CHAPTER 1

Introduction to the study

1. Introduction

Scientific literacy is defined as the public's understanding of science (Laugksch, 2000). Laugksch (2000), points out that despite the different meanings and interpretations of the concept to different people, there are various aspects of scientific literacy that some authors generally agree should be included in describing the concept. Today, there appears to be consensus within the science education community that scientific literacy consists of three fundamental dimensions. These dimensions are: an understanding of scientific knowledge; an understanding of the nature of science (NOS); and understanding and appreciation that science, technology and society are interrelated (DeBoer, 2000; Laugksch, 2000). In many parts of the world, developing students' understandings of the nature of science has become a major goal of science education (Abd-El-Khalick & Lederman, 2000; DeBoer, 2000; Khishfe & Lederman, 2006; Laugksch, 2000). For this reason, teachers' understandings of the NOS have become important for both the practice of science education and for research. The assumption is that if teachers understand the NOS, they can teach about it in such a way as to develop desirable NOS understandings among the students. However, research done around the world (Abd-El-Khalick et al., 2000; Dekkers & Mnisi, 2003; Dekkers, Oguniyi, Mosimege & Marenga, 2005; Lederman, 1992) has shown that in many countries teachers' understandings of NOS are inadequate. Research on teachers' NOS understandings done in South Africa (for an example, Dekkers, 2006; Dekkers et al., 2003; Linneman, Lynch, Kurup, Webb & Bantwini, 2003) confirms this assertion. While some studies in South Africa (for an example, Dekkers et al., 2005; Linneman et al., 2003) have focused on understanding and describing teachers' NOS understandings, there has been little effort to look at the nature of interaction between teachers' NOS understandings and their instructional practices. This was the major focus of the study being reported here.

1.1 Background and rationale

A new curriculum was introduced in South African schools after the country had obtained political independence in 1994. The new curriculum is founded upon principles of Outcomes Based Education (OBE). It has been modified over the years and the current version is based on curriculum statements called the National Curriculum Statements (NCS) (Department of Education, 2003). The NCS-based curriculum was introduced in Grade 10 in 2006, in Grade 11 in 2007 and in Grade 12 in 2008. It requires teachers to structure their teaching towards the achievement of outcomes called learning outcomes (LO's). This requirement needs to be evident in both their teaching plans and classroom instructional practices. Teachers are therefore required to assess whether an outcome has been achieved or not.

In Physical Sciences, one of the learning outcomes, Learning Outcome 3, (LO3) is about developing students' understandings of the NOS and the interrelationships among science, technology, society and the environment. So when teachers assess students they are expected to assess whether this LO has been achieved or not. For an example, a student shows evidence of achieving LO3 when he or she is capable of identifying and critically evaluating scientific knowledge claims as well as the impact that the knowledge has on the quality of socio-economic, environmental and human development (Department of Education, 2003). Linking this to scientific literacy means in order to be scientifically literate citizens, students should be taught to be able to make informed decisions about scientific claims and data (Lederman, 1999) and also contribute meaningfully in debates on socio-scientific issues (Kolsto, 2001).

It has been asserted that students can only benefit from teachers' understandings if the teachers themselves have adequate understandings of the NOS (Abd-El-Khalick et al., 2000; Lederman, 1992). Kang and Wallace (2004) suggest that teachers' naïve beliefs are reflected in their teaching practices. The assumption is that the manner in which teachers will plan and implement instruction depends on their understanding of the subject matter**.** In this case, it is about teachers' own NOS understandings. Research (for an example, Abd-El-Khalick et al., 2000; Abd-El-Khalick, Lederman, Bell & Schwartz, 2002; Lederman, 1992;) has revealed that in many parts of the world both primary and secondary school teachers have inadequate understandings of the NOS.

Furthermore, some studies suggest that even when teachers do possess adequate knowledge of NOS, there is very little reference to it in their planning and teaching practices (Abd-El-Khalick et al., 2000). According to Lederman (1992), teachers' understandings of NOS do not necessarily translate into classroom instructional practices. He argues that the translation of teachers' NOS understandings into classroom instructional practices is impeded by such factors as curriculum and administrative constraints and availability of time and resources. According to Vhurumuku and Mokeleche (2009) the exact nature of the relationship between teachers' NOS understandings and their instructional practices is still not fully understood. The present study contributes to shedding more light on this issue.

Improvement of teachers' understandings of NOS has been based on the assumption that teachers' understandings influence their classroom practices (Lederman & Zeidler, 1987). Assumptions have also been made that teacher understandings and classroom practices will necessarily translate into students' NOS understandings. Given the above facts, the questions to ask are: Do South Africa's teachers have adequate NOS understandings so as to be able to meet the challenges of the new curriculum? How do teachers' NOS understandings translate into classroom practices? Are South Africa's teachers capable of implementing this part of the new curriculum? Are they able to develop students' understandings of NOS? This study set out to answer some of these questions.

1.2 The purpose of the study

The aim of this study was to investigate South Africa's teachers' understandings of NOS and their teaching about the NOS in the classroom in order to find out whether there is implementation of the new curriculum, the focus being on LO3 of the NCS. Within that effort, the study sought to understand the nature of interactions between teachers' NOS understandings and their instructional practices.

1.3 Research questions

The study was guided by the following questions:

1. What NOS understandings are held by the science teachers?
2. How do the science teachers teach about NOS?

3. What is the nature of the relationship (if any) between teachers' NOS understandings and their instructional practices?

1.4 Theoretical framework

This study is guided by the theory on teachers' understandings of the NOS and practices in NOS teaching developed during the past fifty years. Gallagher (1991) states that science teachers who hold the positivist views of science emphasize a scientific method and not the tentative nature of science and such teachers do not spend much time teaching NOS. Constructivist teachers on the other hand include NOS in their teaching practices (Hashweh, 1996).

Tsai (2003) has categorized teachers' NOS understandings', which he calls scientific epistemological views, as either positivist or constructivist. Some scholars (e.g. Abd-El-Khalick et al., 2000; Kang et al., 2004) have categorized the individuals' NOS understandings as either naïve/inadequate or sophisticated/adequate. Teachers can be described as harboring naïve scientific epistemologies if they subscribe to such notions and beliefs as: scientific knowledge is certain and is a fixed, true and "objective" representation of reality; there is one method of science which practicing scientists adhere to; an objective reality which is independent of the knower, exists; and scientific observations are free from human preconceptions (Kang et al., 2004; Southerland, Guess-Newsome & Johnston, 2003). Harboring sophisticated scientific epistemologies entails subscribing to such views and ideas as: scientific knowledge is dynamic, tentative, revisionary and the result of active interaction between the knower and the known; there exist multiple truths and realities which are neither fixed nor absolute; there is no one method in science; and scientific observations are theory-laden and dependent on the experience and preconceptions of the observer.

In developing students' understandings of the NOS, the use of explicit rather than implicit curriculum and instructional approaches has been recommended (Dekkers, 2006; Lederman & Lederman, 2004; Linneman et al., 2003; McComas & Olson, 1998; Vhurumuku, Holtman, Mikalsen & Kolsto, 2006). Curriculum and instructional approaches are described as explicit when the subject content, teaching methodology and assessment deliberately aim to develop students' NOS understandings. Students are taught about the NOS. Their understandings of the NOS are formally assessed. This is in contrast to implicit approaches where students' NOS understandings are assumed to develop as a secondary product of instruction. There is no deliberate effort to teach and assess students' understandings about the NOS. It is assumed that by being involved in science (practicing science) students can develop "adequate" or "desirable" understandings of the nature of scientific knowledge and the scientific process (the development and validation of scientific knowledge). This framework is used to understand the nature of teacher instructional practices

1.5 Research methodology outline

Using a case study approach, the research design for this study pivoted around use of interviewing teachers for their NOS understandings and observing their lessons to ascertain their classroom practices. Data was analyzed using typological analysis (Hatch, 2002) and interpretive analysis (Gall, Borg & Gall, 1996).

