchers, students of all the grade levels studied generally possessed inadequate views of NOS aspects prior to instruction. However, they were able to improve their views over the course of the program resulting in adequate views of the targeted aspects of the NOS.

Studies designed to change secondary students' views of the NOS showed varying effects to their beliefs after being exposed to an intervention. Jelinek (1998) examined the attitudes of high school students towards science and their views of the NOS. Twenty students from 9 different schools participated in this study. Their ages range from 12 to 16 years. The researcher employed an explorative case study approach in which students' pre and post views of science instructional processes and their perceptions of the NOS were measured. This approach was used as it helped to explain causal links and describe the real life context of the program. Data about students' views of the NOS was collected using multiple sources such as writing activities, interviews and debriefings, questionnaires and projects. Some of the questions used in this study were adapted from the Views of Science, Technology and Society instrument developed by Aikenhead and Ryan. The data was categorized and codes were used to develop themes. Emerging from the data analysis were three categories of students' perceptions of the NOS. These included naïve, moderate and advanced perceptions. The findings suggested that the majority of participants initially possessed naïve pre-perceptions of the NOS. However, their views changed to a more moderate one after the program.

Likewise, Bell, Blair, Crawford and Lederman (2003) investigated the impact of an 8-week apprenticeship program on a group of high-ability secondary students' understanding of the

NOS. Ten volunteers (6 females, 4 males) were purposely chosen to participate in this study. Their views of the NOS were elicited before and after the program using a modified version of the VNOS-B. This modified instrument consisted of six open-ended questions from the VNOS-B plus two additional items designed to assess the students' knowledge and ability to conduct scientific inquiry. Also, semi-structured interviews allowed students to elaborate on their responses in the questionnaire and further develop their understanding of the NOS. Additionally, the interviews allowed the researcher to triangulate their responses on the pre- and post questionnaires. Observation notes made by the researchers were also used to supplement students' responses. Analysis of the data revealed that participants possessed inadequate understandings of the NOS. Although most students appeared to have gained knowledge about the processes of scientific inquiry, their conceptions about key aspects of the NOS remained virtually unchanged after the program.

Additionally, Khishfe and Ledeman (2007) investigated the relationship between instructional context that explicitly teaches about the NOS and students' view of NOS across three disciplines; Environmental Science, Chemistry and Biology. The participants comprised of 129 high school students who were divided into 6 groups and three teachers who were purposely selected. Two groups were taught each of the disciplines. One of these groups was taught using the integrated approach in which NOS was embedded into the lessons while the other was not. An open-ended questionnaire comprised of five items which was developed by the researchers was used to assess participants' views of NOS. Semi-structured interviews were also used in conjunction with the questionnaire to further establish validity of the instrument. Findings indicated that the majority of participants in both the integrated and non-integrated groups held naïve views of the target aspects of NOS. However, the students' post-instruction views of the

intact groups (integrated and non-integrated) showed major changes for the five emphasized NOS aspects across the three disciplines.

As part of their study Kim and Irving (2010) explored the effectiveness of the contextualized history of science on students' learning of the NOS. The participants comprised of two classes of 10th-grade high school Biology students: an experimental group (16 students) and a control group (17 students). Both classes were taught by the same teacher. Students' understanding of NOS was measured using several methods including NOS Terms Definition with Concept Mapping, the View of Nature of Science-Form C (VNOS-C) developed by Abd-El-Khalick in 1998 and semi-structured interviews. Inferential analysis of the data indicated that the experimental group showed greater understanding of NOS after the intervention relative to the control group. Thus, the experimental group appeared to have benefited from the targeted NOS instruction using historical contextual materials.

Furthermore, Tao (2003) utilized peer collaboration instruction in order to elicit junior secondary students' understanding of the NOS. The participants comprised of a convenient sample of 150 boys from a secondary school in Hong Kong. Multiple data collecting instruments were used to evaluate students' views including a pre-test, interviews and a closed-ended questionnaire adopted from Solomon et al in 1996. This instrument consisted of four simple multiple choice questions. Interviews were used to probe more deeply into students' understanding of the NOS as elicited by the pre-test and questionnaire. As expected, the results indicated that many students held inadequate views of the NOS showing only marginal improvement in their understandings following the instruction. Although the peer collaboration technique allowed students to develop a shared understanding of the NOS, many students changed from one set of inadequate views to another set rather than to adequate views.

Meichtry (1995) carried out a study designed to reveal students' views of the NOS before, during and after completion of an elementary science methods course. This course employed strategies and activities which helped students develop a more adequate understanding of the NOS. Seventy two college senior and graduate students participated in this study. Several strategies were used to reveal their conceptions of the NOS throughout the study. They were asked by the researcher to respond in writing to two open-ended questions at the beginning and the end of the course. Additionally, the Modified Nature of Scientific Knowledge Scale (MNSKS) developed by Meichtry in 1992 was administered to students to measure and compare their views of the NOS. This instrument consisted of 32 items in a Likert scale format. The results of this study indicated that students' understanding of the NOS was largely incomplete at the beginning of the course. However, they developed a significantly greater understanding of the NOS throughout the semester.

Similarly, Abd-El-Khalick and Lederman (2000) investigated college students' and preservice teachers' conceptions of the NOS, how these views changed after being exposed to History of Science (HOS) courses and the aspects of the HOS course that were effective in influencing students' views. The study focused on 166 undergraduate students and 15 pre-service secondary science teachers. An open-ended questionnaire consisting of 9 items was used to assess students' conceptions of the NOS. This instrument was adapted from questionnaires developed by Lederman and O'Malley in 1990 and Abd-El-Khalick et al. in 1998. Additional items were also developed by the primary researcher. Furthermore, semi-structured interviews were used to assess students' views. Similar to past studies, almost all the participants held naïve views of many of the emphasized NOS aspects. At the conclusion of the study, the results indicated that there was very little change in students' views of the NOS.

Students' scientific literacy. The level of students' scientific literacy has been measured in different ways using various instruments. Ozdem, Cavas, Cavas, Cakiroglu and Ertepinar (2010) examined the scientific literacy levels of elementary students who were enrolled in grades 6, 7 and 8. Data was collected from 946 students ranging from ages 12 to 15 from several elementary schools located in Turkey. Students' scientific literacy levels were assessed using The Test of Basic Scientific Literacy (TBSL) questionnaire which was developed by Laugksch and Spargo in 1996. This instrument consisted of 110 closed-ended items related to the dimensions of scientific literacy and were divided into three sub-categories; physical settings, human organisms and the living environment. The data was analyzed using SPSS 11.5 statistical analysis package program. Both descriptive and inferential statistics (ANOVA) were used in the data analysis. The results showed that elementary students in Turkey have a moderate level of scientific literacy.

Moreover, Michalsky, Mevarech and Haibi (2009) explored the effects of metacognitive instructions at different phases of reading scientific texts on elementary students' scientific literacy and metacognitive awareness. A total of 108 grade 4 students (49 boys, 59 girls) were randomly selected from four Israeli elementary schools to participate in this study. Four groups were formed from these participants, three of which received metacognitive instruction while one group did not. Students' knowledge of the science curriculum was measured using The Test of Science Knowledge (TSK) which was developed by the National Science Committee of the Israel Ministry of Education in 2004 while students' metacognitive awareness was evaluated using the Metacognition Awareness Questionnaire (MAQ) adapted from Schraw and Dennison. Additionally, participants' scientific literacy level was assessed using the Test for Scientific Literacy (TSL) which was developed by the researchers for the purpose of this study. It consisted

of 15 items; 9 open-ended questions and 6 multiple choice items. Students' responses to these instruments were measured both before and after the being taught using metacognitive instruction. Findings indicated that reading scientific texts embedded with metacognitive instruction were effective in developing 4th-grade students' scientific literacy.

Researchers who conducted studies at the secondary level also report a positive relationship between SL and achievement after being exposed to an intervention designed to increase their SL. In their study Mbajiorgu and Ali (2001) investigated the relationship between the Science-Technology-Society Approach (STS), SL and students' achievement in Biology. A total of 246 students ranging from ages 16 to 18 years from four secondary schools in Nigeria were randomly assigned to either the experimental or control groups. Two instruments were used to test the outcome of the treatment. These included the Achievement Test on Reproduction and Family Planning and a Scientific Literacy Scale (SLS) consisting of 20 closed-ended items. The SLS was developed by Aikenhead, Ryan and Fleming and covered three aspects of SL including NOS, STS interactions and the concept of cells. Findings revealed a weak positive relationship between SL and achievement in Biology for the experimental group. This relationship appeared to have been mediated by the STS approach.

Glasgow (1986) conducted a study on 643 grade nine Jamaican students to determine how specific factors affect their SL. This sample was selected from schools in the urban capital of Kingston. These factors included students' reading level, the science tone of their homes, early schooling, their motivation and mental ability. Data regarding students' SL was collected using several closed-ended and open-ended instruments which were based on the seven dimensional model of SL proposed by Showalter et al. in 1974. The results of this study indicated that students' mental ability, motivation and reading ability were important predictors

of achievement. While urbanization made a significant positive impact on performance, the tone at home strongly influenced students' interest in science. Gender and type of school, though, did not significantly impact on their SL scores.

Murcia (2009) conducted a study in Western Australia in which they sought to identify and document a group of university students' engagement with science news briefs. Students' engagement was used as an indicator of their scientific literacy. Two hundred and thirty first year students were administered a questionnaire, consisting of four open-ended questions, to measure their engagement in the news brief. Students' responses were analyzed based on their ability to explain why the text should be accepted or rejected and by the type of request made for extra information. Based on the results of this study, more than 50% of the participants did not demonstrate the ability to critically engage in science as reported in the news brief.

Likewise, students entering university appear to have relatively low or moderate scientific literacy levels. Laugksch and Spargo (1999) conducted a survey to examine the scientific literacy of first year university students and factors that are directly related to their scientific literacy levels. Data analysis was based on a sample of 4223 students from five different tertiary level institutions. Their scientific literacy levels were measured using a survey which consisted of demographic questions as well as the 110 closed-ended items from the TBSL which was developed by the researchers. Analysis of the results indicated that the scientific literacy level of the participants was found to be 36%. Additionally, males possessed higher scientific literacy levels than the females. This survey also confirmed that students' scientific literacy levels were likely to be influenced by the number and combination of science subjects studies in their senior year of high school.

In a study conducted by Chin Chin (2005) the level of scientific literacy of first-year pre-service teachers from four colleges was investigated using two closed-ended instruments. These included the 110 item TBSL developed by Laugksch and Spargo in 1996. This questionnaire contains items from three major categories: the NOS, science content and the influence of Science, Technology and Society. Additionally, the Test of Science-related Attitudes (TOSRA) which was designed by Fraser in 1978 was used to measure the participants' attitudes towards science and their scientific literacy. This instrument measured four dimensions: the NOS, science content, STS and attitudes towards science. Responding to these questionnaires were 279 students of which 141 were elementary education majors while 138 were science education majors. The data was analyzed using the SPSS statistical package in which descriptive statistics were generated. Furthermore, two-way analysis of variance (ANOVA) and Cohen's *d* value was used to examine whether any significant interaction existed between the two groups of teachers and gender. The results showed that the basic scientific literacy of both groups of teachers was at a satisfactory level. However, there was no significant difference in attitudes between genders.

Similarly, Akgul (2004) examined the scientific literacy levels of Turkish pre-service elementary science teachers. Twenty senior students were randomly chosen from the Science, Technology and Society course at Marmara University, Turkey. Data about students' scientific literacy was gathered via performance portfolios consisting of student generated artifacts produced during the course. Interviews and field notes from the class were used for data triangulation. Students' definitions of scientific literacy was determined using document analysis and open coding of data. The findings revealed that although the participants had some traditional understandings of science, they possessed more contemporary views of scientific literacy.

