Larrisa Mohammed

Exploring the nature and influence on two science teachers' epistemologies

ABSTRACT

This study examined two secondary school teachers' beliefs about the nature of science and about teaching and learning science. The study assessed the influence of explicit reflective activities on their beliefs about the nature of science and also on how a consideration of the nature of science in lessons changed their beliefs about what makes a good science lesson. The main goals were to improve or change the teachers' beliefs about the nature of science and their beliefs about what makes a good science lesson. Data was collected through the Views of the Nature of Science Form C (VNOS-C) survey, semi-structured interviews and any informal conversations which the participants had with the researcher about the topic. Both surveys and interviews were conducted before and after the intervention. It was concluded that teachers have positivistic beliefs about the nature of science and that they believed firmly in the traditional method of teaching. However, after the intervention one teacher changed her beliefs about most aspects of the nature of science and the other just changed her beliefs with regards to the tentative nature of scientific knowledge. Both teachers' beliefs about what makes a good science lesson remained the same except that they were now willing to include the history of science in their science lessons. The teachers were also shown how to include aspects of the nature of science in their lessons on a continuous basis and not a one shot deal. This was done in this study by keeping in constant communication with one of the teachers about the nature of science and how it can be included in various aspects of the science curriculum using a few historical cases.

Key words : nature of science, history of science, teacher epistemological beliefs, scientific literacy, critical thinking.

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Chapter 1

Introduction

Background to the Problem

According to the Central Association of Science and Mathematics Teachers (1907) as cited in Lederman (2008) understanding of the construct nature of science has been advocated as an important goal for students studying science for the past 100 years. According to Lederman (2008) this goal has appeared in many science education documents such as the American Association for the Advancement of Sciences (AAAS), (1993), the National Committee on Science Education Standards and Assessment (1996), and the National Science Teachers Association (NSTA), (2000) and according to Ogunniyi (1982) in many developing countries it is one of the most commonly stated objectives for science education.

Sweeny (2003) has advocated that the typically defined “developing countries” of the Caribbean share with the more fully developed industrialized nations the need to educate and prepare their citizens to be competitive in the global economy and over the past 29 years have been engaged in the process of education reform. Watson (2001) reports that at the 1997 CARICOM Heads of Government Summit in Montego Bay, Jamaica, it was accepted that “education is the major mechanism to bring about the necessary transformation in Caribbean society,” (p.5) and, therefore, that it must have as its ultimate goal the creation of a type of society which allows for the “evolution of a new Caribbean person” (p.5). According to Watson (2001) one of the goals of education for the Caribbean was to produce a citizen who could: demonstrate multiple literacies , independent and critical thinking, question the beliefs and practices of past and present and bring this to bear on the innovative application of science and technology to problem solving. This goal is also in alignment with having a proper understanding of the construct of the nature of science.

Locally, Fraser-Abder (1985b) advocates that the goal of producing students who have scientific capabilities has been in existence as far back as 1977, with the introduction of Science-A Process Approach for Trinidad and Tobago (SAPATT), in primary schools (as cited in Barrow & De Leisle, 2009). More recently in 2000 under the People's National Movement in Trinidad and Tobago the draft policy labelled "Vision 2020" was created for the holistic development of the country. One of the goals from the Vision 2020 plan is to develop a pipeline of students coming through primary, secondary and tertiary education prepared in the sciences (People's National Movement National Plan, 2000). Retrieved on March 30, 2010 from http://www.pnm.org.tt/pdf/National_Plan.pdf . The word "prepared" could be interpreted to mean a wide variety of things but for the purposes of this study the researcher takes it to mean a proper understanding of the nature of scientific knowledge is acquired after exposure to science in school.

So it is quite clear that having a proper understanding of the nature of science is important for science educators and it is this goal for science education that propelled researchers over the past fifty years to find ways in which they can assess and improve both teachers' and students' beliefs about the nature of science. Although there have been many efforts to reform science education in many countries by changing the curriculum, many of these reforms have been met with great dissatisfaction and there is still general consensus that both students and teachers have inadequate understanding of the nature of science (Abd-El-Khalick & Lederman, 2000; Driver et al, 1996; Finson, 2002; Hogan & Maglienti, 2001; Lederman, 1992; Moss, Abrams & Robb, 2001; Ryder, Leach & Driver, 1999 as cited in Wong & Hodson, 2008). There seems to be a general consensus globally that the beliefs about the nature of science held by teachers are inadequate. Internationally, studies done from Weaver (1964) as cited in Ogunniyi (1982) and more recently by Morrison, Raab and Ingram (2009) have revealed that the way that science is taught in schools is not in accordance with a true reflection of the nature of science.

Regionally, according to Sweeny (2003) in countries like Barbados and Jamaica where the governments invest a great deal of funds into education programs such as the Education Sector Enhancement Program (EDUTECH 2000) in Barbados and Science Matters In Life Everyday (SMILE) in Jamaica, which are supposed to enhance the way that students view the nature of science, there have never been any teacher educator programs which are specifically designed to upgrade or understand teachers' beliefs about the nature of science.

Locally there have been many reforms in science education in an effort to produce students emerging from the secondary level with "scientific capabilities". *Scientific capability* is the label the Government has given to the eclectic notion that all graduates from the secondary education system of T&T must be what historically has been described as being scientifically literate (Barrow & De Lisle, 2009). Curriculum reform began as early as 1977 with the introduction of the SAPATT programme in primary schools which was a curriculum developed for children 5-12 years old and spanned 1977-1985. Then there was the introduction of the National Certificate of Secondary Education (NCSE) which was a science reform initiative designed for lower secondary schools and according to George (1997) the program was having an impact on the science experience of students at the lower secondary level (as cited in Barrow & De Lisle,2009). She reported that many students were enjoying science; however the nature of the impact of this programme, however, appeared to vary depending on the orientation of the teacher. Smith and Southerland (2007) describes these "orientations" toward teaching as teachers' beliefs or personal theories about teaching that inform the decisions they make concerning teaching methods and strategies as well as the information they choose to share with the children (Brickhouse & Bodner,1992;Laplante,1997; Smith,2005). Another major reform effort was the introduction of the Secondary Education Modernization Programme in 1999 (SEMP) which replaced the NCSE program.

More recently in 2010 when the People's Partnership Government came into power in Trinidad and Tobago, The Ministry of Education of Trinidad and Tobago (2010) initiated the eConnect and Learn (eCAL) Programme which has introduced laptops into secondary schools as a means of addressing the "digital divide". The program aims to develop the learner into a person who is excellence-driven, global in perspective, innovative, ingenious, creative and prepared to participate fully in the global economy of the 21st century (Ministry of Education, 2010). This initiative puts technology in the science classroom and as such if used properly can help to produce students which have a proper understanding of the nature of science. In order to execute this vision however the formal science curriculum must be adapted for utilizing the computer as a tool to actualize these educational outcomes.

However, since the introduction of science into the primary schools in 1977 to date, the Governments have never implemented any research programs to assess or to reform teachers' beliefs about the nature of science, as a result of that, there are many students who are being taught by teachers who have beliefs about science which are not congruent with the nature of science. Once the classroom door is closed, teachers can, if they choose, comply only symbolically or fitfully with mandates for change pressed on them by platoons of outside reformers (Tyack & Cuban, 1995 as cited in Smith & Southerland 2007). Teachers have been identified as the root of the problem in failed reform efforts and at the same time, teachers are also seen as the key agents of change (Cohen & Ball, 1990 as cited in Smith & Southerland, 2007), because it is ultimately the classroom teacher who bears the responsibility for implementing reforms (Bybee, 1993, p.233 as cited in Smith & Southerland 2007).

According to Nuangchalerm and Prachagool (2010) teacher preparation and development acts as a major role in the quality of education. Science teachers play a very important part in helping students understand the world in which they live. They act as a bridge between the students' world and the science world. Teachers need to learn how to promote the nature of science in their classroom and how to use the nature of science to make the students the centre of learning. Kattoula (2008) testifies that a student will not be able to understand science if taught by someone who does not understand it. Assessing teachers' beliefs about the nature of science is the only way of knowing what kind of reforms should be put in place and how these reforms should be implemented.

The representation of the nature of science has taken many faces as philosophers and educators try to define what it means. One view, a traditional view, is that all scientific knowledge is knowable, the truth, a reflection of things as they really are (Pomeroy, 1993). Another view, a constructivist view, suggests that scientific knowledge is developed by the construction of knowledge (mental constructions) to explain the world around us (Larochelle & Desautels, 1991).

Researchers have gone back and forth trying to truly uncover the construct of the nature of science so much so that according to Abd-El-Khalick and Lederman (1998) there is no agreed upon definition for it. The beliefs about the nature of science are even more tentative than scientific knowledge itself. The reason for this is that the nature of science is multifaceted, dynamic and complex concept (Abd-El-Khalick & Lederman, 1998).There seems however, in the midst of the confusion, to be some consensus as to what it entails at the secondary school level. Science has been agreed upon by many to be tentative, empirically based, subjective, socio-culturally embedded and dependant on human imagination and creativity (Wong & Hodson 2007; Lederman et al 2002; McComas & Olsen, 1998). Two additional aspects as described by Abd-El-Khalick and Lederman (1998) are (a) the distinction between observations and inferences, and (b) the functions of, and relationships between scientific laws and theories.

It is also agreed upon by many educators and philosophers that instruction about the nature of science should be a major part of the science curriculum (Lederman & Niess, 1997). In making the case for the exploration of the nature of science in the curriculum, Driver, Leach, Miller and Scott (1996) contend that in addition to its intrinsic value, understandings gained would enhance learning of science content, generate interest in science and develop students' ability to make informed decisions on socio-scientific issues based on careful consideration of evidence.

Context of the Study

This study is situated in a denominational school that has been branded as a "prestige" school. The Parent Teachers Association and the Administrative Committee have great control over what the teachers do in the classroom as they are the main financers of the school and many of them have children who are in the science classes. All teachers in the science departments get excellent results when the students at the age of about sixteen years write the Caribbean Secondary Entrance Examination (CSEC) and when students at the age of about seventeen and eighteen write the Caribbean Advanced Proficiency Examination. Annually the students receive scholarships both at the national level and international level. These excellent results have given teachers the confidence to believe that they do not need any kind of help in the classroom.

A typical physics class at this school involves the teachers either reading from notes or from the textbook for the students to take notes, the teacher would then do a calculation on the board and then students would do some in their books for practice. Science is portrayed as a set of facts for recall and there is no room for creativity and discovery. This idea of science is consistent with the views of the textbooks that the teachers utilize and as such science is done as rhetoric of conclusion. McComas, Clough and Almazroa (1998) warn that the significant role in instruction played by textbooks necessitates a look at how they portray the nature of science. The language that teachers use during instruction and in the textbook also significantly affects students' views of the nature of science.

The beliefs that teachers hold about the nature of science are manifested through the delivery of the Caribbean Assessment Proficiency Examination (CAPE) for, Caribbean Secondary Education Certificate (CSEC), and National Certificate of Secondary Education (NCSE) syllabi. Teachers are also in a position to pass on to the students any misconceptions they may have about the nature of science itself. A teacher's own epistemology of science is conveyed to the students and contributes to the image of science that they develop in class. Science teachers' epistemologies- include beliefs about science, beliefs about teaching science and beliefs about learning science- affect the type of instructional behaviour that occur in the classroom (van Driel, Verloop & de Vos,1998). Science teachers' epistemologies shape their teaching paradigms (Jones & Carter, 2007). Prospective teachers enter the teaching profession with images of science and models of teaching that they experienced as students (Eick & Reed, 2002).Hence it is very important that the teachers have views of the nature of science which are accurate so that they would not pass down myths about the nature of science to students. According to Lederman and Bell (2000) given the importance science educators have placed on the ultimate outcome of the nature of science instruction and scientific literacy, it is disconcerting to realise that little research exists delineating the role of one's understanding of the nature of science in decision making.

Our education system in Trinidad and Tobago contributes to the flight from proper scientific knowledge by promoting "encyclopaedic curricula" (Matthews, 1994, 34). Teachers often times teach science as an end product, in an effort to try and prepare the students for the final examinations. For example teachers will teach about the structure of the atom but do they do not teach about the importance of it being a model, they may teach about the sun being the centre of the planetary system but do they teach about how that came to be, they may teach of the derivation of Millikan's Oil Drop Experiment but they do not teach about the ethical issues of his results. Is it that teachers eliminate these things because they are not on the syllabus or is it because they themselves are ignorant of the value of these things or even their history? Is it that teachers themselves have become bored with the subject so they have little appreciation of it? According to Matthews (1994) teachers need to value their subject and be able to convey to students the reason they value their subject. Rutherford (1964) as cited in Da Boer (1991) agrees that teachers' familiarity with the history and philosophy of science is essential for the improvement of science teaching.