Three grade 10 teachers from three secondary schools in Vosloorus, a township south of Johannesburg in the Gauteng province, were interviewed and their teaching and learning activities observed and analyzed with the aim of unraveling how NOS understandings interacted with instructional practices. Interviews to investigate teachers' understandings of NOS have been used successfully by other researchers (Abd-El-Khalick et al., 2002; Dekkers at al., 2003; Linneman et al., 2003). Grade 10 teachers were chosen on the basis that in grade 10, unlike in grade11 and 12, the NCS was being implemented for the second year at the time of the investigation. They were also chosen because their end-of the year examinations start later than the grade 12 so it was envisaged that they would have time available to take part in the study.

1.6 Chapters outline

Chapter 1: Introduction to the study

In Chapter 1, the reader is introduced to the research where a brief discussion of scientific literacy and its link to NOS is given. The rationale, the purpose of the study including the research questions, and the theoretical framework, are discussed. Then a brief outline of the research design is given.

Chapter 2: Literature Review.

A detailed review of literature relevant to the study is given in Chapter 2. The literature reviewed is on the definition of NOS, the NOS tenets, teachers' understandings of NOS and the relationships between the teachers' understandings and their instructional practices.

Chapter 3: Research Design.

The research design is explained and discussed in Chapter 3. It includes the research methodology, the selection of participants, the instruments and methods used to collect data, data analysis methods, issues of validity, reliability as well as ethics.

Chapter 4: Research Results.

The results are analyzed and discussed in Chapter 4. The analysis and discussion of the results is categorized as per research questions. The chapter is divided into three parts which are: teachers' NOS understandings; how teachers teach about NOS and the relationships between their NOS understandings and their teaching practices.

Chapter 5: Conclusions, Implications and Recommendations.

Conclusions are drawn in the last chapter, Chapter 5. The chapter also outlines recommendations for teaching, for curriculum implementation and for future research drawn from the study. Limitations of the study are also explained in this chapter.

1.7 Conclusion

Research on teachers' NOS understandings and their relationship with instructional practices is a subject of interest to South Africa's education system because of the demands of the new curriculum. In the next chapter the literature related to this topic on research conducted throughout the world is reviewed.

CHAPTER 2

Literature Review

2. Introduction

In this chapter the key concepts in this study are discussed. These concepts are the nature of science (NOS) and instructional practice. The theoretical framework for the study is articulated. This is followed by a review of the literature relevant to the study.

2.1 The Nature of Science

In the paragraph below the construct “Nature of science” is described and explained as it is defined and understood by different philosophers and researchers.

2.1.1 What is the Nature of Science?

The concept “Nature of Science” has been a target for research in the science education communities for several decades (Lederman, 1992; Mellado, 1997). A lot of research has been done on both teachers’ and students’ understandings of the nature of science. As said in Chapter 1, the NOS is one of the three fundamental dimensions of scientific literacy (DeBoer, 2000; Laugksch, 2000). Scientific literacy was defined as the public’s understandings of science. According to Laugksch (2000) although the concept scientific literacy still has different meanings to different people, there are some aspects of scientific literacy that are shared by members of the science community. For example, consensus appears to have been reached that a scientifically literate individual understands the nature of science (Lederman et al., 1987). Such an individual is described in the text to understand the uses and processes of science needed to solve problems, and is able to make decisions on scientific issues. Furthermore, the individual understands and appreciates that science; technology and society are interrelated (McComas, Clough & Almarzoa, 1998).

The concept of nature of science is also contentious. Despite the lack of agreement among philosophers of science about the meaning of the construct “nature of science” mainly because of its fluid nature, there is some consensus within the science education community about certain aspects of the NOS (Abd-El-Khalick et al., 2002;

Khishfe et al., 2006; Linneman et al., 2003; Liu & Lederman, 2007; McComas et al., 1998). According to McComas et al. (1998, p.4) "the NOS refers to a description of what science is, how it works, how scientists operate as a social group". It is also about the interaction among science, society and the environment. In this study the (NOS) is seen as intertwining the history, sociology, philosophy and psychology of science. The argument here is that to fully understand the NOS one needs to look at the construct through all of these lenses. McComas et al. (1998) emphasize that in studying the nature of science, (NOS), one has to investigate not only science but scientists as well. One could therefore conclude that from the descriptions given above, an understanding of NOS means one understands how professional scientists work in developing scientific knowledge and the relationship between science and society (i.e. how the society responds to scientific claims). Other authors describe the construct as referring to the attitudes and beliefs that are inherent to the development of scientific knowledge (Abd-El-Khalick, Bell & Lederman, 1998; Gwimbi & Monk, 2002; Lederman, 1992; Vhurumuku et al., 2004). According to these authors NOS refers to whether one believes scientific knowledge is more superior to other forms of knowledge or not, how one believes this knowledge is generated and its value.

Liu et al. (2007) acknowledge what they refer to as a more contemporary but not different view of NOS by Abd-El-Khalick et al. (2000). In this view the authors emphasize a description of characteristics of scientific knowledge, with these characteristics being derived from how the knowledge is developed. The emphasis on NOS, according to this description, is on how scientific knowledge is developed and the implications thereof.

2.1.2 Some basic tenets of the NOS

As it has been mentioned earlier, disagreements exist about the definition of NOS. Consequently disagreements about what aspects should constitute the NOS also exist. However, this being the case there appears to be agreement within the science community about what tenets should be used to describe the NOS (for example, Abd-El-Khalick et al., 2002; Bell, 2001; Tsai, 2000;). Within the science community, there is agreement that scientific knowledge is: tentative, theory-laden, partly the product of human inference, imagination and creativity and that it is socially and culturally embedded. Other important tenets of NOS include the fact that there is no universal recipe-like method for conducting scientific investigations as well as an understanding of the relationship between scientific theories and laws and their roles in science. According to Lederman (1999) these NOS aspects could be applied at different levels of complexity to different grades or levels of the students in order to portray scientific knowledge during teaching. Abd-El-Khalick et al. (2002) point out that these aspects of NOS have also been emphasized by science education reform movements that are very recent. In the following sections some six tenets of the NOS are examined in detail. These tenets were chosen for their relevance to the current study.

2.1.2.1 The theory-laden nature of scientific knowledge

This aspect of NOS is based on the fact that the starting point for scientists to build knowledge is not only through observing natural phenomena. When scientists investigate, their existing beliefs and experiences influence how they observe, plan and conduct experiments and interpret findings (Lederman, 1999). This implies that scientific knowledge is not as objective as it is taken to be since the theoretical experiences and expectations of scientists influence all they do. For the classroom the implication is that students need to be made aware that the questions, problems or hypotheses of investigations are never neutral but are framed within the beliefs and theoretical backgrounds of the investigator. This means different findings from an investigation are possible. Students, therefore, need to be taught how to reach consensus and settle disputes in a science classroom. By so doing they would be learning to work the way scientists do.

2.1.2.2 Scientific knowledge is tentative

This tenet of NOS states that scientific knowledge is not the absolute truth but it can be revised in the light of new evidence (Lederman, 1999; McComas et al., 1998). Science knowledge in the classroom, therefore, should not be presented as a body of facts that students need to learn by memorization. Scientific knowledge should be understood to be acquired through criticism, negotiations and validation. Students are not to see themselves as reproducers of knowledge or absolute truth that already exists but they are producers of tentative and dynamic knowledge that is subject to change in the light of new evidence (Tsai, 2000). Accordingly, new evidence can either dispute or affirm previous knowledge. The classroom implication is that, students should be taught to be critical and interrogate both knowledge and evidence.

2.1.2.3 The creative and imaginative nature of scientific knowledge

While scientific knowledge is acquired through experimenting, researching and making observations of natural phenomena, explanations are often invented and some require creativity by scientists (Abd-El-Khalick et al., 2002; Gwimbi et al., 2002; Lederman, 1992; Vhurumuku et al., 2006). The models that scientists come up with are their imaginations and creativity and might not necessarily be true copies of reality. Furthermore the instruments that they use to observe the phenomena do not give them direct accessibility to the phenomena but some of the information is filtered by the instruments. Scientists then become creative and come up with models in their attempt to explain a phenomenon.