Furthermore, Bacanak and Gokdere (2009) investigated the level of primary school teacher candidates' scientific literacy and whether there was a relationship between the latter and gender. Participating in this study were 132 4th-year student teachers (90 females, 42 males) from Amasya University, Turkey. Their levels of scientific literacy were measured using a multiple choice test which was developed by the researchers and consisted of 35 items. The mean of teachers' scores on this test was found to be 56.71% indicating a moderate level of scientific literacy. Also, the data suggests that males are not more significantly scientific literate than females.

The impact of an intervention design to change students' scientific literacy. Studies conducted at the primary, secondary and tertiary levels reveal that interventions which were designed to change students' scientific literacy levels generally have a positive impact. This is evident in a study done by Bauer, Nelson, Parsons and Purdum (1998) where they investigated the impact of integrating science-processing skills into the curriculum on the scientific literacy of pre-kindergarten and second grade students. The participants were taught units of lessons in which they were explicitly exposed to scientific processes using hands-on and real-life experiences. Their scientific literacy was measured by teacher observation checklists, students' skills posttest and teacher journal entries. Post intervention data indicated that there was an increase in students' SL as there was an increased development in the target scientific skills.

Bardeen (2000) studied the effects of an inquiry-based integrated science course on high school students' science literacy. Twenty four freshmen and sophomore students from were randomly selected from three classes to participate in this study. The students were taught the topics according to the curriculum using an inquiry-based approach and integrating real-world issues into the lessons. The teacher also used a combination of teaching strategies such as class

discussions, individual and group work. Their scientific literacy was assessed using three instruments which were developed by the researcher. These included a free-response journal entry, a written analysis of an article from the newspaper and an essay test. Based on the data analysis it was concluded that the students showed an improvement in scientific literacy and an increased awareness of scientific issues. They also showed an increased ability to critically analyze scientific information.

Additionally, in an attempted to increase elementary students' scientific literacy Reveles and Brown (2008) utilized a case study approach which examined the ways in which teachers can make science content more accessible to students by explicitly emphasizing the relationship between identity and language. Data was collected from two elementary science classrooms by means of videotapes of classroom interactions, field notes, students' science projects and interviews with both teachers and students. The first case study comprised of 17 third-grade students ranging in age from 8 to 9 years. The second case study included 34 fifth-grade students (21 females, 13 males) from a low income, urban school in the USA. In both cases the teachers provided opportunities for students to acquire scientific literate practices and develop their academic identity and their scientific literacy. The findings revealed that the teachers' explicit focus on student scientific identities helped support students' access to literate practices in science.

Similarly, Caswell and Lamon (1998) examined the cognitive and social aspects of fourth-graders' development of scientific literacy in a Schools for Thought (SFT) classroom located in Toronto, Canada. In this type of classroom students engage in an active, reflective and social nature of learning. Thus, the researchers compared the way in which students constructed knowledge in a STF classroom to that of previous years without the SFT classrooms. Students'

scientific thinking and their changing nature of the social construction of knowledge was evaluated using interviews, research journals kept by students and videotaped interactions with both the teacher and peers. Analysis of the data indicated that the students' initially possessed simple, naïve understandings of scientific ideas. However, at the end of the study they developed a deeper understanding of science as they were able to initiate, design and conduct complex science experiments.

Studies which have examined students' scientific literacy at the secondary level indicate that students develop a deeper understanding of scientific concepts after being taught using an explicit instructional strategy. Palincsar, Anderson and David (1993) conducted a study which was designed to promote the scientific literacy of 5th-grade students using collaborative problem solving instruction in the classroom. The students worked in small groups during the ten-week course on matter and molecules and were required to solve nine contextual problems. The participants included approximately 130 students of mixed gender and race from 5 different science classrooms. Their understandings of the targeted scientific concepts were measured using multiple data sources. These included student logs, examination of students' quotes about their epistemological beliefs, interviews and videotaped group activities. Additionally, pretest and posttests consisting of closed-ended and open-ended questions were administered to the participants. At the end of the investigation students were able to shift their naïve views of science to more scientific views.

Likewise, Spector-Levy, Eylon and Scherz (2009) explored the impact of Scientific Communication (SC) skills instruction on the scientific literacy of 7th-8th grade students from four different schools over a period of two years. An intervention group consisting of 160 students was taught using the SC instruction while a control group of 42 students were not. Their

performances were assessed using The 'Learning Situations' questionnaire and the 'Update Report' complex assessment task which was designed to measure students' content knowledge and SC skills. The results indicated that the students who received the SC skills instruction achieved higher scores than the comparison group. Also, the researchers concluded that the explicit integration of skills into science topics, implementing these skills into different contexts and the use of performance tasks for assessment were all necessary features for enhancing students' scientific literacy.

Kaelin, Huebner, Nicolich and Kimbrough (2007) reported on a field test conducted in the New Jersey school district during the 2002-2003 year in which a middle school epidemiology curriculum known as *Detectives in the Classroom* was implemented. This curriculum sought to capture students' interest as well as enhance their understandings of health-related issues. Participating in the evaluation were 378 experimental grade 7 students and 620 control students. Their scientific inquiry, scientific literacy, understandings, knowledge and attitudes towards science were all measured using a closed-ended 62 item instrument. The strengths of this study included the large sample size and the availability of data. However, the field test was limited by the relatively short term and the inconsistency of the proportion of the curriculum that was actually taught. The findings suggested, though, that this curriculum can potentially enhance students' perceptions of their science abilities and their scientific literacy.

Moreover, Mutonyi, Nielson and Nashon (2007) conducted a study in order to establish whether direct engagement of high school students' prior knowledge students can result in a deeper understanding of the science of HIV/AIDS. The inquiry process was used to engage students with their own preconceptions of this topic. Approximately 160 grade 11 students from four different schools in Uganda were purposely selected to participate in this qualitative case

study. Students' overall understanding of HIV/AIDS was measured using a 12-item open-ended questionnaire. Also, each lesson was videotaped following which focus group discussions were conducted and audio recorded. The data collected was transcribed, coded and analyzed for emerging themes. The findings revealed that the students needed to discuss their beliefs of HIV/AIDS with each other, resulting in them either challenging their own beliefs or making connections between conventional science and their prior knowledge.

At the tertiary level students' scientific literacy skills are also enhanced using non-traditional classroom instruction. Elliott (2006) attempted to help undergraduate student-teachers become more scientifically literate by including the analysis of newspaper articles in their biotechnology course. The participants of this study comprised of 19 undergraduate students in their fourth year of training to become primary school teachers. Their ability to critically analyze the newspaper articles and their subsequent discussion of them in the coursework essay were used to determine their success at completing the task. At the end of the study not only did students' enhance their scientific literacy skills but they were also more interested in the activities and developed a greater awareness of the issues presented in the media.

Similarly, Carr (1997) conducted a case study to examine the effects of using a constructivist approach in fostering college students' critical thinking in science; a key component of scientific literacy. Qualitative data regarding students' thinking skills was collected by means formal and informal interviews, videotapes, audiotapes, coursework, fieldnotes, final examination and student reflective journals. At the end of the study complete data was only gathered from 15 students in this course. The findings of this study indicated that the constructivist approach used in this course fostered higher levels of reflective judgment by

students in a science context. Furthermore, the researchers contend that a collaborative learning environment is a more authentic reflection of the scientific process.

Summary and Justification of the Study

The literature reviewed indicates that many studies have investigated students' views or perceptions of the NOS and the extent to which these views have changed following explicit NOS instruction. Students' views of NOS have been measured using various closed-ended instruments such as the VNOS and the POSE questionnaires. Additionally, interviews consisting of open-ended items designed by the researchers have also been used to elicit students' understanding of NOS. In most of the studies reviewed students possessed naïve views of the NOS before the intervention. However, their understanding of NOS generally increased following instruction designed to change these naïve views.

Similarly, closed-ended questionnaires such as the Scientific Literacy Scale and the TBSL have been frequently used to assess students' SL. Other assessment strategies include portfolios, document analysis and journal entries. The findings of these studies, though, indicate that students generally possess relatively low or moderate levels of SL. However, in most of the cases reviewed the students were able to achieve higher SL levels and a deeper understanding of the epistemology of science.

Although much research has been conducted on students' views of the NOS and SL, very few studies have investigated the correlation between NOS and SL. Furthermore, researchers have rarely explored the possible impact of both of these variables on students' achievement. Thus, this study is an initial attempt to fill that gap in the literature. It seeks to determine whether there is a correlation between the way in which science is presented to students and their

scientific literacy. Moreover, the study examines how students' understanding of science impacts on their achievement.

Chapter III

Methodology

Introduction

This study resulted from observation made by the researcher where, although students' at a boys' school in south Trinidad performed well on high stakes examinations, their SL level still appeared to be low. Using action research, the researcher investigated the impact of a Unit of Lessons infused with the NOS on students' SL and achievement. Such a design was selected to be the most appropriate method since it has been used extensively in the past by many researchers including Kaelin et al., 2007; Spector-Levy et al., 2009; Bauer et al., 1998 and Bardeen, 2000 just to name a few. The hypotheses which were tested in this study included:

1. H_0 : There is no significant change, at the .05 alpha level, in students' traditional and non-traditional views of NOS after being taught a unit of lessons infused with the NOS.
2. H_0 : There is no significant change, at the .05 alpha level, in students' SL level after participating in an intervention designed to change their NOS views.
3. H_0 : There is no significant relationship, at the .05 alpha level, among students' views of NOS, SL level and their achievement.

Research design

In this study the researcher investigated the impact of NOS and SL on students' achievement by conducting action research. This form of research seeks to "solve practical problems in the social world" (Leacock, Warrican, & Rose, 2009, p. 6). It is used by researchers who wish to study current problems ((McMillan & Schumacher, 2006) in which participants are actively involved in finding possible solutions to the given problem (Cohen, Manion, &

Morrison, 2000). For this reason the researcher chose to utilize this methodology since the sociological framework assumes that science is a social enterprise (Driver et al., 1996). Also, the researcher was required to conduct action research in partial fulfillment of the Master in Education programme.

This study is grounded in the quantitative paradigm. According to Leacock et al. (2009, p. 6) the mode of research “depends on how the data are collected, the nature of the data and the methods of analysis.” In this case, data on students’ views of science, their SL and their achievement were collected using surveys, a rating scale and a test. These instruments yielded numerical data which was then quantified. The data was analysed statistically using SPSS in order to test the research hypotheses.

Within this paradigm, a quasi-experimental strategy of inquiry was used by the researcher. This design seeks to determine the cause and effect relationship when there is direct manipulation of the conditions. Also, the participants are not randomly assigned to groups (McMillan & Schumacher, 2006). In this study one group of purposely selected students were taught a unit of lessons infused with the NOS to determine the impact of NOS and SL on their achievement. A single-group Pretest-Posttest design was selected to assess students’ achievement. A control group was not included in the study since the researcher believed that it would have been unethical to deprive other students of learning science without the inclusion of NOS and SL.

The Population

The population consisted of 105 Form One students from a denominational boys’ school located in south Trinidad. The school is located in a busy, urban area and is regarded by the

community as a 'prestige' school. Thus, it is known for producing students with outstanding results at both the CSEC and CAPE levels. Although the school is denominational, approximately half of the population is Muslim while the remaining 50% is comprised of Christian, Hindu and Roman Catholic students.

Most of the boys, though, are of East Indian descent with only about five mixed-race or African students. They range between ages 11-12 years and are of mixed ability. Their achievement in Science was determined by the researcher using their term one scores. Also, most of the boys indicated that they did not attend extra Science 'lessons' while in primary school and are not currently doing so. They reside mainly in the surrounding urban and sub-urban areas while only a few students commute from rural areas. Hence, they attended primary schools mainly in the urban and sub-urban districts. Additionally, the students belong to a middle-upper socio-economic background as many of their parents are business owners.