However, new trends in education require science teachers to have a new thinking and develop new skills. Modern approaches to the development of science curricula put students at the centre of the teaching/ learning process and emphasize the learning of science through innovative methods. Inquiry based learning is a constructivist approach to teaching science which teaches students how to handle situations which they encounter when dealing with the physical world by using techniques which are applied by scientists. It is an open ended and ongoing process which engages the learners in the investigative nature of science. According to the constructivist model, learning is the result of ongoing changes in our mental frameworks as we attempt to make sense out of our experiences (Osborne & Freyberg, 1985). It is hoped that exposing teachers to this type kind of learning will encourage some kind of restructuring to their existing conceptual frameworks thus enhancing their views about the nature of science.

This study seeks to investigate how the beliefs held about the nature of science by two Physics teachers, at a local school in the St. George East Division, change or are, enhanced when they are exposed to:

1. Explicit reflective activities (Lederman & Abd-El-Khalick, 1998).
2. A series of ways in which they can include a consideration of the nature of science into their teaching strategies.

Justification for doing the study

I have attended the University of the West Indies at least four different times, every time enrolled in a different program. Each time however, the program was always science oriented. I was almost sure that by now I would know what science is. In 2009, I embarked on a Master of Education programme and one of the first things I was asked to do was to write down in a few lines about what is this enterprise called science: to this day I am ashamed and horrified as to what I wrote in my book:

"Science is what I teach it is what I have my degree in and it is what I prepare the students to write examinations for..."

Later on during that term my worldview of science quickly changed as what the lecturer said made more sense to me. This course along with the other courses within the Masters programme really opened up my eyes as to how I could make science come alive in my classroom. It was not about putting up charts or doing power point presentations. It was much deeper - it was about knowing where the science came from. Understanding the history and the philosophy of science and not seeing it as the end product really humanizes the subject and makes you appreciate it more. Soon after I began to wonder if I had been a lone ranger in my ignorance so I conducted a small survey by asking teachers in my department to write down their thoughts on “What is science?”. I realised that we were all the same, we were taught to regurgitate facts and pass examinations with good grades and this lulled us into thinking that science is all about getting good grades. We never bothered to improve our views about the nature of science and as such we teach science in a manner which is clinical and didactic with a lack of creativity and imagination.

I wanted to share my new knowledge about the nature of science with the other science teachers at my school as I felt that this could be the turning point in our careers. If I could assess the teachers’ beliefs about the nature of science I would be able to work with them to enhance their beliefs about the nature of science and this would help them to deliver a more effective and productive curriculum to their students. I wanted to share with them how to incorporate understandings about the nature of science into their classroom instruction. It was hoped that this would be the beginning of the era where the students no longer regurgitate facts but could make connections and apply knowledge to their everyday lives.

Statement of the problem

Teachers' beliefs of the nature of scientific knowledge have never been assessed at this school. The major stakeholders are lulled into thinking that science teachers have a proper understanding of the construct of the nature of science because the students excel annually at all the high stake examinations. Most of the science teachers have an improper understanding of the nature of science and this deficiency is impacting on how they present science to the students.

Teachers do not include the nature of science into lessons maybe because they are in conflict with how to include it in the lessons. According to Brickhouse (1990) the relationship between the teachers' beliefs about the nature of science and their classroom practice is affected by the curriculum design. Teachers may have trouble with designing activities which would spark the students' interest and which would continually motivate them to be involved in science. This problem is partly because the teachers have themselves been taught in ways which never sparked their curiosity and so they were cultured into thinking science can only be taught in one way. As a result of this students develop an understanding that there is no room for new discoveries and that whatever is learnt in school is absolute and final (Iqual, Azam & Rana, 2009). They teach science as an end product and use textbooks and syllabi as their main resources which has led to science being portrayed as a dull and boring subject.

Purpose of the study

The main purposes of this research is to find out what are the beliefs held by science teachers about the nature of science, to seek to change these beliefs as appropriate by exposing them to a series of explicit / reflective activities and by showing them how to incorporate teaching about the nature of science in their classroom instruction (Lederman & Abd-El-Khalick, 1999).

Research questions:

1. What are the beliefs held by two teachers at School Z about the nature of science?
2. In what ways (if any) have these beliefs changed after being exposed to various ways to incorporate ideas about the nature of science into their lessons?
3. What are the beliefs held by teachers at School Z about the hallmarks of a good science lesson?
4. In what ways (if any) have their beliefs about the hallmarks of a good science lesson changed after being exposed to various ways to incorporate ideas about the nature of science into their lessons?
5. How are the teachers' beliefs about the nature of science manifested in their classroom practice?

Challenges to conduct the study

Limitations and delimitations.

1. The interviews took a long time to organise as the teachers have full timetables so it was a challenge to get all the interviews done.
2. Participants took a long time to return the open-ended questionnaire after the intervention because of their busy schedules.
3. The researcher was an insider and it was difficult at times to be objective.
4. The research was conducted with only two teachers so results cannot be generalised.
5. The research was conducted in one school and cannot be generalised.

Significance of the study

This study was significant because it;

1. allowed teachers to reconstruct their views about the nature of science,
2. encouraged collaboration and team work between the two teachers involved,
3. serves to inform major stakeholders how science is taught in school and as such internal programs can be put in place to improve the beliefs teachers have about the nature of science,
4. may encourage future studies about the beliefs teachers have about the nature of science and how it relates to science teaching and learning and
5. allowed teachers to reflect on a meta- cognitive level which will lead to self improvement.

Expected outcomes

The research project was expected to generate the following outcomes:

1. The teachers would have enhanced/changed beliefs about the nature of science.
2. The teachers would try to incorporate nature of science into their lessons.
3. Their beliefs about what makes a good science lesson would improve or change.
4. The teachers would develop the habit of working in groups to plan lessons.
5. A compilation of lessons with varying degrees of the nature of science would be produced.

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Chapter Two

Literature Review

What is the nature of science?

Assessing both teachers' and students' views about the nature of science is currently a very active research issue. It is therefore very important to look at what philosophers and the educational researchers say about it. The construct "nature of science" has been defined by many and still there is no general consensus as to what it is exactly. However, there seem to be a few common traits in all the explanations thus far. In the early 1900s according to Lederman (1992) the nature of science objective placed emphasis on increased scientific method. In the 1960s the nature of science was all about scientific process and inquiry and more recently it has been included as a critical component of being scientifically literate (AAAS, 1989 as cited in Lederman,1992). Ogunniyi (1982) says that the so called nature of science is a complex concept and it involves the processes, the products, the ethics, the regulative principles, and the logico-mathematical systems-all defining and controlling the methodological inquiries of science.

As the 19th century turned into the 20th century one popular and fashionable idea was that for knowledge to be termed scientific it had to be derived empirically. Empiricists such as Ernst Mach (1943) would say that anything which cannot be expressed in terms of law like behaviour cannot be deemed as science. This idea of empiricism was extended in the 1920s to include theoretical entities, models and ideas by the positivists like Rudolph Carnap. The positivist relies on the use of logical analysis and deduction. In 1972 Karl Popper refuted positivism with what he called "falsification". Popper suggested that we should use empirical evidence to disprove a theory rather than to prove it. Later on that century in 1975 an anarchistic theory of knowledge appeared on the scene by Paul Fayerbend in his book called " Against Methods". In his book he supports the claim that "anything goes", he argues that there is no one scientific method which serves to capture the specialness of science. He justifies his theory of relativism by saying that the world is increasingly being dominated by western science and that if we are not careful this western science will rape us of our culture, destroy the environment and eventually eliminate life. He purports that witchcraft, traditional medicine and magic also be taught in the school curriculum and that they be given the same attention that western science is given in the curriculum.

More recent researchers like Lederman and Zielder (1987) refer to the nature of science as the values and assumptions inherent to the development of scientific knowledge. This would refer to the individuals' personal beliefs about whether scientific knowledge is tentative, creative, empirical, cultural or objective. Lederman (1992) defines science as a way of knowing as the epistemology of science. More recently McComas, Clough and Almozroa (1998) define the nature of science as

....a fertile hybrid arena which blends aspects of various social studies of science including history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientist operate as a social group and how society itself directs and reacts to scientific endeavours.(p.4)

So ultimately science is not just about the regurgitation of facts, laws and theories but it is also about the scientist who made them and how they came about doing it. It is about the attitudes they have and how they functioned as a part of society and also on how their work affected the society at large. Therefore a proper understanding of the applications of science and also its limitations is a huge part of the nature of science understanding. Science is also a human endeavour it is not what is described as the rhetoric of conclusion. Lederman and Schwartz (2002) advocate that although there has been significant progress in the characterization of science there is still no one definition for it (as cited in Irez, 2006). Some of the central aspects of all scientific knowledge are that it includes “laws” and “theories” which are tentative, it is based on empirical evidence, it is subjective in nature because evidence collected by scientists, it is interpreted based on their experiences and beliefs, it is a product of human imagination and creativity and the products and creation of science are influenced by society itself (Lederman & Schwartz, 2002 as cited in Irez, 2006).

According to Abimbola (1983) the nature of science can be classified into two categories logical empiricism otherwise known as traditional (Pomeroy, 1993; Palmquist & Finley, 1997) and the contemporary views (Palmquist & Finley, 1997). According to Lin & Chen (2002) aspects of traditional view included the following:

1. Theories are based directly on observations.
2. Scientific knowledge progresses by an accumulation of observations.
3. Theories represent absolute truth.

The contemporary view about the nature of science holds true for the following:

1. Theories are a result of creative work within the scientific community.
2. Theories are inventions of scientists and used to explain, describe and predict scientific phenomenon.
3. Observations are theory laden and influenced by social factors.
4. Scientists create knowledge based on prior knowledge.

5. Theories fit within certain paradigms.
6. Scientists do not follow one scientific method (Bauer, 1992; Palmquist & Finley, 1997 as cited in Lin & Chen 2002).

There is however a consensus among the nature of science objectives extracted from eight international science standards documents (Mc Comas, Clough & Almazroa, 1998). They are listed as follows:

- Scientific knowledge is durable and has a tentative character.
- Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and scepticism.
- There is no one way to do science.
- Science is an attempt to explain natural phenomenon.
- Laws and theories serve different roles in science.
- People from all cultures contribute to science.
- New knowledge must be reported clearly and openly.
- Scientists require accurate record keeping, peer review and replicability.
- Observations are theory laden.
- Scientists are creative.
- The history of science reveals both an evolutionary and revolutionary character.
- Science is part of social and cultural traditions.
- Science, technology and society impact on each other.
- Scientific ideas are affected by their social and historical milieu.

Most recently the nature of science has started to be considered as a critical component of scientific literacy (AAAS, 1989; NSTA, 1982 and the National Research Council (NRC), 1996 as cited by Karakas, 2009). Researchers believe that scientific literacy is the proper acquisition of scientific knowledge which will aid students in applying their knowledge to make decisions in life which would improve their quality of life. There are many definitions of what it means to be scientifically literate. The definitions span from the narrow version of just being able to recognise formulae and give correct definitions to a broader version of a measure of cultural awareness. According to Abd-El-Khalick, Bell and Lederman (1998) a scientifically literate person is commonly portrayed as one who makes decisions within a science/technology context by drawing upon his/her rich scientific knowledge, such as an understanding of the concepts, principles, theories, and processes of science.

Tan and Boo (2003) agree that scientific literacy deserves special attention in this age where the calls are for reengineering the economic machinery for the “knowledge based economy”. As economies become more knowledge-based the quality of human resources becomes more important for the success of any economy. Scientifically literate individuals may therefore be in a favourable position to exploit new job opportunities and be able to take advantage of technical developments in the work place (Tan & Boo, 2003). However, there is no empirical data to show that improving one’s knowledge about the nature of science knowledge will improve one’s ability to make life decisions. According to Lederman (2008) there needs to be a critical mass of people who have a good understanding of the nature of science before any data can be collected to connect nature of science understanding to being scientifically literate. So the jury is still out on that notion that a proper understanding of the nature of science makes a scientifically literate person. However as educators if we are to teach about the nature of scientific knowledge then understanding about it becomes an important aspect which should be purposefully included in the science curriculum.