This notion of the NOS encourages constructivism in the classroom (Driver, Newton & Osborne, 1999). This implies that science students are not supposed to see themselves as reproducers of knowledge and their work as confirming facts that are already known but as constructing reality based on what they observe and interpret and validate. This can be achieved if ideas are explored, compared and criticized through listening and talking to others. Students need to be taught to construct their own models, that through debating and arguing knowledge can be accepted or rejected in a classroom.

2.1.2.4 Social and cultural embeddedness of scientific knowledge

The acquisition of scientific knowledge does not occur in an empty mind but it occurs in an individual who already had his or her opinion about the phenomenon to be studied (Abd-El-Khalick et al., 2002). The kind of questions asked by scientists and the investigations they embark on depend on where they are and the culture they belong to as well as the socio-economic and political conditions they live under. Scientific questions or investigations are formulated when individuals interact with other members of their social and cultural groups. They are not formulated in a vacuum. The ideas that an individual acquires in his/ her community affect what he/she perceives, observe and learn. This implies that during learning students need to be exposed to the various forms of science, including indigenous knowledge. Linneman et al. (2003) point out that in learning how science is practiced in different cultures and communities, students also learn that indigenous knowledge has a place in the science curriculum.

2.1.2.5 There is no ONE scientific method

Abd-El-Khalick et al. (2002) point out that the belief that there is a recipe-like method for conducting investigations by all scientists is a misconception. Scientists research by various methods without following any specific procedure. This tenet implies that students need to be exposed to tasks or activities where they cannot always follow a step-by-step method when they carry it out. The use of open-ended inquiry tasks is a good example. In science classrooms there is need to emphasize that there are many methods of science. Students, therefore, need to be encouraged to use various methods to conduct investigations. This tenet further implies that students should learn that it is acceptable in the science community to interpret a phenomenon in different ways. Thus, different findings in the same practical do not necessarily mean that something was not done correctly by students.

2.1.2.6 The relationship between scientific theories and laws

Scientific theories are described by Abd-El-Khalick et al. (2002) as explanations for observations that have been established over a period of time and they are based on indirect evidence, so they cannot be tested. Through a theory, a lot of observations, related and unrelated, can be explained and the explanations can even be extended to non-observable situations. On, the other hand, scientific laws are statements or descriptions of relationships based on observable phenomena. Abd-El-Khalick et al. (2002) also point out that students often hold the incorrect view that theories can be changed into laws if there is supporting evidence for a particular observation. It is important that science teaching should develop students' understandings of the difference between a law and a theory. Laws are based on what is observed. They describe what happens whereas theories explain why things happen (Lederman, 1999).

2.2 Instructional practice

It is logical that in attempting to give meaning to the concept of "instructional practice" a description be given of the term "instruction". The term *instruction* has been used synonymously with teaching (Bruner, 1966). Currently, debate rages on about whether or not the two terms mean different things and which of them is the broader and more encompassing term. Some authors are of the view that instruction should be taken to mean all that is done by the instructor (and others for example, teachers, curriculum developers, headmasters, education officers, etc.) to support and facilitate students' learning. In this view, instruction encompasses the whole process of communicating information to the learners, planning and stimulating relevant learning activities and assessing and evaluating the effect of those activities. (Romiszowski, 1984)

2.3 Theoretical framework

The literature on the NOS forms the framework for this study. The collection of data was limited to selected NOS tenets. The way understandings are categorized here is discussed below. The discussion also covers how teachers teach about NOS as well as whether there are links between those selected NOS understandings and the teachers' instructional practices.

2.3.1 Categorizing teachers' NOS understandings

Tsai (2003) has categorized teachers' NOS understandings, which he calls scientific epistemological views, as either positivist or constructivist. Positivists hold the view that scientific knowledge is more valid than other forms of knowledge. According to positivists the laws and theories generated by experiments describe the real world and science is the primary source of truth. Constructivists, on the other hand, have been described as subscribing to such views as: scientific knowledge is tentative and science is not the primary source of truth (Tsai, 1998). Other constructivists' views include saying that there is no one method in science and scientific observations are fettered with human preconceptions.

Some scholars (for an example Abd-El-Khalick et al., 2000; Kang et al., 2004) have categorized the individuals' NOS understandings as either naïve/inadequate or sophisticated/adequate. Teachers can be described as harboring naïve understandings if they subscribe to such notions and beliefs as: scientific knowledge is certain and there is a fixed, true and "objective" representation of reality; there is one method of science which practicing scientists adhere to; an objective reality which is independent of the knower exists; and scientific observations are free from human preconceptions. Harboring sophisticated scientific epistemologies entails subscribing to such views and ideas as: scientific knowledge is dynamic, tentative, reversionary and the result of active interaction between the knower and the known; there exists multiple truths and realities which are neither fixed nor absolute; there is no one method in science; and scientific observations are theory-laden and depend on the experience and preconceptions of the observer.

It is interesting to note that the naïve/inadequate views correspond with the positivists' views and the sophisticated/adequate views correspond with the constructivists' views as these are described in Kang et al. (2004) and Tsai (2003).

In this study, the categorization of teachers' NOS understandings as positivist/naïve and constructivist/ sophisticated is used as a framework to examine and analyze teachers' NOS views. A few NOS aspects have been selected and were used to collect data about the teachers' understandings of NOS. They are used in order to answer the first research question.

2.3.2 Teaching about NOS

In developing students' understandings of the NOS, the use of explicit rather than implicit curriculum and instructional approaches has been recommended (Bell, 2001; Dekkers, 2006; Lederman et al., 2004; Linneman et al., 2003; McComas et al., 1998; Vhurumuku et al., 2006). Curriculum and instructional approaches are described as explicit when the subject content, teaching methodology and student assessment deliberately aim to develop students' NOS conceptions. Students are taught about the NOS. Their understanding of the NOS is formally assessed. This is in contrast to implicit approaches where students' NOS understandings are assumed to develop as a secondary product of instruction. There is no deliberate effort to teach and assess students' ideas about the NOS. It is assumed that by being involved in science (practicing science) students can develop "adequate" or "desirable" understandings of the nature of scientific knowledge and the scientific process (the development and validation of scientific knowledge).

In whichever way the explicit teaching is done it can also be judged according to the extent to which students are involved in inquiry. Inquiry is about the extent to which teachers give students freedom to solve problems, formulate hypotheses, collect data and make their own conclusions from investigations (Khishfe & Abd-El-Khalick, 2002).

There are also a variety of explicit instructional approaches used to teach students about the NOS. The explicit strategies used to instruct students on NOS can be broadly described as a combination of the explicit-reflective approach described by Khishfe and Abd-El-Khalick (2002) and the historical approaches as advocated by Matthews (1998). In the explicit-reflective approach, which is largely constructivist, the teacher elicits students' prior understandings, explicitly introduces them to selected NOS aspects and then asks them to reflect on their prior ideas. The historical approaches generally ask students to read and reflect on selected historical case studies (e.g. the discovery of penicillin; the discovery of cholera) from a NOS perspective. During class and group discussions students are encouraged to argue for positions, arrive at consensus, or agree to disagree. As part of class and group discussions students are involved in debating socio-scientific issues (Driver et al., 1999).

In the current study, to answer the second question, teachers were examined in terms of whether they teach NOS explicitly or implicitly using the definitions stated above as a guide (i.e. do they teach and assess NOS aspects or are students only left to practice science with the hope that they will develop the desired understandings; are the students given explicit inquiry-orientated or implicit inquiry-orientated activities and whether the explicit-reflective activities are given or not).

2.3.3 Teaching practices

Tsai (2000) explains that the learning environment created by a science teacher i.e. the way the teacher explains scientific ideas and organizes information, can be classified as either constructivist or positivist, which he also refers to as empiricism and realism. These views play a role in the way in which students perceive the way science is practised and therefore the way they prefer to learn science. In a realist or positivist environment there will always be one correct answer and therefore one method of getting to the answer since science is a body of truths and is fixed. A typical example of such an environment would, according to this author, be one where a specific didactic method is emphasized and students would be expected to mimic it accurately. In an empiricist or constructivist environment, on the other hand, a teacher would allow discussions, arguments and negotiations as a process of acquiring knowledge because scientific knowledge is perceived as being produced through creativity and imagination instead of being reproduced, and because it is understood that natural phenomena can be interpreted in more than one ways.