Sampling Procedure

The participants were purposefully selected to participate in this study as this was one of the two Science classes being taught by the researcher. This class was chosen since the boys were more disciplined than those of the other Form One classes. Hence, they were more focused on their tasks making classroom management easier for the researcher. Additionally, they were selected because of their enthusiasm and interest in Science which was expressed verbally to the researcher. This sample is a true representation of the Form One student population as the students share common features with the other boys from the population.

The Sample

The sample comprised of 34 students from the Form One population. These students belonged to one of the three Form One classes at the school. The researcher was the Science teacher for two of these classes including the sample group. Consequently, the participants were not explicitly exposed to the components of NOS and SL prior to the intervention. This was purposefully done in order to measure the impact of the intervention on students' views of NOS and SL. They were taught science using traditional instructional strategies such as questioning and classroom discussions. Their academic achievement was determined using formative and summative assessment methods.

Instrumentation

NOS Survey. Students' views of the NOS were measured using a questionnaire which was adapted from Pomeroy (1993). The instrument designed by Pomeroy consisted of a 50-item survey with agree-disagree statements on a 5-1 Likert scale. These statements ranged from "Baconian beliefs to some alternative ideas suggested by Popper, Polanyi, Keller, Gould, and Kuhn." (Pomeroy, 1993, p. 263). It also explored beliefs about science education, "including statements about the role of the laboratory experience, process vs. content, depth vs. breadth, and mastery vs. exploration." (Pomeroy, 1993, p. 263). The 50 items on the survey were organized into three clusters: traditional views of science, non-traditional views of science and traditional views of science education.

However, for the purpose of this study the instrument used by Pomeroy was modified to consist of seventeen items from two clusters, traditional views of science and non-traditional

views of science. A total of eight traditional statements and nine non-traditional statements were included in the survey (see Appendix A for NOS survey). An example of a traditional statement was ‘Most scientists believe nature strictly obeys laws’ while a non-traditional statement read ‘Intuition plays an important role in scientific discovery’. Also, this modified survey was used by the researcher to elicit students’ views of NOS as opposed to scientists, secondary and primary school teachers’ views of science in Pomeroy (1993). Furthermore, on the PreNOS survey the participants were asked to respond to three open-ended questions which provided the researcher with demographic data. These three questions were omitted on the PostNOS survey.

This survey was selected for two main reasons. Firstly, the scales of the survey have been validated over a three year period by my supervisor, Dr. D. Barrow, in Trinidad and Tobago using primary and secondary school science teachers. The reliability of the scale was found to be moderate. Secondly, this closed-ended instrument was selected compared to an open-ended one as it allows fairly accurate assessment of opinions (Mc Millan & Schumacher, 2006).

SL Survey. Students’ SL level was assessed using an instrument which was adapted from Carrier (2001). It consisted of 24 True or False statements about SL (see Appendix B for SL survey). One such statement included ‘Scientific laws are absolute or certain’. Carrier (2001) suggests that in this case SL refers to the nature of science and not its content. This instrument was chosen by the researcher to measure students’ SL level since it is closed-ended and the resulting data can be easily analyzed statistically.

Achievement test. A criterion-referenced test was developed by the researcher to assess students’ achievement in science (see Appendix C for achievement test). This test was used as both the Pretest and the Posttest to determine whether there were any changes in the students’

achievement following participation in an intervention designed to enhance their SL and views of the NOS. It consisted of ten short answer questions carrying a total of 56 marks. The test was based on the unit of lessons on Matter which was taught during the intervention. The degree of difficulty of the questions ranged from simple lower order questions to complex higher order ones. Six of the ten questions were higher order (application, analysis, synthesis) while the remaining four questions were lower order (knowledge and comprehension). This is illustrated in the table of specification (TOS) which was developed for the test to illustrate the cognitive level of each question (see Appendix D for TOS). This ratio of questions was determined according to the objectives of the lesson. The TOS also ensured that there was a direct match between the lesson objectives and the test items. The test items were also infused with the components of SL (see Appendix E for SL components and test items). Additionally, a mark scheme was developed and used by the researcher to grade students' performance on the test (see Appendix F for mark scheme).

Data Collection

Prior to the intervention each student was assigned a code number for use during the study to protect their identity. This number allowed the researcher to record students' progress from Pretest to Posttest. Their views of the NOS were obtained using a survey which was administered before the intervention. The same instrument was administered to students after the unit of NOS-infused lessons to determine whether there were any changes in their initial views of NOS (see Appendix G for students' PreNOS and PostNOS scores). The boys were required to complete this survey in one period of forty minutes. Both the PreNOS and PostNOS surveys

were conducted on the same day of the week during the same time period to maintain internal validity of the results.

Similarly, data about students' SL level was collected using a survey which was administered before and after the intervention. The PostSL survey was used to determine the impact, if any, of the intervention on students' SL (see Appendix H for students' PreSL and PostSL scores). The participants were also given a period of forty minutes to respond to the items. This survey was administered to students on the same day immediately following the NOS survey.

Data on students' achievement was collected using the achievement test designed by the researcher. Before the intervention the students were required to complete the ten short-answer questions on the Pretest in one hour. They were then exposed to the intervention in which they were taught a Unit of lessons infused with the NOS based on Matter and its Properties over a five-week period. The Unit consisted of a unit plan and twelve lesson (see Appendix I for unit and lesson plans) plans based on Matter which were infused with various aspects of the NOS and SL. Each lesson explicitly outlined the NOS (see Appendix J for NOS table) and content knowledge of Science. Additionally, the lessons focused on each component of SL at least four times in order to enhance their SL (see Appendix K for SL components in lessons). That is, four of the twelve lessons focused mainly on science as a process, another four on Science as a way of being, two on Science and Society and two on Science and technology. For each of these SL components a graphic organiser was designed by the researcher to actively engage the students in the learning process (see Appendix L for graphic organizers). Each lesson was taught during a period of eighty minutes.

The Infusion Based Approach was used in the delivery of each lesson. Using this strategy aspects of the NOS were explicitly discussed by both teacher and students. The participants then actively engaged in conducting experiments in small groups to enhance their process and life skills. Various media formats such as YouTube videos, animations, PowerPoint and Prezi presentations were utilized during the lesson. Students were then given the opportunity to reflect on what they learnt during the lesson and to apply their knowledge to their everyday life. Immediately following lesson twelve the Posttest was administered to students to determine whether their achievement had changed after the intervention (see Appendix M for samples of students' Pretest and Posttest scores).

Ethical considerations

The participants were assured that all data and demographic information collected during the study will be kept confidential and anonymous. Their identity was kept anonymous through the use of code numbers which were assigned to them for use during the course of the study. Prior to the intervention the students were informed of the purpose of the study and that they may withdraw from the study at any time. Additionally, the identity of the school was kept anonymous in this paper. Furthermore, approval to conduct the study was sought from the school's administration and from the participants' parents. Verbal permission was granted to the researcher by the school's principal while letters were sent to the parents requesting consent for their child to participate in the study.

Data Preparation

For the NOS survey each item was rated 1-5, 1 being strongly disagree and 5 strongly agree. Students received a score of 5 if they strongly agreed with either the traditional or non-

traditional statements. Scores obtained for negative statements were reversed to transform all the items to the same polarity. Thus, students were able to achieve a total minimum score of 17 or a maximum score of 85. Since the survey contained both traditional and non-traditional statements, scores obtained for the traditional statements were reversed so that their total score would represent their non-traditional views of science. Hence, the closer their score is to 85 the more non-traditional are their views of science. Conversely, the closer their score is to 17, the more traditional are their views of science.

Students' percentage scores for the traditional and non-traditional statements were calculated before and after the intervention to determine whether there were any changes in scores. Paired samples t-tests were conducted to determine the significance of these changes and the effect size was calculated measure the magnitude of the effect of the intervention on students' scores. Similarly, the items on the SL survey were grouped into the components of SL and students' scores for each group were obtained and compared to those obtained after the intervention.

Data from the achievement test and the NOS and SL surveys were also analysed using descriptive statistics. Histograms and boxplots were constructed to illustrate the distribution of the data. Paired samples t-tests and effect size were calculated to measure the magnitude of the effect of the intervention on students' views of NOS, SL and achievement. Moreover, Pearson's product-moment correlation coefficients were calculated to determine whether there was any relationship between the two independent variables (NOS and SL) and the dependent variable (achievement). Finally, the standard multiple regression test was conducted to determine which of these two independent variables made a greater contribution to the variance of the students' achievement scores.

Chapter IV

Data Analysis and Interpretation of Results

Scientific Literacy

Students' responses to this instrument indicated that while the SL increased in some areas after the intervention, it also decreased in other aspects (see Appendix N for students' SL responses). The items on this survey can be classified into seven aspects of NOS (Table 1). Table 1 also shows that there was an overall decline in only 2 of the 7 aspects of NOS. These were science as an empirical faith (-10%) and experiments are a goal-oriented form of scientific observation (-30%). This means that the intervention may have impacted negatively on these aspects of students' SL. However, the other five NOS aspects reported increases in students' responses. Thus, the intervention impacted positively in these areas causing students' SL to increase. A marked 50% increase was observed in the area of science as a tentative process while the smallest increase of only 3% was measured in the science as a creative process component. Significant increases were also recorded for the science is not a single method component (33%), scientific theories are explanations of scientific facts (32%) and scientific laws are descriptions of nature's behaviour (44%).

Table 1

Scientific Literacy Components

NOS Aspects	Question Number	Overall effect (%)
Science is a tentative enterprise	2, 10	50
Science is an empirical "faith"	5, 6, 16, 20	-10
Science is not a single method	3	33
Experiments are a goal-oriented form of scientific observation	1, 7, 9, 11, 12	-30
Scientific theories are explanations of scientific facts	4, 8, 14, 18, 22	32
Scientific laws are descriptions of nature's behaviour	15, 17, 19, 24	44
Science is a creative enterprise	13, 21, 23	3

Descriptive statistics. As shown in Table 2 there was an increase in students' mean score from the Pretest (11.72) to the Posttest (13.18). Similarly, there were increases in both the median and mode scores. The median increased from 11.00 in the Pretest to 13.59 in the Posttest while there was a greater increase in the mode from a score of 11.00 in the Pretest to 15.00 in the Posttest. While there was only a small increase in the minimum score from 8.00 to 9.00 in the Posttest, the maximum score (16.00) remained the same in both tests. This means that the intervention impacted positively on students' scientific literacy scores. Thus, their SL increased after being taught a unit of NOS-infused lessons.

Table 2

Scientific Literacy Descriptive Statistics

		Pretest Score	Posttest Score
N	Valid	33	34
	Missing	5	4
	Mean	11.7188	13.1818
	Std. Error of Mean	.38738	.35438
	Median	11.0000	13.5909
	Mode	11.00	15.00
	Std. Deviation	2.22534	2.06639
	Variance	4.952	4.270
	Skewness	.234	-.500
	Std. Error of Skewness	.409	.403
	Range	8.00	7.00
	Minimum	8.00	9.00
	Maximum	16.00	16.00
Percentiles	25	10.0000	12.0000
	50	11.0000	13.5909
	75	13.5000	15.0000

Boxplot Analysis. Figure 1 and Table 2 both show that the data for the Pre-SL scores is positively skewed (0.23), that is, the majority of the data lies below the mean and cluster to the lower end of the distribution (Figure 2). Additionally, the mean value (11.72) is greater than the median (11.00). The mode (11.00), though, is the same as the median. However, the data for the Post-SL test was negatively skewed (-0.50). That is, the majority of the data falls above the mean of 13.18 and clusters to the upper end of the distribution as shown in Figures 1 and 3. In this case the mean score lies below the median (13.59).