Because of the broad spectrum of the nature of science and the small scale of this study the research will focus on the following aspects of the nature of science:

- Scientific knowledge is tentative.
- People from all cultures contribute to science.
- Scientific ideas are affected by their social and historical milieu.
- Scientists are creative.
- The history of science reveals both an evolutionary and revolutionary character.
- There is no one way to do science.

The nature of science and science education

The inclusion of the nature of science into the science curriculum has been advocated for by many educators and philosophers. In making the case for the nature of scienctific knowledge in the curriculum, Driver, Leach, Miller and Scott (1996) contend that in addition to its intrinsic value, it enhances learning of science content, generates interest in science, and develops students' ability to make informed decisions on socio-scientific issues based on careful consideration of evidence. There have many studies conducted to elicit the perceptions held by both students and teachers about the nature of science and there have also been many reform efforts in countries such as Canada, the United States and countries in Europe to develop a more effective understanding of the nature of science. However, still to date neither teachers nor students possess an adequate understanding of the nature of science (Lederman,2008). This has become evident because of the amount of attention that this area of study has been receiving over the last few years. It seems as if this issue of the nature of science has been put on the front burner in some countries as educators try tirelessly to improve teachers and students views about the nature of science.

Teachers are the ones who are responsible for the delivery of the curriculum and they are the ones who have most influence over what is learnt by the students. Teachers come into the classroom with their own beliefs about science which will inadvertently trickle down to the students. Researchers as far back as 1969 agree that teachers' views on the nature of science do impact on their classroom behaviour and does have an influence on their students' beliefs in the classroom. Hurd (1969) as cited by Mc Comas, Clough and Almazroa (1998) writes in his article that it is undoubtedly true a teachers' conception of what science is influences not only what he teaches, but how he teaches.

Students in the high school level have very malleable cognitive structures and they are easily influenced by their school experiences. So it stands to reason that if teachers have any misconceptions about the nature of science they would pass these misconceptions to their students via the delivery of the curriculum. According to Mc Comas (1998) these misconceptions are usually due to the lack of philosophy in teacher educator programmes or the portrayal of science in science text book which most teachers use as their main resource.

Mc Comas presents fifteen myths which science teachers should be aware of in their teaching practice in an attempt to make the nature of science learning more robust. These include the following:

Myth 1: Hypotheses become theories that in turn become laws.

Myth 2: Scientific laws and other such ideas are absolute.

Myth 3: A hypothesis is an educated guess.

Myth 4: A universal scientific method exists.

Myth 5: Evidence accumulated carefully will result in sure knowledge.

Myth 6: Science and its methods provide absolute proof.

Myth 7: Science is procedural more than creative.

Myth 8: Science and all its methods can answer all questions.

Myth 9: Scientists are particularly objective.

Myth 10: Experiments are the principal routes to scientific knowledge.

Myth 11: Scientific conclusions are reviewed for accuracy.

Myth 12: Acceptance of new scientific knowledge is straightforward.

Myth 13: Science models represent reality.

Myth 14: Science and technology are identical.

Myth 15: Science is a solitary pursuit.

Today in many science classrooms science is presented to the students as absolute truth and as an end product with one method of investigation. Duschl (1988) as cited in Cobern and Loving (1998) refers to this as scientism. This is what has attracted the attention of many researchers who believe that improving the views held by teachers about the nature of science would inevitably improve the way in which science is taught in the classroom.

Ferrales (2007) found that the conventional way of teaching science in schools has mostly been through lecturing Teachers often use this method because of its convenience and it allows for easy control of the class. This method is in alignment with the “cookbook” method which the students follow when they are performing experiments. Students are not being trained to conduct experiments without instructions or to think without the use of textbooks or instructions from the teachers. Instruction based lessons is what has been causing very little excitement from the students in the science classroom. This method of teaching has led to a high level of memorization of facts and as a result science is perceived as cryptic, difficult and requires only smart students.

According to Matthews (1994) Pope John XXIII spoke of the need for aggiornamento in the church: science education has had its share of such calls and constructivism is the major plank in the reform of science education. Constructivist views of learning in science suggest that learners can only make sense of new situations in terms of their existing understanding. Prior knowledge is used by learners to interpret observations; meaning is constructed by individuals in a process of adding to or modifying their existing ideas (Driver, 1983; Osborne &Freyberg, 1985; Scott, 1987 as cited in Keogh & Naylor,1996). The implications of such a view are that teachers need to find out the learners' ideas in order to take these into account in their teaching. Teachers then need to provide experiences which challenge the learners' current understanding in order to help them restructure their ideas (Keogh & Naylor, 1996). This can be done by introducing history and philosophy into the science classroom. According to Matthews (1994) science education is enriched, and is more faithful to its subject, if aspects of the interesting and complex interplay of science and philosophy can be conveyed in the classroom. Matthews (1994) goes on to describe a variety of ways in which the interplay between science and philosophy can be conveyed: reading of selections from original sources; joint projects with history; dramatic reenactments of significant episodes in the history of science, just to list a few. Introducing philosophy into the science classroom allows the students to question science and the work that scientists do and at the same time question and restructure their beliefs where they see fit.

History also provides a vehicle to introduce some basic ideas of logic to students and to assist in the understanding of the nature of science (Matthews, 1994). It can be done in the classroom by introducing some historical cases and by also recreating some historical experiments. According to Dawkins and Glatthorn (1998) textbooks provide little or no relevant information about historical cases or about the nature of science. So it is very important that teachers fill that gap so that students can see science in context and not as an end product. Kipnis (1998) agrees that teaching aspects of the nature of science through a historical approach appeals to teachers if it is intertwined with teaching science content so that it makes the latter more stimulating without taking additional classroom time. Using historical cases in the classroom adds the human element to the classroom and it helps the students to identify with the human and cultural aspect of science.

Students' beliefs about the nature of science

Developing adequate understanding of the nature of science has been a perennial objective of secondary school science curricula for the past three decades (Lederman & Omalley, 1990).Concerns for the development of adequate understandings of the nature of science has worn many hats through the years (Lederman, 1992). The nature of science objectives changed focus from emphasis on the scientific method to the scientific process to inquiry and, most recently, to scientific literacy. What remains very obvious is the urgency of researchers and educators in their advocacy of making students acquire a proper understanding of the nature of scientific knowledge. Their persistence to ensure that students gain this adequate understanding of the nature of science the researchers has focused much of their attention on assessing students' views on the nature of scientific knowledge.

Considering the longevity of objectives related to students' conceptions of the nature of science, it is intriguing that the first formal instrument to assess students' conceptions was developed less than forty years ago (Wilson, 1954 as cited in Lederman 1992). This instrument, the Science Attitude Questionnaire, was used on 43 Georgia high school students in the United States of America and the results indicated that the students believed that scientific knowledge was absolute. The next few years that followed researchers worked tirelessly to assess students' views about various aspects of the nature of science using a variety of instruments which developed around the same time.

Researchers conducted studies at many levels: primary, secondary and tertiary and they came up with the same results; students were deficient in some aspect of the nature of science. Irrespective of the instrument used, studies repeatedly indicated that students' views about the nature of science were not in alignment with the contemporary views of the nature of science (Aikenhead, Fleming & Ryan, 1987; Lederman & Omalley, 1990; Rubba & Anderson, 1978; Ryan & Aikenhead, 1992; Zielder, Walker, Ackett & Simmons, 2000).

Teachers' views of the nature of science

The goal of helping students develop adequate conceptions of the nature of science has been agreed upon by most scientists, science educators, and science education organisations during the past 85 years (Abd-El-Khalick, Bell and Lederman, 1998). However this goal has been long espoused and has been met with little success (Akerson, Abd-El-Khalick & Lederman, 2000). Studies done in the early 1960s have revealed that students develop a proper understanding of the nature of science independent of the teacher. Brown and Clarke (1960) started to realise the important role that teachers play in the development of conceptions that students hold about the nature of scientific knowledge (as cited in Akerson et al, 2000). The teacher is the one who spends the majority of time with the students and they get to decide what is taught and how it is taught. According to Lederman et al (2002) when researchers turned their attention to the teachers in the early 1950s , they realised the importance of the teacher in the classroom. The next step was assessing the perceptions that the teachers had about the nature of science. It became important to assess teachers' perceptions because as Lederman et al (1992) advocate if teaching is viewed as a purposeful act then a teacher must possess an adequate knowledge of what she is attempting to communicate. There were a series of studies done from the 1960s up to present to assess the teachers' perceptions of their understanding of the nature of science. By the end of the 20th century the jury was in about teachers' beliefs about the nature of science, so researchers started to look into reforming teachers' beliefs about the nature of science and various institutions funded programmes to assist in the development of teachers' beliefs about the nature of science. Table 1 and Table 2 in Appendix one show a variety of interventions used to enhance teachers views about the nature of science from as far back as 1968 to present time.

It is quite obvious that irrespective of the instrument used, the place the survey was conducted, the level of experience the teachers possessed, the educational background of the teachers or the researcher conducting the research, the nature of science understanding of teachers remains traditional and naive. It seems to be the general consensus of researchers that teachers believe that science is a body of facts. Many teachers held naive views of the meaning and function of scientific theories and laws and/or ascribed to a hierarchical view of the relationship between the two, whereby theories become laws with the accumulation of supporting evidence (Abd-El-Khalick & BouJaoude, 1997). Teachers also believed in one scientific method as a way of finding out about science.

A wide variety of interventions has been used over the past decade to try and improve teachers' beliefs about the nature of science. According to Pegg and Grummer (2010) models of professional development focused on enhancing in-service and pre-service teachers' understanding of the nature of science have taken many forms, including the integration of nature of science concepts into courses (Akerson et al, 2000 ; Ogunniyi, 1983 ; Scharmann , Smith , James & Jenson , 2005 ; Tairab , 2002) the inclusion of history and philosophy of science into courses (Abd-El-Khalick,2005;Akindehin,1988) and professional development projects involving research experiences with scientists (Schwartz,Lederman & Crawford,2004).

There have been two general approaches used to changing the beliefs held by teachers about the nature of science.

1. The implicit approach: this approach suggests that an understanding of the nature of science is a learning outcome that can be facilitated through process skills instruction, science content coursework, and doing science (Akerson et al, 2000).
2. The explicit reflective approach: this approach is not content specific but comprises of a variety of activities which communicate the important aspects of the nature of science in a hands-on manner. It also utilizes various elements of history and philosophy geared toward various aspects of the nature of science (Akerson et al, 2000).

When both types of studies were reviewed it was reported by Abd-El-Khalick et al. (1998) that the explicit reflective approach was generally more “effective” in fostering “adequate” conceptions of the nature of science among prospective and practicing teachers. Akerson et al (1999) agree that an explicit, reflective approach to the nature of science instruction embedded in the context of learning science would not only facilitate developing teachers’ nature of science views, but it might go a long way in helping teachers translate their nature of science understanding into actual classroom practices.

Beliefs translated into classroom practice.

Instructional practices depend on what a teacher brings to the classroom. What a teacher brings to the classroom may depend on their cultural experiences, professional background, sex, area that they teach in, religion, subject taught, employment status, educational policies and experience in the field. According to Teaching and Learning International Survey (TALIS) (2009) good instruction in any classroom is not determined just by the teachers’ background, beliefs and attitudes; it should also be responsive to students’ needs and various student, classroom and school background factors. As is known from research, effectiveness of schools depends on the quality of the learning environment, cognitive and motivational abilities of the students and teachers, the socio-economic background of the teachers and students and the social and cultural capital of the students and teachers (Harris & Chrispeels, 2006; Hopkins, 2005; Lee & Williams, 2006; Scheerens & Bosker, 1997 as cited by TALIS 2009).

Researchers have long been dismayed by the apparent misconceptions possessed by both secondary school teachers and students (Lederman & Zielder, 1987). So in response to this concern researchers have focused their attention on pre-service and in-service teachers. After all the teacher is the one who is responsible for what happens in the classroom and so cannot be expected to teach something if he/she does not understand it him/herself. Two assumptions appear to dominate policy and research studies related to teacher conceptions of the nature of science: that students conceptions are directly related to the teachers' conceptions and that teachers conceptions necessarily influence classroom practice (Lederman, 1992). As a consequence of this much research has focused on the improvement of teachers' conceptions of the nature of science as a mechanism for improving students' conceptions about the nature of science. However, disagreement continues about the nature and extent of the relationship between teachers' understanding of the nature of science and classroom practice (Abd-El-Khalick& Lederman, 1998; Brickhouse, 1989, 1990; Duschl & Wright, 1989; Gallager, 1991; Lederman & Zielder, 1987; Palmquist & Finley, 1997) despite the fact that there are serious concerns about how well their philosophical conceptions can be inferred from their behaviour (Noddings, 1995 as cited in Lederman 1999).