This study sought to answer the third question by looking at instructional practice in terms of whether a teacher creates a positivist or a constructivist environment as it is explained above. Furthermore, whether teachers teach NOS explicitly or implicitly was used as a guide to examine the link between teachers' NOS understandings and their classroom practices. The findings were then used to answer the third research question of this study.

2.4 Literature review

It has been mentioned in the first chapter that having science students with sophisticated understandings of NOS has, over the years, been seen as a way of improving science learning and has been targeted as a goal in the science community in many parts of the world (Abd-El-Khalick et al., 2002; Lederman, 1992). Teachers were seen to be crucial role players in this goal, the assumption being that if their understandings are sophisticated then they would influence their students' understandings by portraying the correct image of science to them (see McComas et al., 1998). Linked to this assumption was that teachers' understandings would be evident in their instructional practices. These assumptions were reiterated throughout the earlier research on NOS which focused on eliciting teachers' understandings as well as exploring ways of improving their understandings (Lederman, 1992; Lederman et al., 1987). Scholars who eventually challenged and tested these assumptions prompted another line of research which then was on how NOS should be taught so that the desired understandings in students can be achieved. Inquiry-orientated activities as well as teaching NOS aspects as part of the curriculum and assessing them were some of the methods explored (see McCommas et al., 1998). Lederman (2006) states that research from as early as the nineties focused on these teacher instructional practices to explore their effectiveness or otherwise in improving students' NOS understandings. The review of literature below is on research conducted in various parts of the world to find out if teachers have the desired NOS understandings; how teachers should teach NOS so that students' understandings can be improved and if these understandings influence their instructional practices or not.

2.4.1 Studies done on teachers' understandings of NOS

Pioneering work on eliciting teachers' understanding of NOS can be dated back to the early fifties and is attributed to scholars such as Behnke, Miller, Schmidt, Carey & Strauss and Kimball (Lederman, 1992). Researchers only turned their attention to the teacher after other variables such as developing curricula that are designed to improve student understandings had failed to produce the desired results (Lederman, 1992; 2006). The first step in this direction was obviously to assess the teacher's understandings (Lederman, 1992). This research concentrated on what the teacher knows about NOS since a direct relationship between teachers' and students' NOS understandings was assumed (Lederman, 2006; Lederman et al., 1987). The studies, according to Lederman (1992), span more than two decades with each study revealing results that were consistent with earlier findings irrespective of where they were conducted. Lederman (1992) states the first assessment on teachers' understandings of NOS to have been in Minnesota in the early fifties. The study revealed teachers to possess naive understandings of NOS. Similar results were found throughout the sixties and the seventies by Behnke; Miller; Schmidt as well as Carey & Strauss, to mention but a few (Lederman, 1992). Studies that followed much later, however, revealed some teachers to hold a variety of understandings, some sophisticated and some naïve (for an example Lederman, 1999; Lederman et al., 1987). These authors found teachers to hold a wide variety of conceptions or understandings of NOS which differed in complexity. These results were obviously disappointing to the science community and this shifted the focus to ways of improving teachers' NOS understandings (Lederman, 1992). Studies on what the teacher did instructionally emerged much later (Lederman, 2006) and literature shows that the research effort on the teacher led to, amongst other things, a general consensus that teachers need to teach NOS tenets if they are to change students' naïve NOS understandings. This, as well as the research efforts in South Africa, is part of the discussion in the paragraphs to follow.

A review of literature on studies conducted in South Africa in pursuit of this aim suggests that the research only started much later than in other countries. It only started after the introduction of the new curriculum, the NCS, in schools. A study by Dekker et al. (2003) conducted on a group of teachers who had several years of teaching experience suggested that the teachers in South Africa also hold naïve understandings about NOS as it was the case with other countries. Another by Linneman et al. 2003, conducted on teachers from a different province supported the findings made by Dekker et al. (2003). The two studies, then, made similar conclusions that: teachers in South Africa hold naïve understandings of NOS. In their conclusions Linneman et al. (2003) further highlighted the possibility of teachers in South Africa having little, if any, formal exposure to the NOS construct. These results have, as in other countries, prompted research on teachers' instructional practice in addition to only knowing the teachers' understandings. Lederman (1992) points out that throughout the world the current research efforts to assess teachers' NOS understandings are now focusing on the realities of the teachers' instructional practices and this seems to be the trend even in South Africa.

2.4.2 Studies done on teaching about NOS

This line of research, according to Lederman (2006), started in the late 1900s in some countries and early 2000s in others. As a consensus had been reached in the scientific enterprise that students' NOS understandings need to be enhanced through what the teacher does instructionally, researcher explored and recommended a number of ways in which teaching could enhance the students' NOS understandings. For an example Driver et al. (1999) as well as Oguniyi (2006) argue that argumentation is a core activity of scientists and they showed in their studies that it does enhance students' understandings. Some efforts, however, followed another line and explored the effect of teaching NOS as the way of changing students' understandings. The research effort that finally emerged out of this was on whether teaching NOS should be done explicitly or implicitly. The studies to that effect initially focused on inquiry-orientated activities as the scientific activities that would enhance students' NOS understandings (Lederman, 2006). It emerged from several researchers (for an example Bell, 2001; Eick, 2000; Khishfe et al., 2002; Lederman et al., 2004) that teaching NOS effectively can only be achieved if it is done explicitly as it was explained earlier. Bell (2001) reports on a study conducted by German where implicit approach to teaching NOS aspects failed to change the naïve NOS understandings in pre-service teachers. In Lederman et al. (2004) both students and teachers participated in the study and major enhancements of NOS understandings were observed from both groups. In Khishfe et al. (2002) an explicit reflective inquiry-orientated activity improved understandings of sixth graders. More evidence in support of explicit teaching is also reported in Irez and Cakir (2006) as well as Clough and Olson (2008). In both studies the research was conducted on teachers and the findings were consistent with earlier findings. A contradicting revelation was, however, made by Khishfe et al. (2006). In the study mentioned NOS aspects were integrated with science content for one group and not for another and in the end the students' understandings improved for both groups. The implication for this is that there is still much ground to be covered in terms of research about teaching about NOS.

A review of literature shows very few studies conducted on teaching about NOS in South Africa (Vhurumuku et al., 2009). The studies by Dekkers et al. (2003) as well as Linneman et al. (2003) have been on assessing teachers' understandings of the NOS. Their findings match those made internationally which revealed that teachers harbour inadequate understandings of NOS (e.g. Abd-El-Khalick et al., 2002) and that these understandings have a bearing on how teachers teach about the NOS. Other studies (Dekkers, 2006; Ogunniyi, 2006) show that developing teachers NOS conceptions have an impact on their abilities to teach about the NOS.

2.4.3 Studies done on teachers' understandings of NOS and instructional practices.

As it was mentioned earlier, research concerned with teachers' NOS had initially focused on what the teacher knew to the exclusion of what the teacher did instructionally (Lederman, 1992; 2006). A review of literature suggests pioneer work in this direction to have started only in the late eighties. Lederman et al. (1987) reported on a study where the conclusion was that possessing valid NOS understandings does not necessarily result in those understandings being reflected in a teacher's teaching practices. Similar findings are also reported in Abd-El-Khalick et al. (1998). In the study mentioned, the teachers were found to hold sophisticated understandings about some aspects of NOS and naïve understandings about others. Mellado (1997) as well as Lederman (1999) also, could not find correspondence between teachers' NOS understandings and their classroom practices. On the other hand, studies by Hashweh (1996) and Tsai (2002) revealed that teachers' beliefs about science do enhance or affect a teacher's instruction. Other scholars, for an example King, Shumow and Leitz (1999) as well as Kang et al. (2004) showed in their studies that the teachers' naïve understandings are reflected in their practice but the sophisticated ones are not. This was also supported by findings of a later study by Tsai (2006). It is logical to conclude from the findings mentioned above that more work still needs to be done on the effect of a teacher's NOS understandings on instructional practice.

There does not seem to be any documented study in South Africa that was conducted in this direction.