It can also be seen in Figure 1 that there was an increase in the minimum, Q_1 , Q_2 (median) and Q_3 scores from the Pretest to Posttest. Table 2 shows that the minimum score increased by only one unit from 8 to 9. The Q_1 score, though, increased from 10 to 12, a

difference of 2 while the Q2 or median score showed a slightly greater increase from 11.00 to 13.59, a difference of 2.59. However, the maximum score of 16 remained the same from Pretest to Posttest.

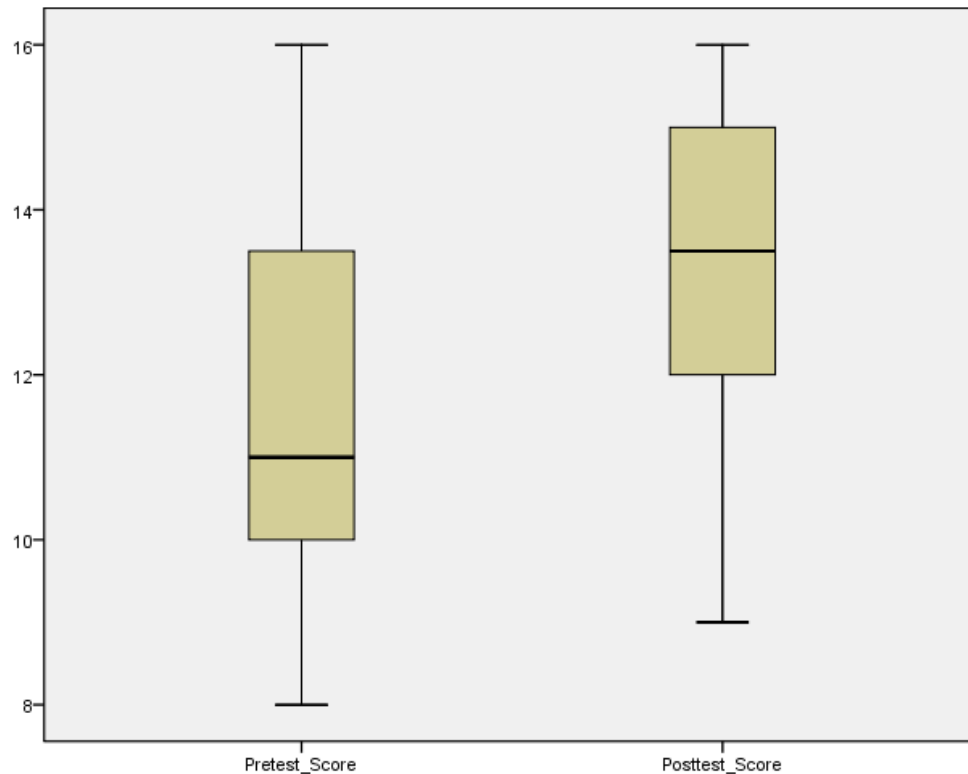


Figure 1. Boxplot of Students' Scientific Literacy Pretest and Posttest scores

Scores for both the third and fourth quarters of the Pretest showed greater variation than that of the Posttest as shown in Figure 1. The third quarter range for the Pretest was 3.50 compared to only 1.41 in the Posttest while the fourth quarter range decreased from 2.50 in the Pretest to 1.00 in the Posttest, a difference of 1.50 (Table 2). However, there was less variation in the range of scores in the first and second quarters of the Pretest as compared to the Posttest. The first quarter interquartile range increased from 2.00 in the Pretest to 3.00 in the Posttest, a difference of 1.00 while the second quarter range showed a slightly smaller difference of 0.59 moving from 1.00 in the Pretest to 1.59 in the Posttest (Table 2).

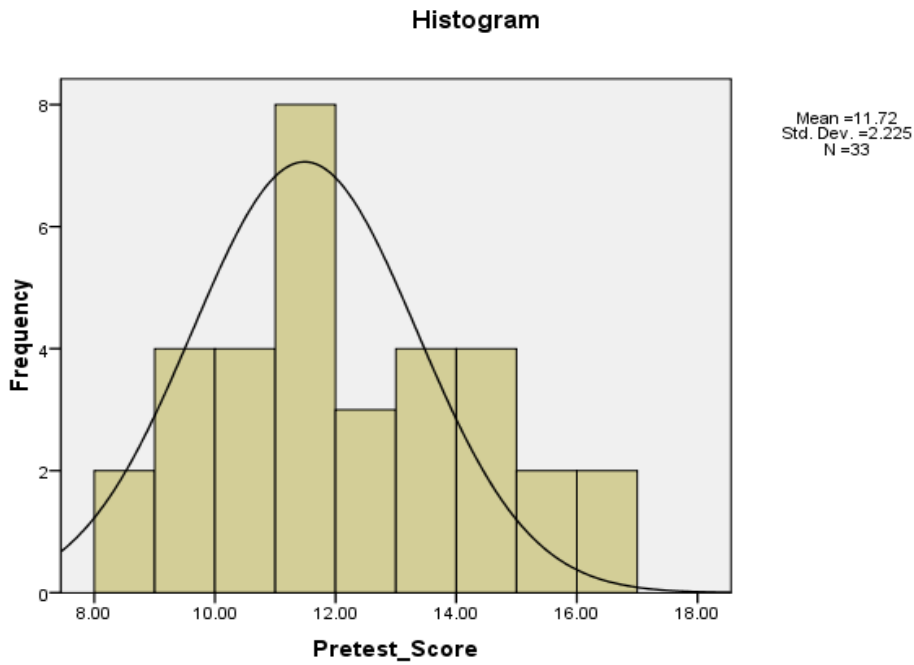


Figure 2. Histogram of Pre-Scientific Literacy scores.

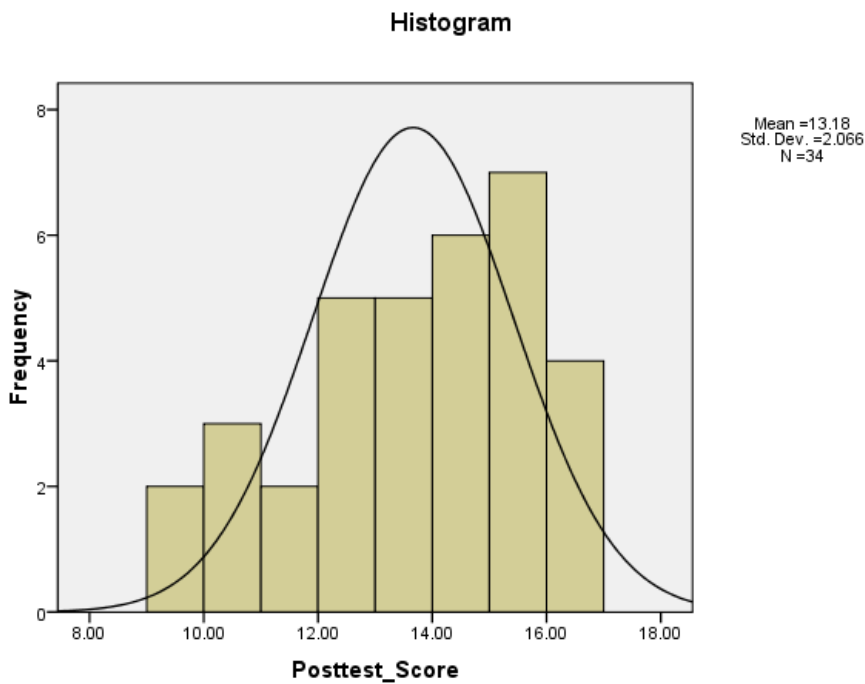


Figure 3. Histogram of Post-Scientific Literacy scores.

Paired samples t-test. A paired-samples t-test was conducted to determine the impact of NOS infused lessons on students' scientific literacy scores. There was a statistically significant increase in students' scores from the Pretest ($M = 11.72$, $SD = 2.26$) to the Posttest ($M = 13.09$, $SD = 2.07$), $t(31) = -2.85$, $p < .008$ as shown in Tables 3 and 4. The eta squared statistic (.21)¹ indicates a large effect size. This means that the intervention had a large impact on students' SL scores causing it to increase significantly from the Pretest to the Posttest. Therefore, students' content knowledge and process skills in science were enhanced after the intervention.

Table 3

Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Pair 1 Pretest Score	11.7188	32	2.26095	.39968
Posttest Score	13.0938	32	2.06912	.36577

Table 4

Paired Samples Test

		Paired Differences		
		Mean	Std. Deviation	Std. Error Mean
Pair 1	Pretest Score - Posttest Score	-1.37500	2.73272	.48308
		Paired Differences		
		Lower	Upper	
Pair 1	Pretest Score - Posttest Score	-2.36025	-.38975	
		t	df	Sig. (2-tailed)
Pair 1	Pretest Score - Posttest Score	-2.846	31	.008

Nature of Science

Traditional Views. The students possessed both traditional and non-traditional views of the NOS before and after the intervention (see Appendix O for students' NOS responses). Nine of the seventeen statements on the survey represented traditional views (1, 3, 4, 7, 9, 10, 13, 16, 17) while the remaining eight represented non-traditional views of the NOS (2, 5, 6, 8, 11, 12, 14, 15). For all the traditional statements, except question 1, there was an overall decrease in students' views.

The average percentage of students' responses for the traditional statements in the Pretest was found to be 50.8% while that of the Posttest was 47.0 % (Table 5). Thus, there was a 3.8% decrease in students' traditional views of the NOS after the intervention. This means that the intervention may have been responsible for reducing their traditional views and moving it towards a more contemporary view of the NOS.

Table 5

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	50.7778	9	16.33843	5.44614
	Posttest	47.0000	9	15.77181	5.25727

Furthermore, a paired samples t-test was conducted on the data obtained from students' responses to the NOS questionnaires using the SPSS 17.0 program to determine the impact of NOS infused lessons on students' traditional views of the NOS. Tables 5 and 6 show that there was no statistically significant increase in students' scores from the Pretest ($M = 50.78$, $SD = 16.34$) to the Posttest ($M = 47.00$, $SD = 15.77$), $t(32) = 1.02$, $p < .336$. Thus, the intervention did

not significantly change students' traditional views to contemporary views of the NOS.

However, the eta squared statistic (.12)² indicates a moderate effect size. This means that the intervention had a moderate impact on students' traditional views of the NOS causing their average scores to decrease from Pretest to Posttest. Hence, their views became less traditional or more non-traditional.

Table 6

Paired Samples Test

		Paired Differences				
		95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper
Pair 1	Pretest - Posttest	3.77778	11.06546	3.68849	-4.72789	12.28344
		t	df	Sig. (2-tailed)		
Pair 1	Pretest - Posttest	1.024	8	.336		

Non-traditional Views. However, students' responses to the non-traditional statements showed both increases and decreases from Pretest to Posttest (see Appendix O for students' NOS responses). Since the study did not emphasize the impact of culture on students' views of the NOS, this variable was controlled for in the analysis. Hence, the data obtained for questions 6 and 12 were omitted from the data analysis. Students' perceptions of questions 6 and 12, though, were more non-traditional. This suggests that the participants view these aspects of NOS as conventional science and do not place much emphasis on their own cultural beliefs and indigenous knowledge.

Consequently, the average response to the non-traditional statements on the Pretest was found to be 56.2% while that of the Posttest was 59.2%; a difference of 3.0% (Table 7). This

suggests that the intervention was effective at increasing students' non-traditional views of the NOS. The participants' average response to the non-traditional questions (56.2%) was greater than that of the traditional responses (50.8%) in the Pretest. This means that before the intervention students possessed a marginally more non-traditional view of the NOS. These contemporary views became more evident after being exposed to a unit of NOS-infused lessons as students now held more non-traditional views (59.2%) than traditional ones (47.0%).