Espada (2001) is in agreement with the fact that educational researchers are still debating whether there might be a relationship, complex and hard to grasp as it might be, between the teachers' science conceptions and their views of the nature of their discipline and their classroom practice. Gess-Newsome and Lederman (1999) suggested that teachers' intentions, content knowledge, pedagogical knowledge, students' needs, teacher autonomy, and time might be important factors in the translation of the science teachers' philosophical ideas into appropriate instructional strategies and activities.

It seems however that researchers' are in agreement that teachers teach science in a manner in which they were taught. Pedersen and Liu (2003) as cited in Lucus (2005) , similarly believe that teacher implementation is tied to experiences the instructor had both as a student and as a teacher. Recent research on science teachers' beliefs has revealed how individuals' epistemological systems are constructed through their formal and informal experiences as students (Jones & Carter,2007). However despite many reform efforts, most science teachers in the United States exhibit beliefs which are aligned with behaviourist traditions and according to Czerniak and Lumpe (1996) the majority of them do not believe that students learn by constructing their own knowledge. Many studies have indicated that if teachers have a traditional view about teaching and learning then they teach science in that way and they also prefer to use traditional forms of assessments to assess their students' learning (Hasweh, 1985; Benson, 1989; Brickhouse, 1990; Richmond and Anderson, 2003; Ziph and Harrison, 2003 as cited in Jones & Carter, 2007). Del Pozo and Porlan (2001) said that the majority of research done in their country reflects an empiricist and positivist view of scientific knowledge, and a traditional conception of teaching/learning as the transmission/reception of knowledge. Recent research, Shah (2009) reflects that it appears that practices of teaching and learning science reflect the teachers' ignorance of the nature of the scientific enterprise. The methods a teacher chooses for these educational situations will reflect her own beliefs (Cuban, 1984, as cited by Lucas 2005) . Science teachers continue to teach science as a collection of facts. As such teaching practices foster students who go on to become teachers who follow their past teachers and the cycle continues (Halai, 2000 as cited by Shah,2009).

Chapter Three

Methodology

The Sample

The sample consists of two female Physics teachers who were purposefully chosen for the study. The teachers at school X are very private about their teaching beliefs and practices and so it was very difficult to choose teachers that I felt will be willing to participate in the study. The majority of them believe that what they do in the classroom does not need any revision. The culture of the school is that good results reflect the teachers' ability to teach. These two Science teachers had worked closely with the researcher over the past year and have been privy to some of the new knowledge the researcher had acquired about the nature of scientific knowledge. They were very keen about participating as they were interested in assessing their views of the nature of scientific knowledge and how it affects their classroom instruction, if at all. The teachers in the science department very rarely collaborate with each other for any lesson planning or assessment planning. The researcher has allowed these two teachers to give themselves pseudo names for the purpose of privacy. X has five years experience and has never had any prior training in education. Y has an administrative post and 15 years experience. Y has had training in the education arena and she posses a Dip. Ed. and acquired an online Masters in Education.

Rationale for methodology

According to Luft and Roehrig (2007), educational researchers have explored a variety of constructs pertaining to teachers in order to help improve the structure and impacts of teacher education programs. This study focused on "teacher beliefs". "Beliefs" have been described in a variety of ways in the literature. Fishbein and Ajzen (1975) as cited in Luft and Roehrig (2007), defined beliefs to be information a teacher held about a person, a group, an event or behaviour. Other researchers lump beliefs, perceptions, conceptions and attitudes together (Garmon, 2004). For the purpose of this research, the following definition was most appropriate: beliefs are personal constructions of entities which inform an individual's decision making process (Jones & Carter, 2007). What one believes about something is as a result of interplays between past experiences and one's culture. A person's identity is a social construction. Beliefs are a part of identity, and therefore arguably also socially constructed. It follows then that beliefs about teaching are socially constructed as well. These beliefs are guides and determiners for the classroom decisions that we make as teachers. Therefore, in order to investigate peoples' beliefs on an issue the qualitative approach was most appropriate because qualitative research is rooted in the social constructivism paradigm. The current research sought to interpret the beliefs held by two science teachers: their knowledge of the nature of science and what they believed makes a good science lesson; which they may have formulated from interaction with past teachers, friends and/or historical or cultural norms that operate in their individual lives (Creswell, 2007). The study was also grounded in the interpretive paradigm which sees human behaviour as an outcome of their interpretation of the environment in which they were previously exposed. According to Gallagher (1991) in the interpretive paradigm researchers develop a relationship with the participants to learn how they teach, construct their concepts and what factors influence their understanding. In order to properly understand the beliefs held by the teachers the researcher allowed the participants to feel empowered to share their views and therefore the researcher had to work in their natural setting, as the researcher cannot separate the context of what is said from where it is said.

The researcher's role in conducting this research was that of an insider and as such she was aware of the cultural norms of the school and knew the participants of the study very well. According to Gallais (2003), since the researcher shared the social world of the research participants there is less likelihood of the researcher experiencing any "culture shock or disorientation". Being an insider allowed the researcher to understand the context and to appreciate it in a way not open to an outside researcher, allowing for enhanced rapport between this researcher and the respondents (Hockey, 1993.p 119). The participants were able to divulge intimate details about the classroom practices and beliefs about their knowledge of the nature of science because of this established sense of trust and loyalty already in place. This also contributed to why the researcher chose qualitative research, since no statistical analysis could provide this researcher with such deep understandings of the teachers. According to Patton (1990) as cited by Hedrick, Mc Gee and Mittag (2000) a qualitative approach to investigation allowed researchers to better determine the unseen and unrevealed beliefs and attitudes of the tutors; provide information that might improve future tutor experiences and provide an unobtrusive approach to collecting data.

This study utilized the case study method of inquiry. According to Stake (1995) as cited by Dinkleman (2000) a qualitative case study is one which yields an in- depth analysis of a limited number of subjects, who together comprise the case in question, in their natural setting. It also allowed for the in- depth collection of data using multiple sources of information such as observations, interviews, documents and open-ended questionnaires. Pajares (1992) and Richardson (1996) stated that multiple forms of data will be needed in order to understand teacher beliefs, although collecting so much data can be difficult even for the most seasoned researcher. The case study also lends itself to purposeful sampling which is the sampling strategy used in this study.

This researcher deliberately chose teachers with varying ranges of teaching experience, who have been known to produce excellent results at the examination level, who posses at least a first degree in their field, who were willing to accept constructive criticism, who were also fairly easy to access and who were willing to participate in the activities of the intervention which was held during the first week of the Easter vacation.

This research also action research, which meant that an intervention was incorporated in the study to try and change/enhance the teachers' beliefs about the nature of scientific knowledge. Action research as suggested by Zuber-Skerritt (1996) is to bring about practical improvement, innovation, change or development of social practice and the practitioner's better understanding of his/her practices. Action research also lends itself to collaborative work and according to Ebbutt (1985), it also encourages reflection, which helps teachers to develop to assess themselves on a meta-cognitive level. Cohen ,Manion and Morrison (2000) offer the argument that an action research methodology is flexible, situationally responsive and offers rigour, authenticity and voice. This kind or research took place within a frame of four phases according to Cohen, Manion and Morrison (2000).

Design

Phase one- identifying the problem.

Before the research began, this researcher conducted a small demographic survey for each teacher. Questions included information about their educational background, past experiences with teachers, family background, religious beliefs and prior work experience (Appendix two).The teachers were then administered the open ended questionnaire, Views of

Nature of Science-Form C (VNOS-C) ,to fill out which was composed and modified by Lederman et al (2002) (Appendix two). Short informal interviews were also conducted about their beliefs about the nature of science and about what makes a good science lesson.

As recommended by Lederman et al (2002) no time limit was given for teachers to respond. They were also reminded that it was not a test and there were no correct answers. The responses were collected and coded using a similar coding developed by Lederman et al (2002). The open- ended responses were used as a guide to conduct semi-structured interviews. They were interviewed to expand on the questionnaire and to clear up any ambiguities arising from the questionnaire.

Phase two- plan and implement the intervention.

The teachers were exposed to a set of explicit/ reflective activities which were designed to help them come to a better understanding of the nature of science. According to Lederman and Abd-El-Khalick (1998), it is highly unlikely that teachers will come to understand that science is tentative, empirically based, partly the product of human imagination and creativity and is influenced by social and cultural factors solely through learning about the content of science and processes. This intervention was chosen because it promoted team work and collaboration between the science teachers and it allowed them the opportunity to reflect on their practices and make improvements to their existing conceptual frameworks about the construct of the nature of science and the teaching of science. The activities spoke to varying aspects of the nature of science and they are in alignment with new trends in teaching which promote constructivism. The explicit reflective activities are not content specific but can be used in lessons as set inductions, class activities or in Inquiry- Based Learning. The sessions were held over a time frame of two days and after the activities the teachers were asked to write reflective pieces describing what they learnt. This researcher also took personal notes and the sessions were tape recorded. All the data collected were analyzed.

The following is a brief description of each of the activities used in the Explicit Reflective Activities that the teachers were exposed to:

Activity #1

Tricky Tracks: The teachers were presented with a picture of what appears to look like animal tracks and they were asked to give an account of what caused these tracks to leave this impression. The teachers were asked to record what observations they make about what caused the tracks and then their ideas were discussed in such a way to ensure that each idea counted.

Activity #2

The Whole Picture: Each teacher was given a sealed manila folder with small holes on the front, containing shapes of varying sizes inside. The teachers were asked to use whatever skills necessary, without opening the folder, to try and figure out what was inside the folder.

Activity #3

The Instructions: The teachers were asked to carefully read some text and describe what they thought it meant. Later on they were told that the text was labelled “The Instructions” and were asked if it made more sense to them now that they knew what label was attached to it.

Activity #4

Young or Old?: The teachers were shown a picture of what appears to look like either a young woman or an old woman and they were asked to see if they could recognise both. If the teachers were unable to recognise both the images, they were shown other pictures which made it easier for them to see.

Activity #5

The Aging President: The teachers were shown a caricature of President Regan in his three terms in office. They were asked to describe how his face changes over the three terms. The pictures are such that after the second term, the face started to look like the body of a young woman. If the teachers were not able to recognise this it was pointed out to them after the discussions about what changes they observed.

Activity #6

The Cube Activities: The cubes were placed in front of the teachers and they were asked to figure out what was on the bottom of the cube by looking at what was written on the other faces. They were asked to record their method of coming up with their solution. At the end, the cubes were removed and they were not told if their answers were accurate or not.

Activity #7

The Black Box Activities: The teachers are described a phenomenon and they are asked to describe how they think it works. They were asked to make observations, collect data, draw inferences and suggest hypotheses to explain their data. They were then asked to devise ways to test their hypotheses and based on their tests, they had to say if their hypothesis was accurate or not. The phenomenon used in this black box activity was a water making machine. The actual apparatus was not used but a diagrammatic representation was substituted instead.

Phase three- implementation continuation

In this phase the teachers were shown various ways in which the researcher managed to successfully incorporate the nature of science into lessons by the use of history and philosophy of the scientific knowledge and also by using the explicit/ reflective activities to initiate discussions among the students about the nature of science. Table 3, 4 and 5 in Appendix One shows a list of the lesson used and the lesson plans associated with them are in Appendix Eight.

Teachers were asked to design frameworks for lessons which will help students to develop a better understanding of the nature of science. Tables Four and Five show a list of the lessons the teachers complied and the lessons plans that they generated. Teachers also wrote reflective pieces about this lesson planning exercise. The reflective pieces, the framework for the lessons and short informal conversations were conducted to collect data about how their beliefs about teaching and learning changed after the intervention. One of the participants did not want the researcher to audio tape this part of the research so the conversations were recorded manually and then transcribed as best as possible. The participants were also given the same open ended questionnaire which they were given at the beginning of the study to complete. This was to see if or how their beliefs about the nature of science changed, or were enhanced after the intervention. The researcher was always in continuous communication with the teachers so the process would be an ongoing data gathering process and as such the researcher used personal notes.

Phase four –evaluate the outcome of the intervention

The researcher would have to follow up on one of the teachers to see if the new knowledge of the nature of science has any effect on their classroom instruction. In order to do justice to this part of the research, the researcher would have to observe one of the teachers for a long period of time for the research to be valid. The breadth of this research does not allow for this to take place as this assignment is due in June. For the purposes of this research, the researcher will not include the observations in the results because of time constraints.