2.5 Conclusion

Most of the research relevant to this study, which has been done on NOS, has been on teachers' understandings of NOS than on the link between the teachers' understandings and their instructional practices. There seems to be a consensus amongst researchers that teachers, generally, harbor naïve or inadequate understandings of NOS, however, the relationship between their understandings and their teaching practices seem not to be clearly understood. In the next chapter the methodology for this study that seeks to add to the work already done is discussed in detail.

CHAPTER 3

Research Methodology

3. Introduction

This Chapter discusses the research design and methodology under the following headings: research design; overview of methodological approaches; sampling and participants; data collection instruments and procedures; data analysis. Issues of validity, reliability and trustworthiness relevant to the study are also examined.

3.1 The research design

A qualitative approach has been used in this study to elicit teachers' understandings of NOS as well as to establish whether these understandings translate into their instructional practices. This approach has been used successfully by researchers such as King et al. (1999) and Tsai (2006). Using a case study approach, the research design for this study involved interviewing teachers for their NOS understandings and observing their lessons to ascertain their instructional practices. Data was analyzed using by typological analysis (Hatch, 2002) and interpretive analysis (Gall, et al., 1996). Three Grade 10 teachers from Vosloorus, a township situated south of Johannesburg in the Gauteng province were interviewed and their lessons observed and analyzed with the aim of unraveling how NOS understandings interacted with instructional practices. Interviews to investigate teachers' understandings of NOS have been used successfully by other researchers (Abd-El-Khalick et al., 2002; Ogunniyi, 2006). Grade 10 teachers were chosen because they had been implementing NCS for two years in 2007, the year in which data was collected.

Figure 3.1 below summarizes the research methodology used for this study.

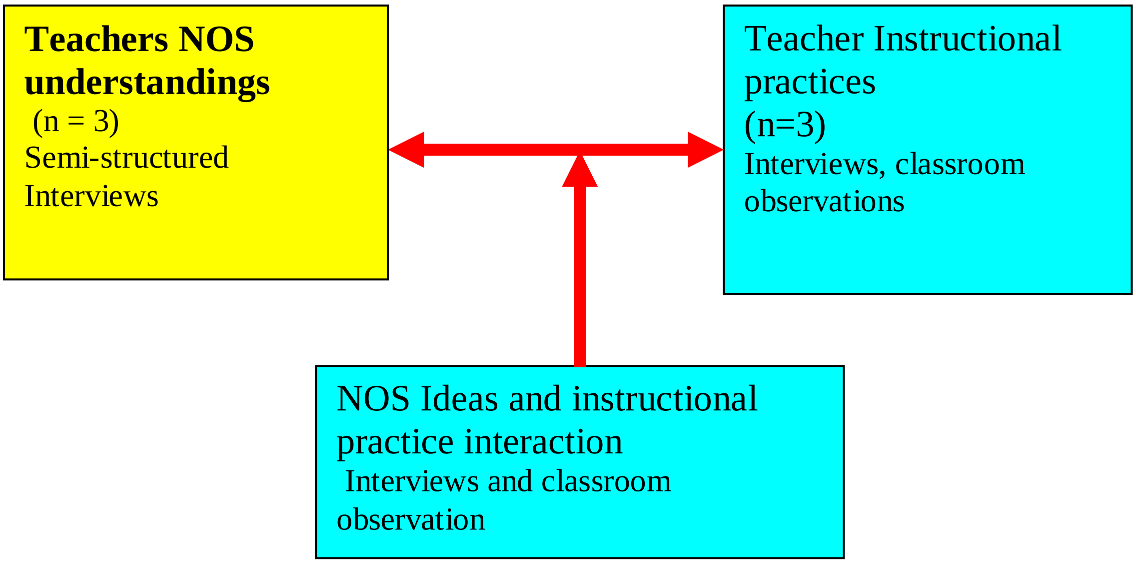

Figure 3.1 A summary of study's methodological design

3.2 Methodological approaches to studying NOS and instructional practices

In the paragraphs below the approaches used in earlier studies to explore NOS understandings and instructional practices are discussed.

3.2.1 Methods used to study teachers NOS understandings

Pioneering work on eliciting teachers' understanding of NOS can be dated back to the early fifties and is attributed to scholars such as Behnke; Miller; Schmidt; Carey and Strauss and Kimball (Lederman, 1992). These studies span two decades and were predominantly quantitative with large samples used for the research. It seems it was then convenient to use the quantitative approach and large samples because research on the concept of NOS had never been done before so the studies were mainly surveys aimed at collecting data from as many participants as possible. According to Lederman (1992), the instruments used such as the Test on Understanding Science (TOUS), the Wisconsin Inventory of Science Processes (WISP) exam, by Carey and Strauss; the Nature of Science Scale (NOSS) used by Kimball, were appropriate for the large samples used then. In current times open ended questionnaires have been used to assess teachers' understandings of NOS (see for example Hashweh, 1996;

Khishfe et al., 2006; Lederman, 1999; Liu et al., 2007). A popular instrument has been the Views of Nature of Science, VNOS form C questionnaire developed by Abd-El-Khalick et al. (2002). Adapted forms of this instrument have been used in a number of researches in various countries. Some of the questions in this questionnaire are used in this study.

Some recent studies have also combined open-ended questionnaires with interviews. Examples include: the study by Liu et al. (2007) where a sample of 54 prospective teachers participated in a study by responding to a questionnaire and follow-up interviews; a study by Akerson, Buzzelli and Donnelly (2010); and another study by Guerra-Ramos, Ryder and Leach (2010). In these examples questionnaires were administered to large samples and then followed up with interviews of smaller groups.

In South Africa, researchers have used a combination of qualitative and quantitative approaches to study teachers NOS understandings. For example, Dekkers et al. (2003) and Linneman et al., (2003) used the VNOS questionnaires on a large sample of teachers. Linneman et al. (2003) used a questionnaire in conjunction with group interviews to assess teachers' understandings of the NOS. The questionnaire, however, was mainly used to stimulate interest in NOS for later discussions during interviews rather than to elicit teachers' views of NOS and it was developed specifically for the study and was validated through piloting, critique and statistical analyses.

3.2.2 Methods used to study teachers instructional practices

Many techniques have been used by researchers to capture what happens in a teaching environment, be it a classroom or a laboratory. A common approach has been classroom observation. Classroom observations have been used to study instructional practices by many researchers (Lederman et al., 1987; Lederman, 1999; King et al., 1999; Tsai, 2006). To collect data during classroom observations, various instruments and techniques have been used including: video-tapes; audio-tapes; and field notes. For this study field notes were used. Field notes have been used successfully by for example, Lederman et al. (1987) who manually recorded everything that happened in the classroom without following a checklist. Cohen and Manion (2000) refer to this kind of observation as unstructured. Classroom observations can be described as participant or non participant observations, referring to the role of the observer (Hatch, 2002). For this study non participant observation was used.

3.3 Sampling and participants

The sample consisted of three teachers, who were purposely selected from a population of seven Grade 10 Physical Science teachers who had responded positively to a request to participate in the study. The teachers were approached at a Physical Science teachers' monthly meeting of the seven high schools in the township. Some, amongst the seven teachers had completed a forty-hour training course offered by the Department of Education on the new curriculum approach, the National Curriculum Statements (NCS). The three teachers were selected because they readily gave their consent to participate in the study. Additionally they held a common minimum qualification which is a three-year diploma in science teaching, and had been teaching science for more than ten years. The three of them had been teaching science in Grade 10 since the inception of NCS in 2006 and had undergone the forty-hour training course on NCS offered by the Department of Education. Their average teaching experience was thirteen years. Details about each teacher are given below. For ethical reasons, the names used below and throughout this report are not their real names.

Mrs. Mafike was a forty-three year old lady, specialized to teach science. She holds a three-year diploma in teaching. She had eleven years of science teaching experience and twelve years experience of teaching other subjects. She had recently completed an Honours degree in Education. She believed that scientific knowledge is acquired through investigations and that students learn best when they observe in class.

Mr. Phiri, the only male among the participants, was also specialized to teach science and also holds a three-year diploma in teaching. He was in his late thirties and had twelve years of experience teaching science. He had not furthered his studies beyond the three-year diploma. He taught Mathematics as well. He viewed science to be an enterprise that is defined by practical experiments and held the view that students are best taught science by using practical work.