Table 7

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	56.1667	6	21.40483	8.73848
	Posttest	59.1667	6	18.26928	7.45840

Additionally, a paired samples t-test was conducted on the data obtained from students' responses to the NOS questionnaires to determine the impact of NOS infused lessons on students' non-traditional views of the NOS. Tables 7 and 8 show that there was no statistically significant increase in students' scores from the Pretest ($\underline{M} = 56.17$, $\underline{SD} = 21.40$) to the Posttest ($\underline{M} = 59.17$, $\underline{SD} = 18.27$), $t(32) = -.638$, $p < .552$. Hence, the intervention did not significantly increase students' non-traditional views of the NOS. However, the eta squared statistic $(.08)^3$ indicates a moderate effect size. This means that the intervention had a moderate impact on students' non-traditional views of the NOS causing their average scores to increase from Pretest to Posttest. Hence, their views became more non-traditional or contemporary after the intervention. That is, students' developed a deeper understanding of the epistemology of science.

Table 8

Paired Samples Test

		Paired Differences				
		95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper
Pair 1	Pretest - Posttest	-3.00000	11.52389	4.70461	-15.09358	9.09358
		t	df	Sig. (2-tailed)		
Pair 1	Pretest - Posttest	-.638	5	.552		

Descriptive Statistics. The data obtained from the PreNOS and PostNOS questionnaires were analysed using the SPSS 17.0 program. Descriptive statistics were obtained in order to determine the impact of an intervention infusing the NOS on students' scores. Table 9 shows that there were increases in students' mean, median and mode NOS scores after the intervention. The mean score increased from 50.78 in the Pretest to 54.55 in the Posttest while the median increased from 50.50 to 54.55. The analysis, as shown in Table 9, indicates that the PreNOS scores is multimodal of which the smallest value is 47.00. This score, though, increased after the intervention to 53.00. Also shown in Table 9 is an increase in the range of scores from 21.00 in the Pretest to 31.00 in the Posttest. These statistics indicate that the intervention of NOS infused lessons had a positive impact on students' views of the NOS.

Table 9

NOS Descriptive Statistics

		PreNOS	PostNOS
N	Valid	32	33
	Missing	4	3
	Mean	50.7813	54.5455
	Std. Error of Mean	.91772	1.25988
	Median	50.5000	54.0000
	Mode	47.00 ^a	53.00
	Std. Deviation	5.19140	7.23745
	Variance	26.951	52.381
	Skewness	-.208	.258
	Std. Error of Skewness	.414	.409
	Range	21.00	31.00
	Minimum	39.00	40.00
	Maximum	60.00	71.00
	Percentiles	25	47.2500
50		50.5000	54.0000
75		54.7500	59.5000

a. Multiple modes exist. The smallest value is shown

Additionally, Table 9 shows that there was an increase in the five-number summary (minimum, Q_1 , Q_2 , Q_3 and maximum) of the data set from the Pretest to the Posttest. The minimum score showed only a very small increase from 39.00 to 40.00 while the maximum score increased from 60.00 to 71.00, a difference of 11.00. The Q_1 score increased by 2.75 from 47.25 to 50.00 while the Q_2 (median) showed a slightly greater increase of 3.50 from 50.50 to 54.00. The Q_3 score, though, showed an even larger increase of 4.75 from a Pretest score of 54.75 to a Posttest score of 59.50.

Boxplot Analysis. Figure 4 and Table 9 show that the distribution of the data for the Pretest is negatively skewed (-0.21). This means that the majority of the scores lie above the mean of 50.78 and cluster at the upper end of the distribution as illustrated in Figures 4 and 5. In such a distribution the mean value is supposed to be less than the median (50.50) but this is not the case. The mean of the Pretest is slightly greater than the median. Likewise, the mode is supposed to be greater than the median but since multiple modes existed, the smallest value (47.00) was given which is less than the median. Conversely, Figure 4 indicates that the data for the Posttest is positively skewed (0.26). That is, more of the data lie below the mean score (54.55) and cluster at the lower end of the distribution as depicted in Figures 4 and 6. Additionally, the mean score for the Posttest is greater than the median (54.00) while the mode (53.00) is less than the median.

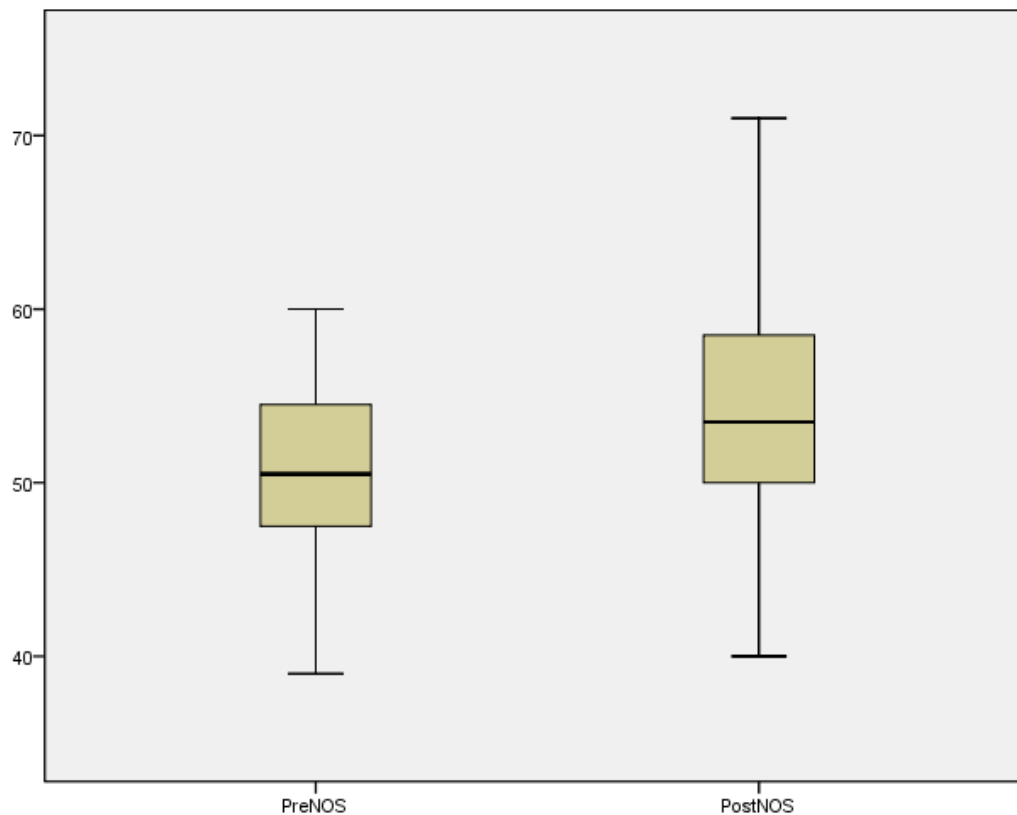


Figure 4. Boxplot of students' scientific literacy Pretest and Posttest scores

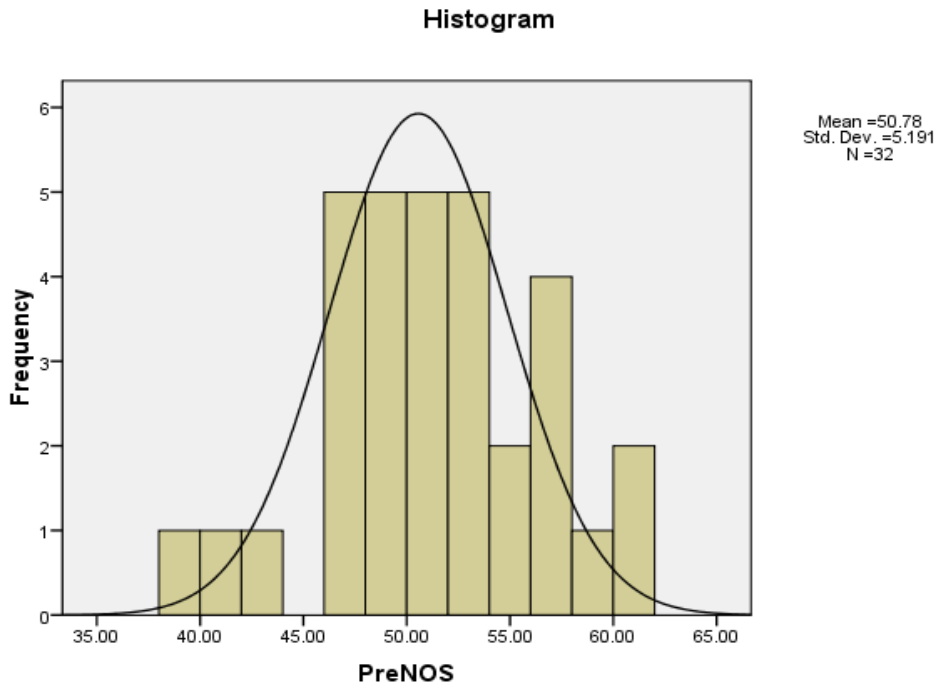


Figure 5. Histogram of Pre-NOS scores.

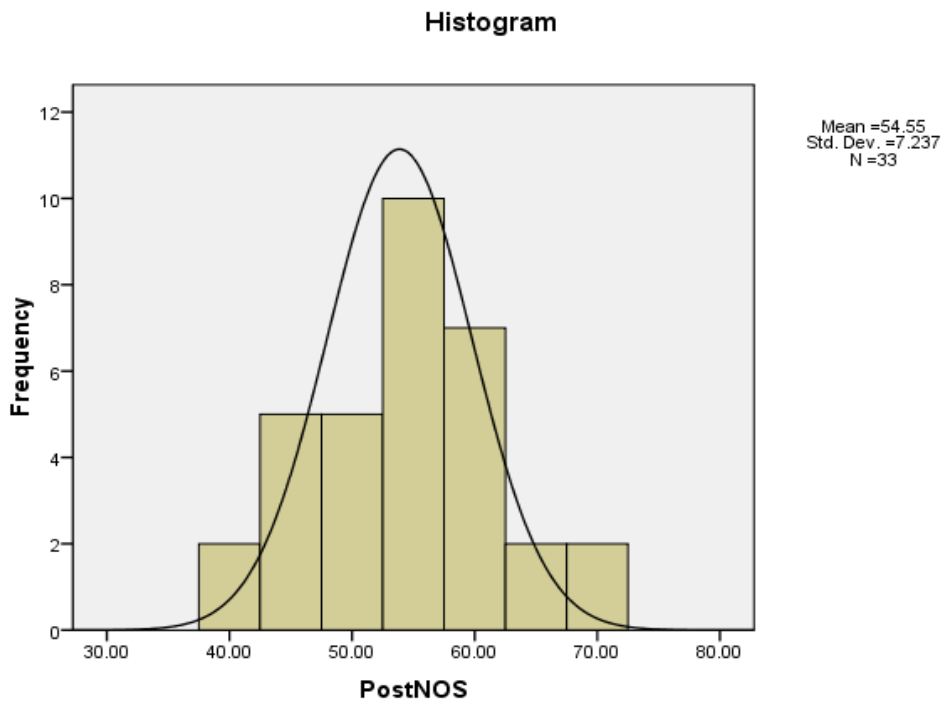


Figure 6. Histogram of Post-NOS scores.

Furthermore, Figure 4 illustrates that the interquartile range of all four quarters is greater in the Posttest as compared to the Pretest. The range in the first quarter increased from 8.25 in the Pretest to 10.00 in the Posttest while the second quarter showed the smallest increase from 3.25 to 4.00. In the third quarter the range increased from 4.25 to 5.50 and the fourth quarter showed the largest range increase from 5.25 to 11.50, a difference of 6.25 (Table 9).