Forms of Data Collection

Open-ended Questionnaires

This form of gathering data is very attractive for a small study. According to Cohen, Manion and Morrison (2000) it is the open ended responses that might contain the 'gems' of information that otherwise might not have been caught in a closed response questionnaire. Open-ended questions have the ability to evoke responses from individuals that are:

- meaningful and culturally salient to the participant,
- unanticipated by the researcher and
- rich and explanatory in nature (Family Health International, 2000) . Retrieved on February 23rd, 2011 from *http://www.fhi.org/training/en/RETC*.

The open ended questionnaire was designed and tested for validity and reliability by Lederman et al (2002). There are different strands of the same questionnaire, however this study will use "The Views of the Nature of Science Form C". This questionnaire spoke to various aspects of understanding of the nature of science, and it is also appropriate for assessing teachers' beliefs of the nature of science, as each question lends itself to a different domain of the nature of scientific knowledge. This questionnaire was piloted with three other teachers fitting the same profile as the teachers involved in the study to ensure that the questionnaire is easy to respond to, and is user friendly.

Interviews

The interviews were face to face, semi-structured interviews and it allowed the researcher to read the body language of the teachers. The researcher believed that a lot of data could be lost if another type of interview was used which did not allow for a visual of the participants. The semi-structured interviews allowed the researcher to access the thinking of the teachers, and to determine aspects of the teacher's thinking that cannot be captured through observations or other modes of data collection (Patton, 1980). The use of the interview in research marks a move away from regarding human subjects as simply manipulable and the data as somehow external to individuals. It is a move towards regarding knowledge as generated between humans, often through conversations (Kvale, 1996). Before the researcher conducted any interviews the researcher ensured as much as possible that she was able to conduct the interview in an informed manner and that the teachers did not feel threatened by any lack of knowledge. It began with information regarding the background of the teacher and then some open-ended questions, with the responses for those guiding the rest of the interview. The interview was conducted to find out about their classroom practice and the researcher used that opportunity to clarify any ambiguities arising from the questionnaires.

The interviews were held in the Physics Office which is located in the Physics lab. It is located away from the general public of the school and is a very quiet location. This location is one where all the teachers are comfortable and where they would be able to respond to the questions without the added pressure of a new environment. Interruptions at this location are minimal, which makes conducting the interview easier. The researcher has been working with the two teachers for a very long time and so believed that she has the inherent ability to motivate them to discuss their ideas without being afraid or intimidated in any way.

In addition to the formal interviews, there were also informal discussions which took place before and after the intervention and in the teachers' spare time, as we all work closely together and therefore were always in constant communication. These discussions were recorded using field notes and later transcribed as necessary.

Observations

Cohen (1998) says that observation data is important as it affords the researcher the opportunity to gather "live" data from "live" situations. This allows the researcher to see things which may have been missed, to discover things that the participants may not have spoken about freely and to move beyond perception based data to get real personal knowledge. The teachers will be observed in their classroom setting to see if their classroom practices are somehow related to their views of science. This should be done by following an observation protocol. The observations should also be done over an extensive period of time for the teacher before the intervention and after the intervention to see if and how she infuses the nature of science in her lessons.

Document Analysis

Worksheets, activity sheets, reflective pieces and lesson plans were also analysed. At the end of the study each teacher was given a copy of the report to ensure that what was reported about their perceptions were true. Both teachers expressed no disagreement to any of the statements made.

Data Analysis Approach

Although the research is a small study the data was analysed in order to address the research questions one, two, three and four, and research question five will not be answered in the analysis because the study is not broad enough to cover this question.

Research question	Question	Data collection strategy	Analysis methods
#1	What are the beliefs held by teachers about the Nature of Science?	Open-ended questionnaires, Face to face interviews	Coding and themes
#2	In what ways (if any) have these beliefs changed after being exposed to various ways to incorporate ideas about the nature of science into their lessons?	Reflective pieces, open ended questionnaires, Researcher's notes	Coding and themes
#3	What are their beliefs about the hallmarks of a good science lesson?	Face to face interviews	Coding and themes
#4	In what ways (if any) have their beliefs about the hallmarks of a good science lesson changed after being exposed to various ways to	Reflective pieces, Interviews	Coding and themes

	incorporate ideas about the nature of science into their lessons?		
#5	How are teachers' beliefs about the nature of science translated into classroom practice?	Observation ,document analysis (before and after intervention)	Coding and themes

The data will be analysed in four stages:

1. The first stage involved managing the data. At the early stages of the data analysis, the data was organised into labelled folders.
2. The second stage of the analysis involved the organisation of the data. The transcripts were continuously perused so that the researcher would become one with the data. During this process the researcher wrote memos on the sides of the transcripts which provided prompts about the things this researcher was unclear about or things the researcher wanted to investigate further.
3. The third phase involved describing, classifying and interpreting the data. The researcher took the data apart and selected phrases of information which appeared frequently and used different colours to code them. Some of these codes were interconnected and so in putting the data back together themes were generated which told the story of the teachers involved.

4. The last phase of the analysis involved the interpretation of the data. The researcher made sense of the data according to the emerging themes and portrayed what was learnt about the teachers' perception of the nature of science, and about what makes a good science lesson in this report.

Ethical considerations in Research

1. The researcher analysed the cost/benefits ratio of the study, and realised that although the participants were embarrassed from the findings, the satisfaction that they accrued after the intervention helped them to become better practitioners and served only to benefit their students. The benefits of this research overtook the cost to the participants.
2. The researcher sought informed consent from the Principal and the teachers involved in the study. Participants were properly informed of the depth of the study, and the possible outcomes of the research as a result of their participation. By giving them the details of the study procedures, they had the freedom to choose if they wanted to be part of the research or if they preferred not to be part of the research. The participants selected for the study were competent enough to understand what the nature of the study is about and all the risks involved.
3. The participants' welfare was always on the front burner and at all times while conducting the research. The researcher was compassionate and understanding to the needs of the participants.
4. The information collected in this research will be disseminated in a manner in which the information will not be able to match the identity of the participants. The participants

were promised confidentiality at all levels and the researcher promises not to disclose any information to the public about their involvement in the study.

5. The researcher promised to be objective in conducting the research, and reported all of the findings without interference from her personal views.

Chapter Four

Findings

Teacher X

This teacher has been teaching Physics for at least three years and had been exposed to the energy industry previously. This is the first school X is teaching at and she has been teaching the examinations classes since entering the school.

Teacher X grew up in the town of Tunapuna in east Trinidad and attended a prestige girls' school in that district. She did a first degree in physics because as a child she always enjoyed "taking toys apart to see what makes it work" and as such developed a love for the subject. X went through the motions of schooling because of family pressure. X describes her past Physics teachers as lazy but very organised, very structured and rigid, old and ready to retire, know their work inside out and very strict.

Teacher Y

Y has been teaching for the past 15 years and has never been at any other school. Y grew up in Cunupia, which is a small rural area in the central Trinidad and attended a local secondary school in her district. Y also did her first degree in Physics but only because her friends were applying to the university, Y was the first person in the family to complete her first degree. Y described her past science teachers as rigid, absent, old, structured and lazy. Y never had a love for the subject but stuck to the degree because she saw it as a way to get out of poverty.

Beliefs about the nature of science

The teachers were given an open-ended questionnaire to fill out which probed their beliefs about the nature of science. The questionnaire consists of ten questions and each question addressed a different strand of the nature of science. The teachers' responses were analysed, before the intervention, and the following themes were extracted: scientific knowledge partly tentative science as a way of knowing, creativity in science, social and cultural factors which affects scientist, observations vs. inferences and laws vs. theories.

Research question #1

What are the beliefs held by the two teachers at School Z about the nature of science?

X's beliefs about the nature of science prior the intervention

Scientific knowledge partly tentative

Only certain aspects of scientific knowledge can be changed. Scientific knowledge was absolute and very durable. She advocated, "Scientific theories can change but the laws cannot" and she believed this because she thinks that laws are more important than theories.

Science as a way of knowing

"Science describes the mechanisms of how things work" and "Science is a collection of facts which is derived from carrying out experiments". Scientists used one method of investigation to form new scientific knowledge. This method is what is known as the "scientific method" to educators. Science can explain everything around us as long as experiments are done to prove theories.

Creativity and subjectivity in science

Science is very objective and things like dreams and intuition cannot be used in scientific discoveries. This is evident when she said "...dreams are just a figment of our imagination..." and scientific discoveries cannot be made from them. Scientific knowledge can only be truly derived from experiments. One's cultural background should not affect how one interprets data and scientists should be objective at all times. There was evidence of this when she said the following: "... scientist interprets data differently which displays some level of subjectivity in the generation of new knowledge";

"...scientists have to learn how to keep their personal beliefs out of their lab work as it may distort their interpretation of data".

Social and cultural aspects of science

Society does impact on science and people who are rich get to determine which aspects of science are furthered in research. Evidence of this was provided by the following quote: "Society does impact on how science is viewed by people and people with money and power could do research and get credited for it....it's all about who you know". People from different countries have different beliefs about science but the western view of science is the correct one. This was obvious in her quotation "...scientists from different parts of the world have different ideas about science but our idea is the correct one and it is the one that should be taught in class". X also believed that people from countries like Africa and belong to tribes "need to move into the real world" as they have no technology and "they need some form of technology to be civilized".

Theories and laws

X was taught by her past teachers that laws are cast in stone and that they are more important that theories so she portrays this belief without doubt. Laws are absolute but theories are durable.

Observations vs. Inferences

Observations and inferences are two different things. X was able to articulate the main difference between observations and inferences. Evidence of this was in her statements: “observations are what we gather using our senses” and “inferences are what judgements we make based on the evidence provided”. However she was very adamant in thinking that scientific knowledge must be supported by observations. Evidence of this was shown when she said; “observations from experiments lead to the development of facts and laws” and “all scientific knowledge is supported by observations”.

In summary X believed that science is a collection of facts which was generated via the scientific method, science is very objective and society determines the direction of scientific research, theories can change but laws cannot, laws are more important than theories and western science is the true science. X also knows the difference between observations and inferences but believed that observations are necessary for the development of scientific knowledge.

Y’s beliefs about the nature of scientific knowledge before the intervention

Scientific knowledge partly tentative

Scientific knowledge is tentative to some extent. The theories in science are able to change but laws are more durable. Scientist cannot just change theories but what is actually done is that the existing theory id adjusted to fit the new evidence. Evidence of this is shown when she said “Change is not automatic but an adjustment of existing data”. Technology is the main reason that scientific knowledge is changing and technological advances are the reason why new experiments are being done. She affirms to this belief when she said “it is very hard to change scientific knowledge however the evolution of technology is causing scientific knowledge to change” and “if you are doing an experiment and you have disproven a theory then it will change” and also “there seem to be a new set of laws trying to replace the old ones”.

Science as a way of knowing

Y believed the following about science: “science is the study of physical and biological environment and the laws which govern them” and “science explains the complex behaviour of nature”. Science uses experiments to come up with facts which can lead to some understanding of a system. Science is different from other disciplines because of the manner in which the experiments are done. She believed in the “scientific method”. Science is a collection of facts which can help you decipher “good science from bad science”.

Creativity and subjectivity in science

Scientific knowledge should be objective and that dreams and intuition have no place in generating scientific knowledge. Experiments must be done to arrive at true scientific knowledge. This is evidenced by the following quotations: “emotions should not interfere with scientific work and that you should only view facts” and “scientific knowledge can only be accepted if experiments were done objectively” .Y also believed, “observations are crucial to the development of scientific knowledge” and “dreams are really our mind working and thinking because our mind works based on what we know already" but "to get valid conclusions we must do experiments".

Social and cultural aspects of science

One's cultural background plays a great role in science and people from different cultures will have gained knowledge differently and as such would have different philosophies about science than western science. This is shown when she says, "culture played a great role in science"; "if you come from a different culture your background will be different and the way in which you gain your knowledge might be different" and "your beliefs and your philosophy will give you a slant on how you see things".

Laws vs. theories

Laws are also more important than theories and this is why theories can change but laws cannot. This became evident when she said, " laws are more important than theories" ;" theories can change but scientists usually hold on to their work" and " a theory is an idea without empirical evidence and laws are theories which have been tested and evidence is concrete" and she gave an examples like conventional current and the caloric theory.