Mrs. Luso was a lady in her mid-forties. She had also specialized to teach science in her three-year diploma in teaching. She had sixteen years of science teaching experience. She had furthered her studies at a nearby university and had completed an Honours Programme in Science Education and was enrolled for a Masters' Programme. She believed that students learn science best when they "do science and act like scientists" but she also felt compelled to teach students expected observations, whilst doing inquiry, for examinations' purposes.

3.4 Data collection

All interviews and lesson observations were done by the researcher in person. The interviews were conducted before and after classroom observations, at each teacher's school and during their free time. Classroom observations were conducted on the day following the interviews and during the normal teaching time for each teacher. Follow- up interviews were then conducted on the same day as the lesson observation. The researcher collected data in the form of notes during classroom observations. There was no observation schedule. This data collection method was selected for this study because Cohen et al. (2000) asserts that the observer gets to collect first hand data that participants would not normally talk freely about and this first hand data is collected from natural settings. The disadvantages of collecting notes are, however, acknowledged and they are that the researcher ends up with pages and pages of notes and that some critical moments may be missed by the observer during note taking (Gall et al., 1996).

3.4.1 Teachers NOS understandings

Teachers' NOS understandings were elicited through semi-structured interviews (see Appendix A). The interviews were conducted at each of the teacher's school, so they were conducted separately. They were conducted during the afternoons so as not to disturb the schools' programmes. In one of the schools, the afternoons are used by the teachers to plan and organize themselves for the next day with the students having already left, but in the other two schools the teachers were ready to leave for home but had to wait for the interviews. They were, therefore conducted over three separate afternoons. An interview guide with core questions was used. The pre-observation interviews that were based on the core questions appearing on the schedule took between 40-45 minutes for each teacher. Each teacher was asked the core questions from the schedule and thereafter probing was done around these questions to get clarity of responses. The core questions were based on four selected NOS aspects. The four NOS aspects are:

- What is science?
- The role and purpose of experiments in science.
- The role of scientific theories and laws in science.
- How scientists settle scientific disputes.

The core questions forming the interview guide were:

- What, in your view is science? What makes science different from other disciplines of inquiry such as religion or art.?
- What is an experiment? Why do scientists do experiments?
- Is there a difference between a scientific theory and a scientific law?
- Some astrophysicist believe that the universe is expanding while others believe that it is shrinking, still others believe that it is in a static state with no expansion or shrinkage. How are these different conclusions possible if all these scientists are looking at the same data?

These questions came from the VNOS questionnaire as used by Dekkers et al. (2003) for the South African settings.

3.4.2 Classroom instructional practices

The data for classroom instructional practices was collected through classroom observations and interviews.

3.4.2.1 Classroom observations

For classroom observations there were no instruments designed instead the researcher sat in the classroom and took notes. The classroom observations focused on whether teaching NOS is done as described in Bell (2001); Khishfe et al. (2002); Lederman (2006) and Matthews (1998). This is about explicit teaching of NOS. While there was an effort to gather everything that happened during the lesson, the observations were guided by the following guidelines aimed at ascertaining how teachers taught science and the NOS:

(i) Lesson introduction and closure
(ii) Aim of the lesson
(iii) Teachers' role and students' role
(iv) Teacher-student and student-student interactions
(v) Reference to NOS aspects
(vi) Lesson exercises
(vii) Classroom discussions

Each teacher was observed for one lesson. The classroom observations were conducted on a day following the pre observation interviews but during teaching time. They were limited to one period at a time per teacher, the duration of which was thirty minutes. The researcher came into the classroom before the lesson started. She was introduced to the students as a student from a university who had come to observe a lesson. She was then ushered by the teacher to a seat at the back so that she was unobtrusive. This procedure was followed at each of the three schools. Field notes were taken while teaching was taking place. A narrative description of everything that happened in the classroom served as a source of data. The notes were later transcribed verbatim (see Appendix C)

3.4.2.2 Interviews

In addition to eliciting the teachers' NOS understandings, the interviews also sought to verify and get better insight about the teachers' teaching philosophies and the lessons observed. Hatch (2000) notes that when such interviews are handled properly, the interviewer even listens for special language and other clues that reveal the unique perspective of the respondent.

The following questions, asked during pre-observation interviews, were used as guides to elicit the teachers' teaching philosophies:

- What is the best way to teach students about science?
- What is your science teaching philosophy?

- What problems do you face in trying to achieve LO3?
- Do you plan to teach students about the NOS? Do you consciously plan to teach them explicitly?

The second set of interviews was conducted immediately after the lessons during the teachers' free periods. These interviews were not based on any core questions but on what was observed since they were meant to get clarity and verify what the researcher had observed.

An audio tape was used to record all the interviews sessions. The reason for choosing a tape recorder was so as to avoid; distracting the interviewee, disturbing the flow of the interview as well as the unconscious selection of data that might result from taking notes manually (Gall et al., 1996). The teachers' responses were transcribed verbatim (see example Appendix D).

3.5 Data analysis

The data for this study was analyzed typologically because there are selected aspects of NOS that the interviews were based on.

3.5.1 Data from the interviews

The teachers' responses on to NOS questions were analyzed using typological analysis (Hatch, 2002). In this analysis, data are categorized using predetermined typologies either emerging from the data or derived from the literature. The transcripts were checked for any emerging characteristics that are consistent with the knowledge of the selected aspect of the NOS. Teachers' responses were read several times to get the essence of the whole text for each response. The text was then read for the purpose of analysis, bearing one typology in mind. Statements/phrases in the text containing information related to each of the typologies were underlined and coded for the respective typologies. The sentences that represented teachers' understandings of the selected NOS aspects were coded. The teachers' understandings were summarized around major themes which are: what science is and how it differs from other disciplines, the purpose of experiments in science, their understanding of the roles of scientific laws and theories; and how scientists solve disputes. This data was represented in a table where it can be classified as either positivist or constructivist. This method of analyzing data was also used in Dekkers et al. (2003) and the findings would lead the researcher to the answer for the first research question.

The data from the questions on how teachers teach was also treated in a similar manner and also represented in tables. This data was used to compliment the data from the classroom observations and help in answering the second research question.

3.5.2 Data from classroom observations

Notes on teachers' practices during the observed lessons were also analyzed using typological analysis (Hatch, 2002) as well as interpretive analysis (Gall et al., 1996). The text was read and re-read, and statements/phrases containing meaning units relevant to teacher practices and NOS understandings were underlined to identify typologies.

The classroom observations notes were also checked for emerging characteristics on; whether teachers teach NOS aspects or not; the type of lesson conducted; what they believe is the best method of teaching science so that these could be linked to their NOS views. The characteristics were coded and these were recorded in a table. It was then established if there was any correlation between the data from the interviews and the teachers' classroom activities so as to be able to compare the findings with the findings about the teachers' NOS understandings. This would help the researcher answer the third research question.

3.6 Issues of validity and reliability

Breakwell, Hammond and Fife-Schaw (1995), asserts that the data elucidated through interviews is not less valid or reliable than the data elucidated through other methods, such as questionnaires, as long as the respondents are willing and able to give answers that are accurate and complete. The author goes on to give methods that can be used to check for internal consistency in the respondents' answers such as complementing data with other sets of data. Issues of reliability and validity in interviews were taken into consideration in this study. The interview schedule used in this study was adapted from an instrument that had already been used, the VNOS (see, Dekkers et al., 2003). The schedule was also checked by the supervisor, also for content validity for those questions not taken from VNOS. This ensured that bias was minimized through making sure that the questions were not ambiguous.

Furthermore, validation was further ensured by piloting the interview schedule on some of the teachers that had responded positively to the request to participate in the research. Feedback from the teachers was mainly used to improve the language of the questions. The results of the piloting, however, do not form part of the results analyzed for this study.

The fact that interviews were audio-taped also ensured accuracy and reliability by eliminating unconscious selection of data that would result if responses were written down during the interviews. The interview transcripts were given to the participants for respondent validity before the data was processed. For classroom observations the notes taken were cross-checked against the interview results for consistency.