Paired samples t-test. A paired samples t-test was also conducted on the data obtained from the NOS questionnaires using the same program to determine the impact of NOS infused lessons on students' views of the NOS. Tables 10 and 11 show that there was a statistically significant increase in students' scores from the Pretest ($\underline{M} = 50.78$, $\underline{SD} = 5.19$) to the Posttest ($\underline{M} = 54.55$, $\underline{SD} = 7.24$), $t(31) = -2.72$, $p < .011$. The eta squared statistic $(.19)^4$ indicates a large effect size. This means that the intervention had a large impact on students' views of the NOS as their mean score significantly increased from Pretest to Posttest. Hence, they developed a deeper understanding of what science is about.

Table 10

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PreNOS	50.7813	32	5.19140	.91772
	PostNOS	54.3438	32	7.25841	1.28312

Table 11

Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation				
Pair 1	PreNOS - PostNOS	-3.56250	7.40504	1.30904			
		Paired Differences 95% Confidence Interval of the Difference					
		Lower	Upper	t	df	Sig. (2-tailed)	
Pair 1	PreNOS - PostNOS	-6.23230	-.89270	-2.721	31	.011	

Achievement

Descriptive statistics were generated for students' test scores using the SPSS 17.0 program to determine the impact of NOS infused lessons on their test scores. From Table 12 it can be seen that there were significant increases in students' mean, median and mode scores from the Pretest to the Posttest. The mean increased from 12.85 in the Pretest to 32.91 in the Posttest while the median increased from 12.00 to 33.00. The mode of the Posttest (28.00) was more than double the score in the Pretest (12.00). Furthermore, the range of scores in the Posttest (35.00) was also greater than that of the Pretest (19.00). All these statistics indicate that there was a significant increase in students' test scores after being exposed to an intervention which infused the NOS into the lessons.

Table 12

Performance Test Descriptive Statistics

		Pretest	Posttest
N	Valid	33	33
	Missing	2	2
	Mean	12.8485	32.9091
	Std. Error of Mean	.83838	1.43902
	Median	12.0000	33.0000
	Mode	12.00	28.00
	Std. Deviation	4.81613	8.26651
	Variance	23.195	68.335
	Skewness	.026	-.548
	Std. Error of Skewness	.409	.409
	Range	19.00	35.00
	Minimum	3.00	14.00
	Maximum	22.00	49.00
Percentiles	25	9.0000	28.0000
	50	12.0000	33.0000
	75	16.5000	39.0000

Furthermore, as shown in Table 12 the five-number summary is significantly greater in the Posttest than in the Pretest. That is, the minimum score increased from 3 to 14, a difference of 11 while the maximum score increased significantly from 22 to 49, a difference of 27. The Q_1 score also increased drastically from 9 to 28 while the Q_2 (median) score increased from 12 to 33, a difference of 21. Lastly, the Q_3 score increased from 16.50 to 33.00, a difference of 22.50.

Boxplot Analysis. Figure 7 shows that the Pretest data is only slightly positively skewed (0.026). That is, the majority of the scores are evenly distributed on both sides of the mean (12.85) as depicted by the normal curve and histogram (Figure 8) but there are slightly more scores that are less than the mean. Hence, the mean, median (12.00) and the mode (12.00) do not

vary to a great extent and they are at the centre of the distribution. However, Table 12 indicates that the Posttest data set is negatively skewed (-0.548) with more of the scores clustering to the upper end of the distribution and lying above the mean (32.91) as shown in the histogram in Figure 9. The mean, though, lies below the median score of 33.00.

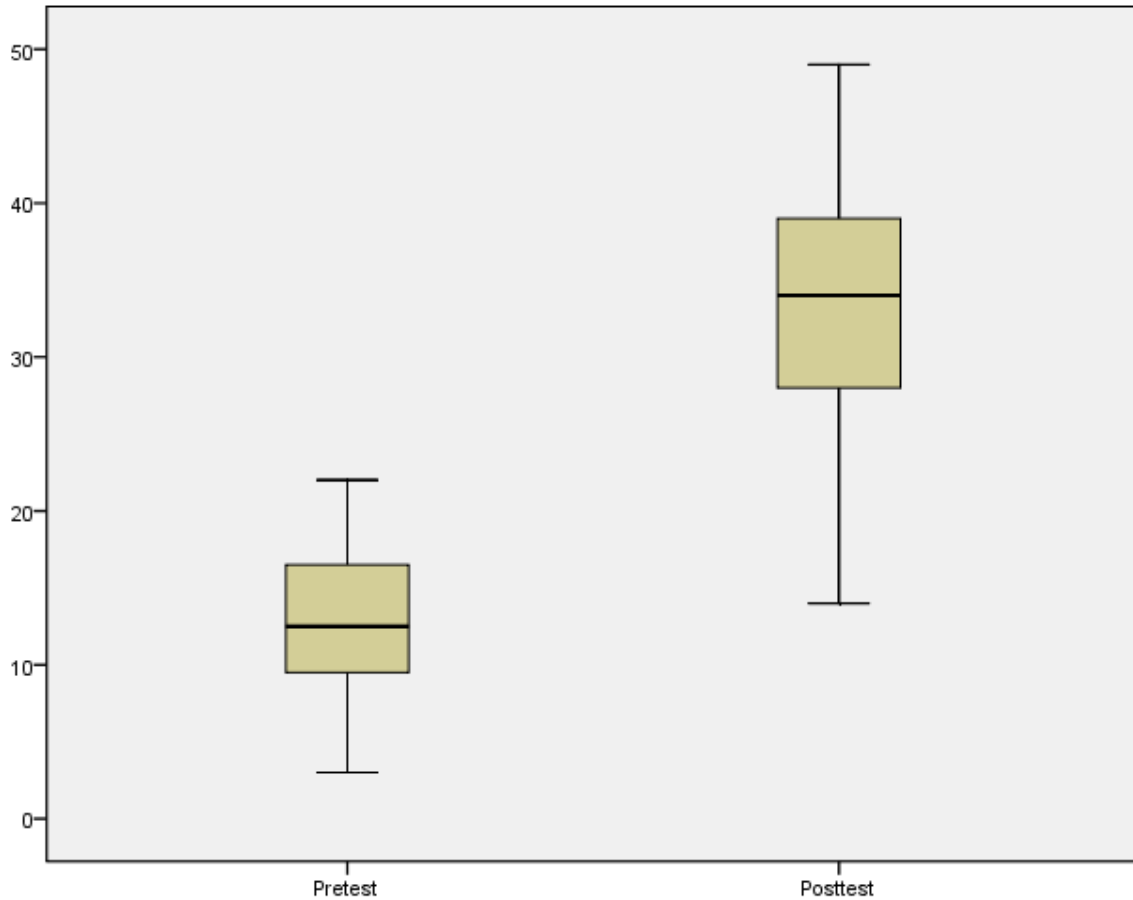


Figure 7. Boxplot of Pretest and Posttest Performance Scores

Also, Figure 7 illustrates that the interquartile range for all four quarters was significantly larger in the Posttest than in the Pretest. As seen in Table 12, the range of the first quarter increased from a value of 6 in the Pretest to 14 in the Posttest. Similarly, there were small increases in the range of scores for the second and third quarters. The second quarter increased

from 3 to 5 while the third quarter increased from 4.5 to 6.0 in the Posttest. Finally, the fourth quarter range increased from 5.5 in the Pretest to 10.0 in the Posttest.

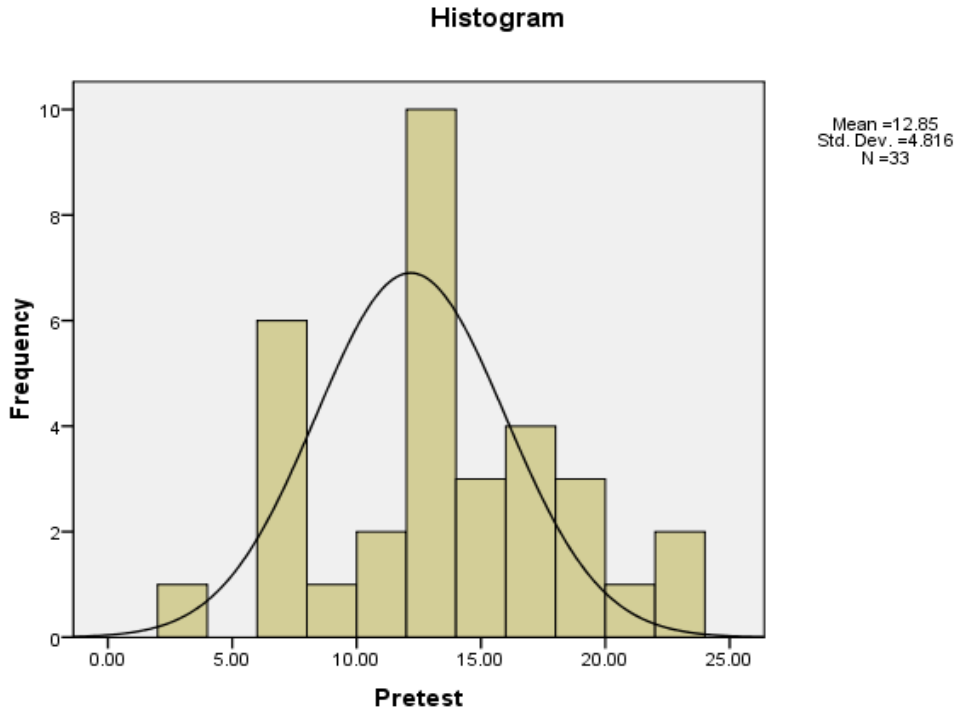


Figure 8. Histogram of Pretest scores.

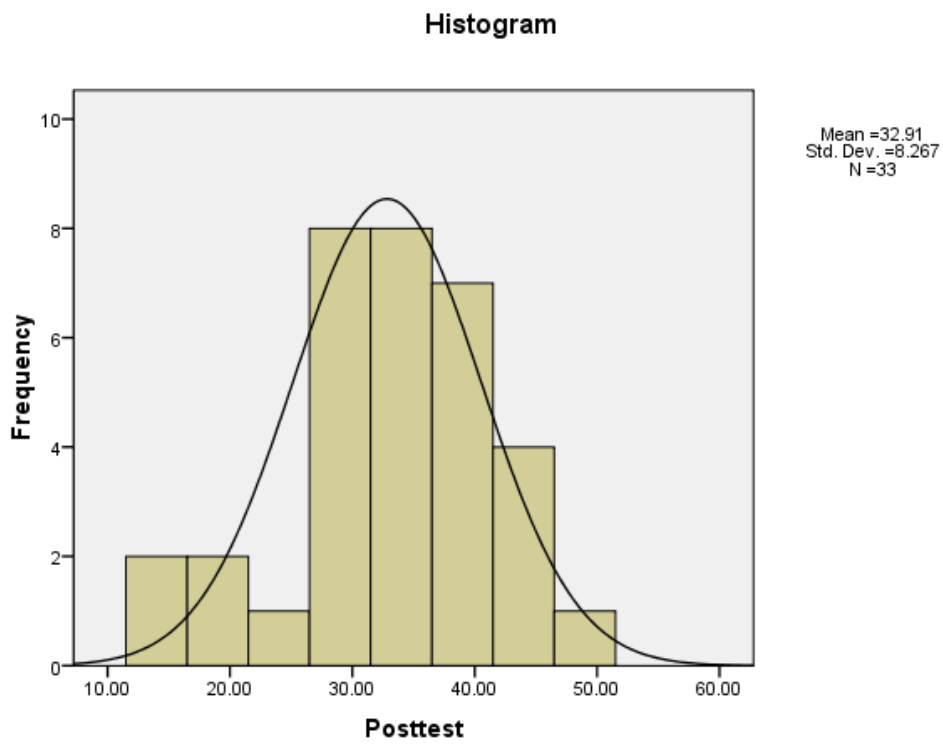


Figure 9. Histogram of Posttest scores.