Observations vs. inferences

Y does not know the difference between observations and inferences as she says, "observations are what we infer is taking place" and "we can make observations from analysing data". Y also believed that continuous observations are what lead to scientific knowledge.

In summary Y believed that theories can change but laws cannot because laws are more important than theories, science is objective and not influenced by emotions, science explains how things function and is special because of the method used in experiments. She also believed that one's cultural background affect interpretation of data. Y does not know the difference between observations and inferences and observations are necessary of development of scientific knowledge.

Research question #3

What are the beliefs held by the teachers about the hallmarks of a good science lesson?

A semi-structured interview was conducted with both teachers and they were also asked to write down some of the things which they believed contributed to a successful science lesson. Both sets of data were analysed and the following themes were used to describe their beliefs about what makes a good science lesson.

Teacher X

Structure and Organisation

X believed firmly in structure and organisation of the classroom, the seating arrangements, her position in the class and even the notes to be given to the students. There is evidence of this in her words, "even the positioning of particular students will determine if a lesson is successful or not". Even her placement in the class will determine the level of success for the lesson: "If I can see the entire class then the then the students will behave well and I will get to teach all the content targeted for that session". X advocated, "...lab scripts should be properly laid out so that the students do not waste time asking silly questions". She was a firm believer in the structure and organisation of the students, the teacher and even the paperwork given to the students.

Preparation

She does not need to do much preparation for a successful lesson. Her preparation extends to reading the relevant textbooks and ensuring that the lab scripts have clearly written methods. This becomes clear in her quote, “I must read the topic from the suggested text so that I could know the work inside out”. She believed that for a lab to be successful the lab script must have “...a proper and clear description of the method...” so that the students can follow.

Classroom environment

The success of the lesson depends on where the lesson is held and how she interacts with the students. She prefers to have classes in the classroom rather than the lab as the lab equipment acts as a distraction to the students. This is evident when she said the following: “...the location of where teaching takes place affects the success of the lesson”; “lessons are more successful if they are done in the classroom rather than in the lab because students get distracted by their curiosity”. She is very firm with the students and does not allow them to communicate much with her or with each other. There is evidence of this in her words, “lessons are more successful and more work is covered if I am is not too smiley with the boys as they tend to interpret this as a sign to initiate unnecessary conversation”.

Student learning

Students have learnt science when they can do past paper questions. She can read their expressions in class to judge if they are learning or not. X believed that her audience is very intelligent and that they will learn regardless of the kind of lesson she has. All of this is evidenced when she said the following, “students understand when they do not ask much questions or when they look happy and not confused: by the expressions on their faces” and "these students will learn because they take plenty extra lessons and they are the cream of the crop".

Strengths

One of her strengths is that she has mastered the art of passing examinations because of her experience as a student and because of this she can teach her students how to develop studying habits which will give them good grades. She can identify with the majority of the science students who have to pursue sciences to please their parents because she was in a similar position. She can improve by "working on delivery methods" as she teaches in the exact way in which she was taught: in a very rote fashion. This method of teaching was boring for her as a student so imagine what the students think now as she using the same method instruction especially, since times have changed so much.

R*easons for teaching*

She teaches in this rote manner because it is how she was taught. Her need for control and structure of the class stems from her past teachers who also displayed a strong need for structure and control of the class. X also believed this kind of teacher centred approach is "less time consuming and more administration and parent friendly".

Role as a teacher

She takes the lead in the classroom and provides the necessary notes to help them understand the topics being covered. Her main goal is to ensure that the students can answer past papers to get good grades in the final examinations. This is showcased when she said, "I am happy being the provider of the required information, which is necessary for them to get good grades or to do well in examinations".

In summary X believed that for her science lesson to be good she must teach in a rote manner, it must be done in the regular classroom, the students must be well disciplined, the students should not communicate in class much, the students must be able to answer past papers very well, she must know the textbook "inside out", the lab scripts must be well prepared and she must take the lead of the class.

Teacher Y

Structure and organisation

Students' behaviour is a crucial factor in determining if the lesson is successful or not. Students who are *trouble makers* can change the mood the classroom if the teacher does not know how to control them. Keeping the students focused on the teacher is important because the students can be very "miserable" if they are left to do work on their own.

Preparation

Preparing for a lesson does not take much time she says it just "going over the ideas for the lesson in my head". Y was very aware of how to do lesson plans but believed that the actual paperwork of the lesson plan was too time consuming so "organising my thoughts about the lesson in my head saves me time". Reading the textbook before the lesson made the lesson more successful because the text book is her main resource and she believed that it helps her "to articulate ideas and science concepts better".

Classroom environment

Lessons will be more successful if she got to know her students but because of the large number of students in her science classes this becomes difficult to do. The majority of her students are comfortable with learning by rote and she has used that method of instruction as her main method. Y was very aware that using a variety of teaching methods will encourage more learning but preferred to stick to what has worked in the past. Y believed “rote learning is the best and easiest option...” and “I have a very rote way of teaching and I stick to it”.

Student learning

Students have learnt science when they can do past papers very well. She can read social cues from the students’ expressions which will indicate to her if they are learning or not. This was evident when she said; “Students have learned when they can do a past paper question and score full marks” and “social cues in the eyes you see the expressions, I look at their faces and how they are behaving in the classroom”.

Strengths

She is a “simple teacher “and this is what has made her lessons successful. Her methods of instruction are very simple and the students follow without any drawbacks. Y believed that she could improve her teaching by using more visual aids in the classroom and by infusing technology into the lesson and also by trying to incorporate more real life applications. Using her personal time to prepare lessons is a waste of energy because it may not have any impact on the students.

Reasons for teaching in this way

The reason she teaches in the rote manner was because it works for her audience and it's just easier. Y believed that because she was taught in that same manner and has been successful that it was a very good way of teaching. She will change her method of instruction if she was in a school where the students were not as sharp as the students she have now.

Role as the teacher

She is a facilitator at times but is more comfortable with leading the class and believed that the teacher centered approach to learning facilitates more content coverage.

In summary Y believed that for a science lesson to be successful she must take the lead, the students must be disciplined, she must read the textbook before the class, the classes should be small, she must give notes and teach in a rote fashion and the students must be able to answer the past paper questions at the end of a topic.

During The Intervention

Discussions for each activity

Tricky Tracks:

In this activity the teachers were given some pictures of some tracks and they were asked to describe what events may have taken place which may have caused these tracks to form.

Observations and inferences

X gave very sophisticated responses which indicated that she had a very good understanding of the difference between observation and inferences. When asked to write what they observed X gave descriptions of the tracks in terms of size, thickness and distance apart of each other she made no inferences as to what type of tracks they were or how they have gotten there. X was very specific about her observations and extremely systematic in the manner in which she listed her observations. X used a ruler to measure the separation between the tracks and even counted the number of matching pairs of tracks. Only when X was asked to make inferences about the tracks then she came up with a number of inferences

"These tracks may have been drawn by someone and it may not even be birds or fishes just drawings".

" or it could be two animals moving in on one spot and then one lifts up the other and they move off together ".

Y on the other hand was confused about the difference between an observation and an inference. Y wrote the following as her observations about the pictures:

"two birds are walking and then they meet up and fight".

The following is what she thought was an inference about the picture:

" two birds are walking and then they meet up and fight and one eat the other and then the winner moves off ".

When we had open discussion about their responses and I explained how an observation is different from an inference then Y grasped and rewrote her observation as " two sets of black tracks moving in the same direction" and an inference stayed the same as before. X was very pleased that she was able to differentiate between an observation and an inference.

Instructions

Both participants were asked to read a set of instructions and to write what they thought it meant.

Context

X was very confused and said that it did not make any sense at all and that " It was total non sense." Y Said that it reminded her of experiment instructions or some kind of procedure for an experiment. When they were told that it was instructions to doing laundry, Y agreed and could see how it made sense but X didn't agree and said "it's a matter of interpretation , these could be instructions to anything ,if we don't read a few lines before or after this paragraph then we may never know what it's about".

Old woman? Young woman?

The teachers were shown a picture of what looked like an old lady from certain angles and like a young lady from another angle and they were asked to describe what they see.

Interpretation

Both participants couldn't see the young lady until the researcher showed it to them. They were both amazed at the fact that the researcher was able to see the young woman and they couldn't. X was determined to see the young woman and turned the picture in many different ways but never saw it until I showed it to her. X was not too concerned with the fact that she had trouble seeing the young lady as she said " I know that I do not think in that way so I will have trouble seeing it".

The Whole Picture

The participants were given an enclosed manila folder which had coloured shapes stuck down inside. They were asked to carry out investigations to figure out what the shapes were.

Methods of investigation

X did her investigations in a very systematic way and asked questions like: Did you cut out the shapes or did your daughter? How many shapes are there? X also counted the number of holes on the manila folder and held up the folder in bright light to determine the exact shapes. Y didn't do too much intricate investigation she just held up the folder above her face and drew what she thought the shapes looked like. They were not allowed to open the folder so they will never know if they were correct.

Caricature of President Regan

In this activity the teachers were given a series of pictures which showed President Regains' three terms in office and they were asked to describe what changes they see taking place.

Interpretation and change

In their descriptions they both only wrote about the changes in Regan's face and neither of them mentioned the lady in the picture. While discussing X mentioned that she saw the lady on the fourth picture but didn't write it because the researcher told them that it's a caricature of president Regan so X wrote about that. Y didn't see the lady in the picture until it was mentioned and said "...wow...because in the back of my head I know it's the President I didn't bother to look for anything else...wow".

What was also a point of focus during this activity was how scientific knowledge changes. X suggested that just as the pictures change over time so too could scientific knowledge and people will see what they want to see and believe what they want to believe. Y also agreed by adding that “changing what someone is accustomed to is very difficult but not impossible”.

Cube Activities

In this activity cubes were placed on the tables and each face had a marking on it except the face that was on the table. The teachers had to look for patterns and try and figure out what should be written on the face of the cube that was not exposed. This activity was a real challenge to both teachers.

Patterns

For the first cube activity X searched for lateral and vertical patterns and used a very analytical approach in searching for patterns. X came up with a mathematical expression to represent one of the patterns. Y was very simple in her analysis and in her methodology in the search for patterns.

For the second cube activity neither of the teachers was able to solve the missing space. X came up with a wide variety of possible pattern but still was unable to solve it. Y gave up and didn’t bother she expressed great frustration with this experiment.

Black Box Activities

In this activity the teachers were given a picture of a box and they were told that it is a water making machine. The teachers had to try and figure out how it worked or what was inside the black box.

Laws and theories

X went about it in a very systematic fashion, she wrote down a number of possible "theories" and then went through a process of eliminations to try and figure out which one of the "theories" was viable. Y was a bit confused and had trouble formulating hypotheses. X proceeded straight to draw possible arrangements of equipment which could have been inside the black box. They both spent a considerable amount of time and eventually they opted to peek at the answer as they felt frustrated at the fact that they could not figure it out. Both teachers could give excellent oral explanations of the Physics principles that they could use which may apply to this situation but neither of them was able to draw a configuration of the apparatus which may be inside the box. Both teachers were very confused about the difference between a hypothesis, a theory and a law.

Research question # 2

In what ways (if any) have these beliefs of the teachers changed after being exposed to various ways to incorporate ideas about the nature of science into their lessons?

Nature of science beliefs

Both teachers were given the same open ended questionnaire (VNOS-C) as from the start of the research and their responses were reanalysed and the following themes were extracted: tentativeness of scientific knowledge, science as a way of knowing, creativity and subjectivity in science, social and cultural factors in science, observations vs. inferences and laws vs. theories.

X's beliefs after the intervention:

Tentative nature of scientific knowledge

Scientific knowledge is durable but tentative. There is proof of this when she said: "Scientific knowledge has stood the test of time" and because of this "...has earned the trust of many". Both laws and theories can change but it will be difficult because for so long nothing has really changed in science. People in general tend to "hold on to what they are familiar with".

Science as a way of knowing

Science is multifaceted and it has many dimensions which many teachers ignore. Science also involves research which is used to improve our daily lives such as technology and medicine and the scientific community is very difficult to penetrate. Science is different from other disciplines because it is "not based on hear say but it is based on reliable information" and also it is very analytical in its approach and it involves many scientists to analyse and verify information.