3.7 Ethical issues

Griffiths (1998) suggests transparency and honesty as necessary measures of ensuring that a researcher observes ethics. For this study the participants were given an information sheet (Appendix B), to read about the study and the researcher when they were requested to participate in the study. The information sheet explained what the research was all about, how it will be conducted what the data will be used for. It also assured the respondents that declining to participate will not have any negative consequences on them or the school and that they were free to withdraw from participation at any time. The respondents were also informed that their identities were to be concealed by using pseudonyms in the report. The information sheet was accompanied by a letter where they were given the freedom to either accept or decline to participate in the study which is also a consent form to be audio-taped.

Permission to conduct the study at the schools was also requested and granted by the principals of the schools where the respondents work (Appendix E). The request letter to the principals was accompanied by a form that also allowed them the freedom to either accept or decline that the study be conducted at their schools.

3.8. Conclusion

The research on record, on teachers' understandings of NOS, was a qualitative research and the findings are generally consistent with international trends. This study, though conducted on a smaller scale, will hopefully add more light to what has already been explored because of its qualitative nature.

In the next chapter the results of this study are analyzed and discussed.

CHAPTER FOUR

Results and Discussion

4. Introduction

This study set out to investigate the following research questions:

1. What understandings about the NOS are held by the teachers?
2. How do South Africa's science teachers teach about NOS?
3. What is the nature of interaction (if any) between teachers' NOS conceptions and their instructional practices?

In this chapter the results are presented and discussed according to the above research questions. The chapter is therefore divided into three major parts based on these three questions.

4.1 Teachers' understandings about the nature of science

Teachers' understandings on four aspects of the NOS were elicited. Table 4.1 below summarises the understandings of the three teachers on the four selected NOS aspects as obtained from semi- structured interviews (see Appendix D). The table gives the major idea expressed by the teacher on each of the explored NOS tenets as an exemplary statement (written by the author), which captures the words expressed by the teacher during the interview. Table 4.1 is then followed by a description and discussion of the three teacher's understandings on each of the selected NOS aspects, which are: understandings about what science is; the role and purpose of experiments in science; understandings about scientific theories and laws; and why scientists arrive at different conclusions about phenomena.

As mentioned in Chapter 3, the three teachers who participated in the study were given pseudonyms of Mrs. Mafike, Mr. Phiri and Mrs. Luso.

Table 4.1: Teachers' understandings on selected NOS aspects

	TEACHERS' UNDERSTANDINGS		
	Mrs. Mafike	**Mr. Phiri**	**Mrs. Luso**
Understandings about what science is	Scientific knowledge is based on empirical investigations other disciplines are not. Scientific knowledge changes in light of new evidence. Science as application of knowledge Scientific knowledge can be put to test Science follows a method or procedure An absolute scientific truth exists.	Science is based on practical work and can be proven. Other disciplines based on beliefs, no proof. Science always follows a method especially school science.	Science is a study of natural world based on experiments. Science is not based on faith (like religion) but on evidence. When doing experiments scientists do not always follow step by step procedures but at school a method has to be followed.
Role and purpose of experiments in science	Experiments are for verifying what is known (scientific theory). Not all scientific knowledge is based on experiments Experiments show us that things are real	Experiments are essential for discovery of new scientific knowledge They are used to reveal the absolute truth. Observations are an important source of scientific knowledge Scientists do experiments to prove their theories	Experiments are done to prove theory Experiments are done to show that things are real All scientific knowledge is based on experimental evidence
Scientific theories and laws.	Theory is a way of thinking or beliefs held by scientist Law is a procedure followed by scientist during investigations I don't have any example of a law Theories can change in the light of new evidence	Theories are based on what you can see and can graduate to become laws. Laws have been proven and can not be changed Theories can change in the light of new evidence	Theory is an idea held by a scientist about something Scientific theories can change when new things are discovered Theories and laws are similar. Laws can also change
Why do scientists arrive at different conclusions about phenomena?	Scientists may produce different theories because of differences in their beliefs. Scientists can come up with different ideas (theories) from their investigations because they perform different investigations Failure to follow procedure might result in scientists arriving at different conclusions.	Scientists may produce different theories because of differences in their beliefs. Failure to follow procedure might result in scientists arriving at different conclusions.	Scientists may produce different theories because of differences in their beliefs. Failure to follow procedure might result in scientists arriving at different conclusions.

4.1.1 Teachers' understandings about what science is

On the issue of what science is and how it differs from other disciplines such as religion, the three teachers expressed a mixture of naïve and sophisticated understandings (Abd-El-Khalick et al., 2000; Kang et al., 2004; Southerland et al., 2003). Mrs Mafike describes science as a theory and a collection of principles and laws and that the discoveries and investigations are what make science differ from other disciplines. She expressed this view in line 2 of the transcript as follows:

> …science is a theory which has been investigated by scientists…and they made some discoveries… and all the principles and the laws are described as science….the difference is in science we discover.

On this aspect of the NOS, Mr. Phiri's understandings can also be described as largely naïve and empiricist/positivist. He compared science with religion by saying that scientific knowledge could be "proven" through experimental investigation while in religion one "simply has to believe". He expressed his view as follows:

> [Science] is a practice that, eh, mostly embraces, eh, the practical…in religious practice, there you mostly believe but in science practice you, you can prove…

To Mrs. Luso as well, the major difference between science and non-science (e.g. religion) was that science was based on experiments and did not rely on faith and beliefs as it is the case with religion. She was a strong believer in empirical evidence. She said:

> It's the experimentation that is involved in science…but in science they don't use faith or beliefs, they discover things…but in science we want to see a substance, hold, see, touch, see or anything.

The three of them portrayed a sophisticated understanding that investigations are important in science but that they are what separate science from other disciplines is a naïve understanding.

The three teachers' understandings on the issue of scientific method can also be described as both naïve and sophisticated. Mrs. Mafike subscribed to the naïve understanding that there is a method of science followed by all scientists (see transcript line 26). She had this to say:

> …Science is a theory which has been investigated by scientists… and then therefore you conduct an investigation by following instructions.

Mr. Phiri and Mrs Luso concurred, although Mrs Luso added that this was more so for school science compared to professional science. She expressed her views as follows:

> It depends on what you are doing the experiment for and what is it that you want. I think if you are studying a new thing you won't need a procedure…if you are in a class, yes, because you follow steps but if you are discovering a new thing you can't.

In her view therefore, school science was different from professional science (science as practiced by scientists operating at the frontiers of knowledge). Her understandings about how professional scientists work are obviously sophisticated but they are naïve about how science should be practised at school, therefore, she has a mixture of naïve and sophisticated understandings on this issue. Mr Phiri also indicated that there are situations where the step-by-step method cannot be followed. The two teachers' understandings can be described as both naïve and sophisticated, which are consistent with what is desirably expected from teachers operating at that level (Lui et al., 2007).

All three teachers (Mrs. Mafike, Mr Phiri and Mrs. Luso) also appear to subscribe to the general understanding that scientific knowledge is empirically based, testable and largely dependent on experimentation and observation. This is partly evidenced by the fact that the words practical, proof, experimentation, test and investigation appear in each of the three teachers' responses to the question of what science is. Mrs. Mafike, for example in line 4 of the transcript, expressed her view as follows:

> …in science we conduct a practical investigation, then you test a hypothesis…the investigation that has been applied…results are based on the research that was done.

Mr Phiri described science as a practical-driven practice and that scientific knowledge could be "proven" through experimental investigation and be seen. The following is an extract from his responses:

> …in science practise you can prove, you do something that you can see…something that people can see…you know that if you combine this and this and this, the colour changes…

Mrs. Luso also subscribed to the understanding that experimentation is the key in science and that in science one wants to see, hold and touch substances as it was indicated in an earlier extract.

That teachers would hold such naive understandings about the NOS is not surprising as teachers around the world have been reported to subscribe to such understandings (see, Abd-El-Khalick et al., 2000; Lederman, 1992; McComas, 1998).