Paired samples t-test. A paired-samples t-test was conducted to evaluate the impact of NOS infused lessons on students' test scores. There was a statistically significant increase in students' test scores from the Pretest ($M = 12.94$, $SD = 4.87$) to the Posttest ($M = 32.91$, $SD = 8.39$), $t(31) = -12.98$, $p < 0.000$ as shown in Tables 13 and 14. The eta squared statistic (.84)⁵ indicates a large effect size. This means that the intervention had a large impact on students' test scores as the mean score significantly increased from 12.85 to 32.91, a difference of 20.06. Thus, their achievement increased after being taught a unit of NOS-infused lessons.

Table 13

Paired Samples Statistics

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	12.9375	32	4.86553	.86011
	Posttest	32.9063	32	8.39877	1.48471

Table 14

Paired Samples Test

Paired Differences				
		Mean	Std. Deviation	Std. Error Mean
Pair 1	Pretest - Posttest	-19.96875	8.70478	1.53880

Paired Differences 95% Confidence Interval of the Difference						
		Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Pretest - Posttest	-23.10716	-16.83034	-12.977	31	.000

Bivariate analysis

Pearson product-moment correlation coefficient. Correlation or bivariate analysis was conducted on the data in order to determine the strength and direction of the linear relationship between students' test scores and their NOS and SL scores. The Pearson product-moment correlation coefficient was calculated for each of the following pairs of variables (Table 15).

Table 15

Variables and Pearson Product-Moment Correlation Coefficients

Independent Variable	Dependent variable	Pearson correlation coefficient (r)
PreSL	Pretest	.451
PostSL	Posttest	-.124
PreNOS	Pretest	-.035
PostNOS	Posttest	.059

The variables which were found to have the largest significant linear relationship as indicated by the r value (.451) were the students' PreSL and Pretest scores (Table 15). The relationship between the PreSL (as measured by the Scientific Literacy questionnaire) and the Performance Scores (Pretest) (as measured by the Performance Test) was investigated using the Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. There was a moderate, positive correlation between the two variables as shown in Table 16, $r = .451$, $n = 31$, $p < .0005$, with high pre-scientific literacy scores associated with high Pretest scores. This means that as the PreSL scores increase, so too do students' Pretest scores.

Table 16

Correlation between PreSL and Pretest Scores

		Pre SL Score	Pretest
PreSL Score	Pearson Correlation	1	.451*
	Sig. (2-tailed)		.011
	Sum of Squares and Cross-products	158.469	141.710
	Covariance	5.112	4.724
	N	32	31
Pretest	Pearson Correlation	.451*	1
	Sig. (2-tailed)	.011	
	Sum of Squares and Cross-products	141.710	742.242
	Covariance	4.724	23.195
	N	31	33

*. Correlation is significant at the 0.05 level (2-tailed).

According to Cohen (as cited in Pallant, 2010) r (.451) indicates that the strength of the correlation⁶ between the PreSL and the Pretest scores is moderate. Additionally, since this value is positive it also indicates that the correlation between these two variables is positive. That is, as the PreSL scores increase, so too do the Pretest scores. This positive relationship can be seen in the scatterplot in Figure 10 which depicts an upward trend of the data. Since all the points are nearly arranged in a cigar shape, this suggests a relatively strong correlation. The coefficient of determination $r^2 = .20$. This means that the PreSL and Pretest scores share 20% of their variance. Hence, there is not much overlap between these two variables.

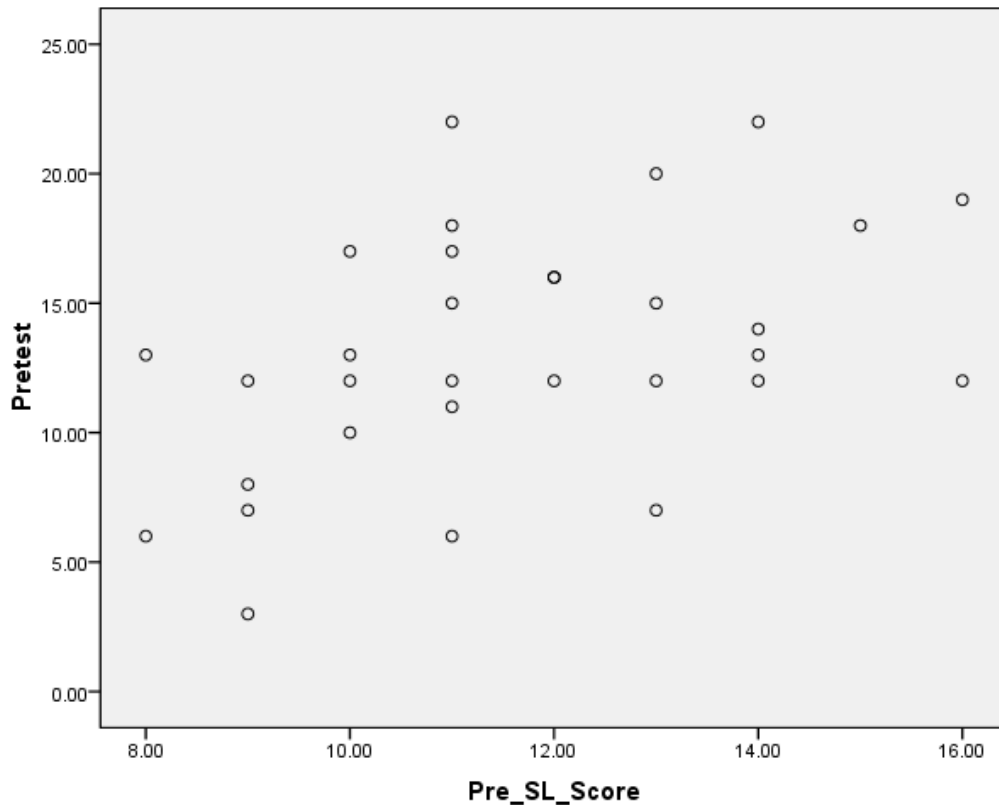


Figure 10. Scatterplot of Students' PreSL and Pretest Performance Scores

Multiple Regression Analysis

The standard multiple regression test was conducted on the data using SPSS. Students' performance scores represented the continuous dependent variable while the two continuous independent variables were their NOS and scientific literacy scores. Three models were generated using these variables as shown in Table 17 in order to determine how much unique variance in the dependent variable can be explained by each of the independent variables.

Table 17

Regression Models and Variables

Dependent Variable	Independent Variables	Adjusted R square	Beta coefficient (larger value only)
Pretest	PreNOS, PreSL	.148	.451 (PreSL)
Posttest	PostNOS, PostSL	-.047	-.130(PostSL)
Posttest	PreNOS, PreSL	.084	.350(PreSL)

The first model was of greatest significance since this model generated the largest Adjusted R Square value of .148 as shown in Table 18. This means that 14.8 percent of the variance in students' Pretest scores is explained by their NOS and SL scores.

Table 18

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.452 ^a	.204	.148	4.36134

a. Predictors: (Constant), PreNOS, PreSL Score

The ANOVA test determines the statistical significance of the results and whether the null hypothesis that multiple R in the population equals 0. As shown in Table 19, a significance value of .041 indicates that model one is statistically significant at the .05 level (2 tailed).

Table 19

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	136.825	2	68.412	3.597	.041 ^a
	Residual	532.595	28	19.021		
	Total	669.419	30			

a. Predictors: (Constant), PreNOS, PreSL Score

b. Dependent Variable: Pretest

Furthermore, the standardized beta coefficient for the PreSL score (.451) is larger than that of the PreNOS score (-.029) as shown in Table 20. This means that the PreSL score makes a stronger unique contribution to explaining the Pretest score than the PreNOS score.

Table 20

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.364	8.814		.382	.706
	PreSL Score	.961	.359	.451	2.674	.012
	PreNOS	-.026	.151	-.029	-.169	.867

a. Dependent Variable: Pretest

Univariate Analysis of Covariance

A one-way between-group analysis of covariance (ANCOVA) was conducted to compare the effectiveness of an intervention designed to enhance students' SL on their achievement scores. The independent variable was students' PreSL and PostSL scores. The dependent

variable was their achievement scores on the Posttest after the completion of the intervention.

Students' age was used as the covariate in this analysis.

Preliminary checks were conducted to ensure that there was no violation of the assumptions of normality, linearity, homogeneity of variances, homogeneity of regression slopes and reliable measurement of the covariate. The results, as shown in Table 21, indicate that there was no significant difference between students' PreSL and PostSL on their Posttest achievement scores, $F = 1.11$, $p = .57$, partial eta squared = .87. There was a weak relationship between the PreSL and PostSL scores on students' achievement, as indicated by a partial eta squared value of .07.

A significance value of .57 (Table 21) indicates that there was no significant difference between students' PreSL and PostSL on their achievement scores after controlling for their age. Also, the partial eta squared value of .87 (Table 21) indicates that 87% of the variance in students' achievement scores is explained by their PreSL and PostSL. This value is significant as it supports the findings of the regression analysis in which students' PreSL made a stronger contribution to their Pretest score than their PreNOS score. Furthermore, a partial eta squared value of .07 (Table 21) suggests that there is a weak relationship between age and achievement while controlling for SL. A significance value of .15 suggests that the covariate (age) is not significant as it only explains 7% of the variance in students' achievement.

Table 21

Tests of Between-Subjects Effects

Dependent Variable: Posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2050.149 ^a	28	73.220	1.547	.469
Intercept	22.312	1	22.312	.471	.563
Age	7.310	1	7.310	.154	.732
Pre_SL_Score	766.852	8	95.856	2.025	.372
Post_SL_Score	629.401	7	89.914	1.899	.388
Pre_SL_Score * Post_SL_Score	631.496	12	52.625	1.112	.568
Error	94.690	2	47.345		
Total	36301.000	31			
Corrected Total	2144.839	30			

a. R Squared = .956 (Adjusted R Squared = .338)

Source	Partial Eta Squared	Noncent. Parameter	Observed Power ^b
Corrected Model	.956	43.302	.122
Intercept	.191	.471	.072
Age	.072	.154	.057
PreSL Score	.890	16.197	.143
PostSL Score	.869	13.294	.138
PreSL Score * Post SL Score	.870	13.338	.102

b. Computed using alpha = .05

Summary of Findings

The data analysis shows that the Unit of lessons infused with the NOS had a significant impact on students' scientific literacy, NOS and performance scores as their mean, median and mode scores increased from Pretest to Posttest. This impact was found to be large for each

variable as indicated by the Cohen d effect size. The bivariate analysis indicated that there exists a moderate positive correlation between the PreSL and the Pretest scores. However, there were no significant correlations between the two independent variables (SL and NOS) and the dependent variable (Posttest) after the intervention. Furthermore, multiple regression analysis showed that 14.8 percent of the variance in students' Pretest score can be explained by their SL and NOS scores although their PreSL score made a stronger unique contribution than the PreNOS score. After the intervention, though, only 8.4 percent of the variance in the Posttest is explained by students' SL and NOS scores. Students' age also impacted on their achievement as it explained 7% of the variance in their Posttest scores.

Chapter V

Discussion, Summary, Conclusion and Recommendations

Introduction

In this section the findings of the study will be discussed extensively. That is, the impact that a unit of NOS-infused lessons has on both the SL and achievement of a group of Form One boys in a school in South Trinidad. The results of the participants' views of the NOS and their SL will be presented and compared to previous studies to determine whether these findings are consistent with the literature in these fields. Changes to these two variables after the intervention will also be highlighted. Discussions will be presented on the impact of both the NOS and SL on the students' achievement as well as which of these variables makes the strongest impact on achievement. Additionally, the findings will be argued in light of the social theory presented in Chapter 1. Following these discussions will be the implications of the study, its conclusions and recommendations for stakeholders and finally suggestions for future studies.

Discussion

This study investigated students' perceptions of the NOS and whether there were significant changes to these views after participating in a unit of NOS-infused lessons. This intervention was designed by the researcher to change students' traditional or naïve views of science to one that is more contemporary or non-traditional. It also seeks to determine how their understanding of science impacts on their SL and achievement.