Creativity and subjectivity in science

Science is also based on creativity and X gave an example as the "formation of the structure of the atom" which is a model that evolved from creativity and intuition of the scientist. Scientific knowledge is not only formed from experiments but also from imagination and *gut feelings* that scientists have sometimes. Many scientists build on the work done by others to help them come up with new scientific knowledge. The use of imagination and creativity in the formation of scientific knowledge can produce a wide range of possibilities for science as different people would have varying thoughts and ideas about different aspects of science. This makes science very subjective.

Social and cultural factors in science

The social upbringing of a scientist affects the interpretation of data and hence generation of scientific knowledge. X believed that western science is not the only science which exists and it's not the one true science. This is shown when she said, "Social, cultural and political aspects are different throughout the world and are not universal" and "ones environment can depict how science is portrayed to that individual".

X was now making connections between western science and other origins of scientific knowledge. This was evident when she spoke of; "Science in Africa and India is different from western science because the culture that the people adopt in those countries is in alignment with their beliefs so they have created a science which is coherent with their culture" and "in Africa they may use herbs and homemade remedies to cure many ailments" but here "we call that alternative medicine". There exist some commonality between the sciences and it should not be discounted because it is not western.

Laws vs. theories

Theories are more important than laws and they could both change. She also identifies with the consequences of change in scientific knowledge. This was evident in her quote: "If a new atomic theory is developed which allows for easy production of nuclear weapons, then society could be in big trouble" and "If the theory of evolution is suddenly deemed as wrong then the Catholic Church would have won the science-religion battle, scientists would be in for a rude awakening".

In summary X now believed that all aspects of scientific knowledge could change, science is a multifaceted enterprise which involved models and experiments was not the only means of developing scientific knowledge. She now believed that theories are more important than laws and that science is very subjective because different people come from different backgrounds. X's beliefs about the nature of science changed drastically, she is now able to articulate beliefs about the nature of science which are more congruent with current beliefs about the nature of science.

Y's beliefs about the nature of science after the intervention

Tentative nature of scientific knowledge

Theories are not as durable as laws and so they are easier to change. Theories can change or will be totally abandoned when new experiments are done.

Science as a way ok knowing

Science is a system or process of gaining knowledge it incorporates all mostly observations which can be interpreted to generate new scientific knowledge. Laws are formed through experiments only. The scientific method is the true method of generating scientific knowledge.

Laws vs. theories

Laws were still more important than theories and that a hypothesis and a theory may be the same thing.

Creativity and subjectivity in science

New scientific knowledge is formulated through the development of experiments only. Scientists can use their imagination to envision models but experiments are necessary to verify their thoughts. She believed firmly that experiments and interpretation of observations is very important thread in the cloth of scientific knowledge.

Social and cultural factors in science

Science is affected by society and culture. This was evident when she said, “The interpretation of observations is shaped by the cultural experiences of the scientists” and in any situation “interpretation is always with contextual relevance”.

In summary Y’s beliefs about the nature of science did not change much. She still believed that scientific knowledge was only generated via experiments, laws are more important than theories and the scientific method was what made science special. The only obvious change was that scientific knowledge was tentative.

Research question #4

In what ways have these beliefs about the hallmarks of a good science lesson changed after the intervention?

Teachers were shown how to incorporate ideas of the nature of science into their lesson by using some of the explicit reflective activities and by using history of science in science lessons. The teachers were also asked to do some lessons of their own to incorporate nature of science and these lesson were used in collaboration with short interviews and field notes to see if their beliefs about what makes a good science lesson is changed/enhanced.

X's beliefs about what makes a good science lesson after the intervention

Structure and organisation

The nature of science activities presented in the intervention would encourage a lot of classroom discussions and so the teacher would have to choose which activities are to be used and for which class "as these kinds of activities could lead to poor classroom management if not structured properly" and "by implementing proper structure to the activities that the students will be able to stay on task and not stray from the topic".

Preparation

Including the nature of science into lesson will mean that a lot more time would have to be spent preparing for the lesson as the textbook does not have adequate information about the historical aspects of science. X has made many suggestions as to where history can be included in science but advocated the need for extra preparation time as "it requires research beyond the textbook". X believed, "If I want to include the nature of science into my classroom instruction them I would have to invest more time in preparing to get more familiar with it".

Classroom environment

Using the history of science in lessons would appeal to the students' human side because they may be able to relate to some of the trials that scientist have to go through and she sees this as a positive thing as the students will get an opportunity to learn more about each other and she will be able to learn more about the students which may help her to understand why they behave how they behave. X maintained her belief that the students should be very quiet as it is easier to control them this way.

Student learning

X was confident that when the students were able to answer past papers then they have learned. Having a proper understanding of the nature of science is not a requirement of the syllabus then she shouldn't have to assess if they have learned from it or not. X has faith in reading the social cues that the student's exhibit like "the shrug of a shoulder" or "the raised eyebrow" or even "the occasional setups" in the class which will let her know if they have understood the work that was done in class.

Strengths

She was bored of how she presented science to her students and was willing to change her teaching techniques as long as she was shown how to do so. She is a team player and if the entire department worked together then the change would take place at a faster rate. If she alone was willing to change then that would not have any impact on the students' understanding of the nature of science. She saw administration as a reason why she wouldn't be able to teach about the nature of science in her classroom. This was evident when she said, "The administration serves as an obstacle toward this goal of having students develop a proper understanding of the nature of science".

Reasons for teaching

She taught in this way because it was how she was taught and it is the preferred style of teaching in her environment. This was evident when she advocated, "...I teach this way only because it is what I am accustomed too as this is how I was taught as a student". X is very willing to try other things as X is "bored of the repetition".

Role of the teacher

She is the dominant figure in the classroom and is quite comfortable with being the provider of information. This was apparent when she said, "...the teacher should take the lead of the class...". Her role was to ensure that the syllabus was covered and that the students do well in their final examinations. This was evident when she said "at the end of the day what is important is that the students can do well in exams".

Y's beliefs about what makes a good science lesson after the intervention

Structure and organisation

Science teachers have to learn how to incorporate open discussions in their science lessons without causing havoc then the lesson will be very successful. If the activities are not structured or planned properly then learning will not be "optimized" .Using the history and philosophy of science and the explicit reflective activities the students will be given an opportunity to work in groups which will not only develop their social skills but it would give them an opportunity to share ideas and to understand each other and at the same time it will help them to get a good grasp of what science really is about.

Preparation

Y admitted that to have successful lessons there ought to be major planning and that the teacher needs to be very up to date with new information and not use the textbook as their bible. Y believed that because of her post as head of department Y was unable to meet such demands so Y's main source of preparation was always the textbook. Y has also made a variety of suggestion as to where the nature of science can be included in the science syllabus but believed "it is not as easy as it looks, it means spending lots of time doing extra research".

Classroom environment

She was aware that if she understood her students and how they learned then they may learn more but stressed on the fact that her classes were too big for that and as much as she would love to get to know all of them it's impossible. By setting the general tone of safety and comfort in the classroom that the students would learn better.

Student learning

The school is very exam oriented and parents are only interested in their children getting good grades so teaching the students how to get good grades is very important. Evidence of this was shown when she said; "The school is very exam oriented so the main focus is passing exams so we teach for the test" , " the students do well in exams, they achieve their goals" and "All the parents care about is their child doing well in exams, winning scholarships and getting into a university of their choice". When the students use their knowledge in practical application then we could say that they have truly learned but while they are in school their focus is on the exam so she assesses their learning based on their ability to answer past papers. A students' ability to do labs without instructions is another indication that they have understood a concept. There is evidence of this when she said, "...when students can plan and design and carry out an experiment without my instructions then I know that they have truly understood a topic".

Although the nature of science is not on the CXC or CAPE Syllabus but the skills they develop from understanding the nature of science will help them in practical work for example like "understanding the difference between observation and inference".

Strengths

Y believed, “being a simple teacher” and “understanding the needs of the students to get good grades are her strengths”. She could improve by “including more history in the classroom because it really softens the subject” and by “using more technology lessons with more visual aids”. She also feels that because her rote way of teaching has worked for such a long time then there is no reason to change it.

Reasons for change

She may not actually change her method of delivery but she will try to include aspects of history into her lessons as it is not very time consuming and it really does peak the curiosity of the audience. The explicit reflective activities should be done in lower school as they are not exam oriented as yet and so, time is much less valuable at those levels. Introducing nature of science at the lower level would form a proper foundation for them. Y believed, “at the form four, five and six levels time is of the essence those kinds of activities are a definite no”.

Role as the teacher

Y believed her role is to “teach the students about science for them to pass examinations”.

In summary both stuck to their original beliefs about what makes a good science lesson, except now they were willing to try to incorporate some history of science in their lessons. They both share the belief that labs should not be done in a cookbook fashion but prefer it because it is easier and because it is what is accepted by the higher authorities. They both shared the same concerns about this inclusion of history of science: time management, syllabus requirements and administrative issues.

Chapter Five

Discussion

This research results is in alignment with what most research reports have indicated that teachers hold naive or inadequate science philosophy (Gallagher, 1991; Lederman, 1992 & Pomeroy, 1993). According to Ozedemir (2007) a naive epistemology indicates a positivist perspective describing scientific knowledge as true, real and existing independently of personal theories. It seems as though both teachers fit the profile of a traditional scientist or a positivist. A traditional scientist holds the viewpoint that scientist have theories about phenomenon and use empirical tests to confirm theses theories. X relies on the use of logical analysis and deduction and believed that scientific knowledge is only generated from observations. They both believed that scientific knowledge can be proven to be true and used the textbook as their main resource. This notion that one has a theory and then set out using empirical enquiry to prove it, is seated very comfortably in their classrooms. Both teachers' classrooms are very minds on and the experiments are done in a very cookbook fashion. The positivist believes that the laws in science are cast in stone and the experiments are conducted based on these laws so the students know what the results should be at the end of the experiment. According to Chalmers (1999) empiricism and positivism share a common view that scientific knowledge should in some way be derived from the facts arrived at by observations.

According to Mac Comas (1998) there are fifteen myths which are commonly used in classroom discourse, textbooks and in the minds of many science educators. Both teachers have some major misconceptions about science: one of them being the false hierarchical relationship between laws and theories. The teachers believed that laws are more important than theories.

According to Akerson, Abd-El-Khalick and Lederman (2000) teachers should know the relationship between theory, laws and observations and should stress the process of science rather than only facts and laws. Actually, demonstrating the process of science by emphasizing the explanatory power of prominent scientific theories could be an effective approach for explaining how scientific knowledge is constructed (Duschl & Wright, 1989).

Another misconception they seemed to have is that scientific laws cannot change but theories can. However, Matson and Parsons (1998) says,

"Essentially, in constructivism, knowledge is not considered to be absolute. Knowledge is the result of the social, cultural, and historical milieu. In this sense, knowledge is constructed individually based on a person's socio-cultural background Saunders (1992)."

It is therefore very important that teachers know that laws and theories are subject to change based on new findings however, they can withstand the test of time as they are very durable thought models. Teachers should understand that the existing theories are the ones which have withstood falsifiability. Harding and Hare (2000) go on to suggest that maybe it is better to abandon the image of scientific knowledge as tentative and replace it with the idea that scientists accept concepts as true but are open-minded about them and that students should be so, too. However it has been my experience that people hold on to their old beliefs because of the security of familiarity and in any event the term open-mindedness is subject to interpretation. In fact, Gardner (1993), as cited by Harding and Hare (2000) concluded that open-mindedness requires that a person remain undecided about some matter to which she has paid attention. It is defined as a kind of neutrality. Matson and Parsons (1998) say that the conditional nature of scientific knowledge is distressing to people. Generally teachers will adhere to the idea of knowledge being stable because it is easier to adapt to that way of thinking.

A third misconception they have is that there exist one scientific method, one method of discovery, one way of finding new knowledge. According to Ozdemir (2007) a naive epistemology assumes that scientific knowledge is out there and everybody can reach the same truth by following the same experimental procedure. According to Monk and Dillon (2000) when students devise fair tests and collect sets of data to determine empirical relationships, they are realizing the empiricist’s views on the nature of science. The teachers in this study described experiments in the cookbook setting. This cookbook method of experiments is in sync with one of the greatest myths of science which is that science is procedural rather than creative. Although the authors of science textbooks do a very good job in portraying this myth to be true it actually is not. McComas (1998) says only the creativity of the individual scientist permits the discovery of laws and the invention of new theories. Certain authors of science textbooks work against the creativity of science by giving prescriptions for the experiments. McComas (1998) goes on to say that not only is this approach the antithesis of the way in which science actually operates, but such a portrayal must seem dry, clinical and uninteresting for many students.