It was found that students' possessed a moderate understanding of the NOS before the intervention. However, their views were only marginally more non-traditional than traditional.

This is consistent with the findings of Moss (2001) who found that high school students began the school year with either a partial or full understanding of the NOS.

These findings are in contrast, though, to those obtained by many researchers (Dawkins & Dickerson, 2003; Griffiths & Barman, 1992; Haidar & Balfakih, 1999; Kang et al., 2004; Muslu & Akgul, 2006; Ryder et al., 1997) who found that students' initially possessed naïve, vague or traditional views of the NOS. These researchers utilized either qualitative strategies or a combination of open and closed-ended instruments to measure students' NOS views. The differences in findings may be due to varying methodologies as the researcher of this study utilized only a closed-ended instrument to evaluate students' NOS views. Kang et al. (2004) posit that the use of Likert scale instruments assumes that both researchers and students interpret the items in the same way. This may not necessarily be the case. They suggested that the use of interviews can give a more comprehensive understanding of students' perspectives. Similarly, Muslu and Akgul (2006) concur that the lack of predetermined categories and the use of qualitative methods such as interviews allow the researcher to generate more in-depth, open and detailed data.

Also, the findings of this study indicate that students' views of the NOS were enhanced after the intervention becoming more non-traditional and less traditional. That is, the participants developed a deeper understanding of the epistemology of science. This is supported by the findings of studies (Akerson & Donnelly, 2010; Jelinek, 1998; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2007; Kim & Irving 2010; Meichtry, 1995) in which students developed more informed views of the tenets of NOS. The intervention appeared to have impacted on both their traditional and non-traditional views to a moderate extent as indicated by the effect size. It was more effective, though, at reducing their traditional views ($\eta^2 = .12$) than enhancing

their non-traditional views of NOS (eta squared = .08). When both of these views were analyzed together, the results showed that the intervention had a large impact on students' views of the NOS (eta squared = .19).

Furthermore, the results show that while the intervention was successful at enhancing students' non-traditional views of NOS, this increase was not significant. This may be due to the short five-week period during which this study was conducted. Such a short time may not have been sufficient to drastically change students' views of science (Dagher & Brickhouse, 2004) which would have taken them years to establish. Given a longer period of time students' NOS views may change significantly with continuous explicit instruction. Khishfe and Abd-El-Khalick (2002) believe that one factor which influences students' changing views of the NOS is the duration of the intervention. In their study they concluded that while more participants in the experimental group developed informed views of NOS, it proved difficult to change students' NOS views over the course of 2.5 months.

Students' SL was measured using a closed-ended instrument based on the NOS which was developed by Carrier (2001). In this instrument it was assumed that the NOS was a measure of students' SL level. Although many researchers have also utilized closed-ended instrument for such a purpose, their questionnaire items focused more on the content and process skills dimensions of SL rather than on the tenets of NOS. In this study the descriptive statistics indicate that prior to the intervention students' possessed a moderate level of SL. This finding is consistent with the results obtained by Akgul (2004), Bacanak and Gokere (2009), Chin Chin (2005) and Ozdem et al. (2010).

However, after the intervention students reported an overall increase in 5 of the 7 aspects of SL assessed in the survey. Additionally, the paired t-test analysis showed that the unit of

NOS-infused lessons impacted their SL level to a great extent as indicated by the large effect size (.21). This means that students' content knowledge and skills in science, as measured by their SL, were enhanced after the intervention. These results concur with that of many studies (Bardeen, 2000; Bauer et al., 1998; Carr, 1997; Caswell & Lamon, 1998; Elliott, 2006; Kaelin et al., 2007; Palincsar et al., 1993; Reveles & Brown, 2008) conducted in the past which sought to enhance students' SL following implicit or explicit instruction.

Bivariate analysis of the data revealed that there exists a moderate, positive correlation between students PreSL and achievement scores. This means that as their SL scores increase, so too do their achievement scores. However, the PreSL and Pretest scores share only 20% of their variance which means that there is not much overlap of these variables. Further multiple regression analysis indicates that while NOS and SL only contributed 14.8% of the variance in the Pretest, students SL makes a larger unique contribution than their views of NOS. This is supported by the findings of the ANCOVA test which indicates that 87% of the variance in students' Posttest achievement scores is explained by their PreSL and PostSL.

These findings suggest that students' cannot learn the tenets of SL and the NOS through content and process skills alone, as was done in this study. This may be one possible reason why we are producing students with low levels of SL. Such traditional instructional strategies may only result in minor changes to students' views of the NOS and SL. Allchin (2004, p.6) states that "no amount of scientific content alone will ever be enough to develop full scientific literacy. Nature of science lessons must be inserted into the standard curriculum and regularly reinforced to encourage habits of mind". Many researchers (Abd-El-Khalick & Lederman, 2000; Allchin, 2004; Bell et al., 2003; Clough & Olsen, 2004; Cochrane, 2003; Dawkins & Dickerson, 2003; Khishfe & Abd-El-Khalick, 2002; Larson, 2000; McDonald, 2010; Musante, 2005; Schwartz &

Lederman, 2008;) believe that the most effective way to teach the NOS and thus, enhance students' SL is by using direct contextual, explicit and reflective instruction. Khishfe & Abd-El-Khalick (2002, p.574) argue that students "should be provided opportunities to apply their acquired NOS understanding to novel contexts for them to appreciate the applicability and fruitfulness of such understanding in making sense of the development and characteristics of scientific knowledge." Likewise, Bell et al. (2003) suggest that educators need to provide students with the opportunity to explicitly reflect on their actions so that the NOS and scientific inquiry are adequately emphasized in science teaching.

Following the intervention, though, the impact of students views of NOS and SL on achievement decreased. This means that while students' views of the NOS and their SL contributed towards their achievement, other factors which were not controlled for such as cultural beliefs, socioeconomic status, location of primary school attended and the influence of extra 'lessons' may have also significantly impacted upon their performance. Such factors appear to have impacted participants' achievement to a greater extent than NOS and SL combined, especially after the intervention. For instance, when one of these factors (age) was controlled for using the ANCOVA test, the results indicated that students' age explained 7% of the variance in their achievement scores. This means that students' age did positively impact on their achievement.

Moreover, students' achievement increased significantly after participating in the unit of NOS-infused lessons designed to increase their SL. The eta squared statistic (.84) indicates that the intervention had a large impact on students' achievement. The findings of this study also reveal that there exists a moderate positive correlation between students' SL and their achievement prior to the intervention. Mbajjorgu and Ali (2001), though, reported a weak

positive relationship between secondary students' SL and achievement in Biology following instruction using the STS approach. This difference in results may be explained since the instruments used to assess students' SL level in both cases did not measure the same components of SL. While the instrument used in this study was comprised of the tenets of NOS, it only formed a portion of the SLS utilized by Mbajiorgu and Ali (2001).

Implications

In this study the researcher investigated the impact of a unit of NOS-infused lessons on students' SL and their achievement. The findings of this report can impact upon various stakeholders including students, teachers, administrators, policy makers and even society. Students may develop a deeper understanding of science and scientific processes, resulting in an increase in their SL. They would then be better able to apply their knowledge and skills to real world contexts; making more informed decisions about scientific issues. Students may develop greater interest and motivation to learn science and become more engaged in scientific activities. Thus, teachers and administrators may be faced with less indiscipline in the classrooms. This may also result in more students entering science-related careers leading to an increase in productivity in the country.

Additionally, this intervention could assist policy makers and educators in realising their initiatives for enhancing the SL of the population. This would mean that the current science curriculum would need to be reformed to accommodate the NOS and explicit, reflective instructional activities. Currently, the science curriculum only facilitates content and knowledge skills which are insufficient to adequately enhance the SL of students. However, in order to implement a new curriculum more teachers would have to be convinced of the importance of

explicit NOS instruction. Like policy makers, they too would need to possess a comprehensive understanding of the NOS and the most effective ways in which it should be taught.

The community, too, may benefit from students' enhanced understandings of science as they develop into more productive citizens. They would be able to make a more meaningful contribution to society and to the economy of the country. Furthermore, a more scientifically literate workforce will allow the country to compete more effectively on global markets (Yuenyong & Narjaikaew, 2009).

Conclusion

Research in the fields of NOS and SL continue to indicate that these two variables impact on each other as well as on students' achievement. Educators and policy makers globally advocate for enhancing the SL of their people so that they become more proficient and engage in scientific issues. In order to achieve these reform efforts, science must be presented to students in a more holistic and meaningful way. Thus, the NOS becomes an essential component of science curricula as it is an important aspect of SL. Although the generalizability of this study may be limited due to the small sample size, the results may have valuable implications to various stakeholders. The findings reveal that students stand to benefit tremendously when they are actively involved in learning the epistemology of science. Their views of science become more contemporary and their SL increases. Such knowledge and skills are needed by our students if they are to become more productive citizens who are capable of making well-informed scientific decisions.

Recommendations

The findings of this study may be used by policy makers to develop curricula which can potentially enhance the SL of students. In order to achieve this daunting task, teachers would

need to be trained extensively in the field of NOS. Such training could be conducted at workshops and professional development seminars host by the Ministry of Education (MOE). The MOE can even make this training compulsory for all science teachers so that they will be adequately equipped with the knowledge and skills from which their students will benefit. The teachers may need to move away from traditional instructional strategies such as ‘chalk and talk’ and adopt a more constructivist approach to learning. This may require additional resources in schools which could be supplied by the MOE.

Suggestions for Future Studies

In light of the findings of this study, the researcher suggests that future studies could investigate the impact of students’ culture on their SL level and achievement. Also, the relationship between culture and SL could be explored in order to determine if they affect students’ achievement. Additionally, teachers’ views of the NOS could be examined to determine whether they possess adequate views of science and how their views impact on students’ SL level and achievement.

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Footnotes

Effect size:**Scientific Literacy**

$$\begin{aligned} {}^1 \text{Eta squared} &= \frac{t^2}{t^2 + N-1} \\ &= (-2.846)^2 / (-2.846)^2 + (32-1) \\ &= 8.099716 / 39.099716 \\ &= 0.207155366 \\ &= 0.21 \text{ (large)} \end{aligned}$$

0.01= small

0.06 = moderate

0.14 = large

(Cohen, as cited in Pallant, 2010)

Traditional NOS views

$$\begin{aligned} {}^2 \text{Eta squared} &= \frac{t^2}{t^2 + N-1} \\ &= (1.024)^2 / (1.024)^2 + 8 \\ &= 1.048576 / 9.048576 \\ &= .1158829 \\ &= .12 \text{ (moderate)} \end{aligned}$$

Non-traditional NOS views

$$\begin{aligned}^3 \text{ Eta squared} &= \frac{t^2}{t^2 + N-1} \\ &= (-.638)^2 / (-.638)^2 + 5 \\ &= .407044 / 5.407044 \\ &= .0752803 \\ &= .08 \text{ (moderate)}\end{aligned}$$

NOS views

$$\begin{aligned}^4 \text{ Eta squared} &= \frac{t^2}{t^2 + N-1} \\ &= (-2.721)^2 / (-2.721)^2 + (32-1) \\ &= 7.403841 / 38.403841 \\ &= 0.192789075 \\ &= 0.19 \text{ (large)}\end{aligned}$$

Achievement

$$\begin{aligned}^5 \text{ Eta squared} &= \frac{t^2}{t^2 + N-1} \\ &= (-12.977)^2 / (-12.977)^2 + (32-1) \\ &= 168.402529 / 199.402529 \\ &= 0.844535572 \\ &= 0.84 \text{ (large)}\end{aligned}$$

⁶ Cohen (as cited in Pallant, 2010) *r* guidelines:

Small $r = .10$ to $.29$

Medium $r = .30$ to $.49$

Large $r = .50$ to 1.0