Both teachers in this study believed that science is about facts and it is a way of knowing the truth and hence they deliver science to the students as a package which they have to reproduce. As a result of their beliefs they over emphasize product and not process. Teachers should stress on the process rather than the product of instruction in science (Ozdemir, 2007). Many studies have shown that teachers consistently set up their instruction in science around fixed knowledge and so these teachers do not pay much attention to the students’ existing knowledge.

Both teachers however believed that science has some kind of social and cultural framework and that it is important to teach about the history of science. Physics has many different areas where the history of science could be married into the curriculum. In the late 1950's, James Conant suggested that all necessary knowledge of the nature of science could be gained from studying a few historical cases Kipnis (1998).Students often describe Physics as an abstract subject and according to Rudge and Howe (2004) the use of history can potentially humanize science, help students refine their critical skills, promote a deeper understanding of scientific concepts and address common student misconceptions that often resemble those of past scientist (Matthews ,1994).

Although these two teachers have varying years of experience and training the methods in which they deliver the syllabus is almost the same. They both believed that a teacher centered class is more successful, discipline weighs heavily on the success of a science lesson, the textbook provides all the information necessary, the students will succeed regardless of their role in the classroom because the students are very focused and self motivated and when the students are able to do past paper questions very well then they have learnt. The teacher-centered approach assumes that all students have similar levels of knowledge in the subject being taught and they absorb new material in a similar pace. This would mean that this method of teaching does not cater for students with different learning abilities or styles. According to Ozdemir (2007) teachers who have a naive epistemology of the nature of science largely use the teacher centered approach with closed controlled activities, emphasize transmission of knowledge and consider students as simple receptors of that knowledge.

According to Getkin (2009) unfortunately, too many of today's educational leaders are aligning their sights on old-school practices while expecting new-school great performances.

These old practices encourages learners to be absorbers of knowledge and cause them to have a low level of critical thinking skills, they never become autonomous learners and hence may never grasp the ability to apply their scientific knowledge to real life situations. Teachers need to realise that times have changed and research have shown that students learn in different ways and as such we such adjust our pedagogical strategies to meet the needs of all students. With this in mind Gullath and Loftan (1996) identified the need for teachers and administrators to shift from the traditional approach to programmes which are comprehensive and meet the needs of students and a proactive approach to curriculum development.

Both teachers in the study used the same forms of assessments: past papers and worksheets. According to Ozdemir (2007) teachers understanding of the nature of science strongly affect their assessment choice. The teachers in this research very rarely spoke of port-folios, journals and projects for assessing student performance. Traditional assessments tend to lead students to memorization and regurgitation of facts and formulas which is what leads to meaningless learning. When science is taught as a body of facts for reproduction it is very unlikely that there will be any connectivity between what is taught in school and everyday life applications. This kind of teaching reinforces existing misconceptions that the students may have or it may even create new ones. Students have misconceptions from a very young age which are resistant to change and using direct instruction to bring about conceptual change is not sufficient because students’ epistemological commitments have an impact on their learning science (Posner, Strike,Hewson & Gertzog,1982). This has serious consequences as teaching for the test does not allow the students to develop critical thinking skills or problem solving skills which are tools necessary for making decisions in life later. According to Mouza (2003) professional development can help teachers to keep up to date with new and effective practices in teaching and learning. Teachers need to make learning an active process instead of teaching for the test.

X has no professional training and so could not do lesson plans and does not know of various learning styles and teaching strategies. Y on the other had makes no secret of the fact that she is aware of how to do lesson plans and how teaching strategies should match the learning needs of the students but does not use it in her classroom because teaching time is very limited and preparation time is not allocated to accommodate such practices. Y's administrative post has consumed most of her time and so she sees anything extra as a burden. Nevertheless, it is the challenge of the teacher to develop methods of changing the way they teach to include the proper understanding of the nature of science. These changes challenge teachers' beliefs of learning and teaching on the one hand, and provide an opportunity for restructuring organizational culture (Tam, 2010). It is important that the Head of Department understand this leadership role since a Head of Department has the delegated responsibility for the introduction, planning, implementation and evaluation of a subject-based curriculum which is directly related to learning and teaching (Hannay, Erb, & Ross, 2001 as cited in Tam, 2010).

After the teachers were exposed to the explicit /reflective activities X's beliefs about the nature of science changed much more than that of Y's. After the intervention X was able to articulate the difference between laws and theories and explained the tentativeness of all scientific knowledge. X understood that the scientific community was difficult to penetrate and why scientific knowledge was so durable. X was also able to give examples of creativity and imagination in science and how society has influenced the direction that science had taken over the years. X agreed that science is not what she thought it was but now believed it has so many dimensions which made it a lot more interesting to teach. X's drastic change was also partly due to the fact that she sat next to the researcher in the office and so was always being exposed to history and philosophy of science because they were always in constant communication. Jones (2007) believes that communication is the most critical component of any relationship. The researcher acted like a peer coach and so X was not only subjected to the explicit /reflective activities but also to ongoing conversations about the dynamic nature of science and according to Showers and Bryce (1996) peer coaching study teams enhance staff development efforts and offer support for teachers implementing new strategies.

After the intervention Y's beliefs about the nature of science were slightly enhanced Y articulated that theories can change and was able to give examples but Y was still not clear about the hierarchical relationship between laws and theories. Y has been teaching for much longer than X and has formulated her own belief system about the nature of science based on her personal experiences. It is therefore very difficult to change her beliefs as her cognitive structures are not as malleable as X's. According to Jones and Carter (2007) teachers' epistemological beliefs tend to be relatively stable and resistant to change especially for more experienced teachers. Another factor which the researcher believed would have helped Y to enhance her beliefs was if Y was spending more time with the researcher, then communication would have been more frequent and maybe that would have had a more fruitful effect on her.

After X and Y were shown how to include the nature of science in their lessons they both seemed very eager to use it but they both agreed that it would require a lot of preparation and extra research as the textbooks does not provide adequate information on the history and philosophy of science. According to Jones and Carter (2007) one way that science educators have promoted social justice and empowerment is through the inclusion of history of science in science instruction. X identified with the importance of using history of science as a mechanism to humanise the subject, and Wand and Marsh (2002) as cited in Jones and Carter (2007) agree as they advocate including history of science is a way to show that science is a human endeavour and helps students understand how social factors or political power are tied to science. The teachers in this study have both indicated that they were willing to include the history and philosophy into their lesson but only at the lower levels where the students are not preparing for high stake examinations. They have also both acknowledged that introducing the nature of science into the science curriculum would lend itself to more group work and a more constructivist type of learning which would require lots of planning, preparation and problem solving. According to Ozdemir (2007) teachers and students should embrace constructivist epistemology to create an ideal environment for science teaching and learning.

The teachers attested to their original belief that once the students can answer past papers questions then they have learnt. Y added though that true learning is only when the student can exhibit application of scientific knowledge to their real life and when they can do labs without instructions. Both teachers preferred to stick to their traditional methods of teaching because it has worked in the past and does not require much time to prepare. They also believed that they have the support of the administration so they feel more comfortable with this traditional method of teaching. They both were very comfortable with transmitting knowledge to the students rather than building on what the students brought into the classroom. Traditional education view is focused on “instructional goals such as recalling facts, generalization, defining concepts and performing procedures” (Almala, 2005). Therefore, this view ignores the fact that students have pre-existing knowledge which they may use to build new knowledge. The constructivist view learning as the product of interaction between existing understanding and new knowledge (Parkinson, 2004). However, in general, constructivist “emphasize reasoning, critical thinking, social negotiation, self regulation and mindful reflection" (Almala, 2005, p.9). Furthermore, constructivists view learning as an active process in which the learners actively construct knowledge as they try to comprehend their reality world.

It is apparent that the intervention was able to change or in some way enhance the beliefs held by the teachers about the nature of science but it did not change their beliefs about their approach to teaching science. They have expressed concerns about time to prepare for lessons, pressure from administration and classes being too large as some of the reasons why they prefer their old methods of teaching. X has added that she will include the nature of science into lessons if she is continuously shown how to do so. X has no training in education and so teaches the only way she knows how. According to Jones and Carter (2007) one's individual epistemological beliefs are constructed through their formal and informal experiences as students and this belief system is resistant to change. Both teachers were taught in the manner in which they teach now and so they believe strongly that this method works. According to Kagan (1992) since teaching beliefs are a product of personal beliefs and values about knowledge, society, education, and politics, as well as a process of enculturation and social construction (Pajares, 1992) , it may be impossible to separate teaching beliefs from life beliefs. Woods (1993) points out that the personal dispositions and experiences accumulated over the years help shape the professional role of teacher as it is subjectively experienced, meaning we are a product of our experiences and environment, and that is reflected in our profession. As Pajares (1992) reminds us, all teachers hold beliefs about their work, students, subject and roles, and responsibilities and the older the teacher the more difficult it is to change their belief system.

The methodology adopted by this study allowed the researcher to really get a close look at the perceptions teachers' held about the nature of science. The data collection strategies employed in this study allowed teachers themselves to critically analyse what they thought about the nature of science. One of the major advantages of this qualitative approach is the use of open ended questions which really gave the participants the opportunity to respond in their own words, rather than forcing them to choose fixed responses, as quantitative methods does. Open ended questions have the ability to evoke responses that are meaningful and culturally salient to the participant, unanticipated by the researcher and rich and explanatory in nature.

The researcher spent a lot of time collecting data and used any opportunity necessary to gather information. Data was not only restricted to interviews and open ended questionnaires but the researcher also used information from phone conversation, lunch time conversations and short corridor talks. One of the participants in the study was very hesitant about her beliefs about teaching being audio taped because she found that she spoke more eloquently when she was not being audio-taped. The constant communication with the teachers also invoked questions in the minds of the teachers as to whether they really had a proper perception of the nature of science and they had successful science lessons.

This research made X realise that she needs to get some form of educational training to enhance her teaching skills. They both suggested that the government should put programs in place to help new and existing teachers to develop proper ideas about the nature of science. In order however, to fully analyse the perception of teachers the researcher will need to spend more time observing the teachers in the classroom setting as a few classes just does not give enough justification for generalization about one’s perception. In order to improve this study the researcher should have more detailed interviews to try and probe the interviewees some more. The researcher should also spend time in the classroom to observe how their epistemological beliefs are translated into classroom practice. The interview data was subjected to analysis by the researcher who also has different views about the nature of science so they may have been some level of subjectivity.

Attainment of Expected Outcomes

Some of the expected outcomes of the intervention were achieved. The explicit /reflective activities helped both teachers' beliefs about the nature of science to enhance or change in some way. A compilation of lessons was produced by one teacher and the researcher, which focused on varying aspects of the nature of science and this helped the both teachers in the study to understand how to use the history and philosophy of science in the classroom. The activities also helped them to work with one another and to understand each others' personality and work habits.

They both would like to include the history and philosophy of science into their lessons but see time as a major constraint. Their beliefs about what makes a good science lesson did enhance but they are not willing to practice these changes.

Conclusion and Recommendations

Current emphasis on achieving scientific literacy is strongly urging teachers and students to hold adequate and contemporary beliefs of the nature of science (NRC, 1996). The explicit/reflective activities did impact on the teachers' beliefs about the nature of science but it was not the only ingredient in this research which caused change. Teachers have inadequate views of the nature of science because they were not exposed to it in any aspect of their science education previously. For teachers' beliefs about the nature of science to change permanently the intervention cannot be a one off thing but it has to be a continuous process of learning and understanding about the history and the philosophy of science. X was able to completely change her beliefs about the nature of science but because she was not exposed to the explicit /reflective activities alone but also we were always in communication about the nature of science and all its dimensions. Teachers are very set in their own belief system whether its beliefs about teaching and learning or beliefs about the nature of science but it may be easier to change their beliefs about the nature of science than their beliefs about teaching and learning. This can be done by developing programs which are ongoing and which continuously educates teachers about the explicit and implicit aspects of the nature of science. According to Abd- El- Khalick and Akerson (2004) , acquiring an appropriate view of the nature of science requires more than short term interventions.

This study was only limited to two teachers so therefore no generalizations can be made but it is quite clear that these two teachers teach in the manner in which they were taught and they believe very strongly that this transmission of information is the path to true learning. A follow up study has to be conducted to see if and how the teachers take their new beliefs about the nature of science back into the classroom. This is not within the scope of this study so it was not done. However if the proper understanding of the nature of science is being transmitted to the students then we are on the right track and eventually the teachers would change how they teach because the nature of science lends itself to a more constructivist type of teaching.

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