4.1.2. Teachers' understandings about the role and purpose of experiments in science

As it was the case with teachers' understandings about what science is, the teachers' responses to probes on the role of experiments in science revealed that they harboured both naïve and sophisticated understandings. Mrs Mafike's response was rather vague because she merely gave steps for conducting an investigation in explaining what an experiment is. She also indicated that experiments are conducted to make discoveries. She expressed this view when she said: "…to test and to make discoveries". (line 12)

This is a positivist understanding implying that scientists conduct experiments and unveil an absolute truth.

According to Mr Phiri, the purpose of experiments in science was not to test predictions but to prove theories and laws and to show that ontologically things are real (ontological truth). He said:

> …[Scientists] they mostly do experiments to prove their theories… so the modern scientists (pause) they are taking it that one, what was ,eh, discovered and said by ancient scientists and they want to test it how, if it's really that

> thing…

More or less the same understandings were also held by Mrs. Luso. She had the view that experiments are done to find something out. She expressed this by saying:

> Experiment is whatever you do to find out something.

but thereafter revealed a naïve understanding implying that all experiments are hands on by saying

> … if you want to find out something you must take things and work with them, experiment with them...

She further expressed her view about why scientists do experiments by saying:

> …to find out new things. To discover new things…[for the] development of scientific knowledge, we need experiments…

These are obviously naïve understandings about the NOS and could also be described as inadequate (Abd-El-Khalick et al., 2000) because it is now generally accepted that science does not seek to prove, in the mathematical sense of proof, but rather to test predictions (McComas, 1998) or to falsify in the sense of Popper (1972).

But she also appeared sophisticated when she said**:**

> [Experiments are done] to falsify maybe what had been said before…improve some of the things that were done before because of new technologies.

The statement suggests that she is conscious that experiments are also used to test predictions, implying that experiments are aimed at achieving better understanding of phenomena by either confirming or disputing knowledge that had been agreed upon (Oguniyi, 2006).

4.1.3. The relationship between theories and laws and their roles in science

In response to the question about what scientific theories and laws are, Mrs Mafike said: (see line 36 and 38)

> …a theory is a way of thinking; a law is a procedure to follow when conducting an investigation.

Her response about a theory can be described as partly adequate because Abd-El-Khalick et al. (2002) describe theories as beliefs or explanations that scientists have about phenomena. More probes were necessary for a better understanding of what she meant about theories but on the other hand her description of a law clearly shows that she has no understanding of what a law is.

Mr Phiri showed some understanding about scientific theories and laws. He had this to say:

> ...a scientific theory it's when a scientist see something, neh, and he think there may be something that causes this something that you cant see… they now come up with a theory that, ok, this particular thing is doing this because there might be 1,2,3, so that is a scientific theory.

This might be considered as a sophisticated understanding because theories come from sets of assumptions about phenomena and are inferred explanations, an idea expressed in Abd-El-Khalick et al. (2002). He further went on to express his understandings about laws by saying:

> ...but when it comes to law, a theory can be changed, when it comes to law, a law is something that, eh, it's proven, it can be seen and it can't be changed…

The understanding that theories can change is a sophisticated one but the one that laws can be seen and are proven is a naive one. Abd-El-Khalick et al. (2002) describes laws as concise statements of relationships among observable phenomena and these statements have been found to be experimentally valid for a wide range of phenomena. It is not clear whether he meant the same when he said laws can be seen and cannot be changed. A further probe should have been done at this stage as well to get a clearer understanding from his response.

Mrs Luso did not say much about theories and laws but her understandings can also be described as a mixture of naïve and sophisticated ones. She emphasized a similarity between a theory and a law by saying:

> …theories can change; a law can also change… so there is a similarity.

Further probes were also necessary at this stage to elicit more. Both Mrs Mafike and Mrs Luso could not think of examples of scientific theories and laws but Mr Phiri named the kinetic theory of matter as well as Boyle's law as examples.

All three teachers also had the understanding that new evidence result in a theory being changed. Mrs Mafike said: "[a theory] it cannot change without new evidence", and Mr Phiri said: "**…**some other scientists, they find some other proofs that make theories to change". Mrs Luso, on the other hand was not very sure but she did express a view that both theories and laws can change. Her exact words were: "Yes, I think it [theory] can change because if someone can discover something…"

What is not clear and was not adequately probed was whether the respondents are aware that new evidence either refutes or strengthens a particular theory (Abd-El-Khalick et al., 2002).This supports findings from earlier studies. For example, a naïve understanding held by teachers, that new evidence automatically changes a theory is reported in Dekkers et al. (2003) as well as in Liu et al. (2007).

4.1.4 Resolving scientific disputes

On the question of why scientists come up with different conclusions from observations of similar phenomena, all three teachers expressed the understanding that the knowledge that an investigator has shapes the investigation. Mrs Mafike expressed hers as follows: (see line 46)

> I believe scientists are different… they've got some belief or their way of thinking…I can say their philosophy it's the one that guided their belief…it means, eh, they are not conducting their investigations in the same way, eh, others they believe they've got their own theories of belief.

Mr Phiri and Mrs Luso also expressed the same sentiments. Mr Phiri said:

> I think it might be because of the beliefs. A certain group might believe in eh, somebody's theory and agree with that particular person because of the ideas and others.

Mrs Luso expressed that:

> It depends on where you come from…so disputes will be difficult to solve because these people will be coming from different points of view.

These are fairly sophisticated understandings implying that teachers understand that investigations can never be totally objective but are shaped by already existing theories, beliefs and experiences that an investigator has (Abd-El-Khalick et al., 2002). The planning, conduction and observations are then influenced by their pre-knowledge. This is then the source of differences in their explanations of data. On this issue, the teachers can be said to hold a sophisticated understanding that scientists do not necessarily have to agree. This finding among teachers is also reported in Dekkers et al. (2003). This understanding, however, was not expressed when questions drawn from school contexts were asked. Mrs Mafike said:

> …maybe they do not follow the correct steps. I can make them change [their results]

while Mr Phiri's response was**:**

> **…**because of some errors that they made and what they believe they will see. You start afresh with them, trying to reduce all the mistakes.

The implication in the above statements is that students make different observations solely because of mistakes they made in the procedure. Mr Phiri on the other hand also acknowledges the possibility of the students' beliefs influencing their observations. Mrs Luso portrayed a mixture of both sophisticated and naïve understandings as it was the case with Mr Phiri. She expressed her views by saying:

> **…**I want them to report what they have observed…after I've taught this is the colour that you were supposed to observe…but I'll encourage them to write what they observed because… maybe the way they conducted the experiment…

She also acknowledged failure to follow procedure as a possibility for different results but she further went on to indicate the importance of reporting what was truly observed. She also appeared to have the idea that for school science, there is some truth that students are supposed to know, irrespective of what they observe. Her exact words were:

> …after I've taught this is the colour that you were supposed to observe you have to know it…

Further probing would have revealed the reason for holding these ideas.

The respondents' understandings on this issue can be described as largely sophisticated because they hold the idea that investigations are never neutral. However, this idea is only true with professional scientists but not with students at school. They seem to strongly believe that at school errors in the procedure which make the validity of observations to be questionable are the main reasons for the explanations to be different. Liu et al. (2007) also made similar findings where respondents hold the view that arriving at a single conclusion seems to be a must in the classroom but not with professional scientists.

4.2 Teaching about NOS

Interviews and classroom observations were used to establish how the teachers teach about NOS. Interviews focused on their teaching philosophies as well as about the explicit versus implicit approaches of teaching NOS, the way the concept is explained in Bell (2001); Khishfe et al. (2002) and Matthews (1998). Some of the interview questions focused on the South Africa's curriculum and were aimed at eliciting how the teachers plan for LO3, the learning outcome in the curriculum that addresses the NOS. Table 4.2 below summarises the major ideas from each teacher's responses to the interviews (see appendix A for questions).

Table.4.2: A Summary of the main ideas about how the teachers teach about NOS.

Major idea	Mrs Mafike	Mr Phiri	Mrs Luso
Teaching philosophy	Students should understand that science is about research.	Students' prior-knowledge should be accommodated in lessons.	Students should be taught to construct knowledge on their own. Students should discover things on their own.
Planning for LO3 achievement.	It is difficult. Students think indigenous knowledge is not science. Indigenous knowledge should be included in lessons.	It is difficult because the method is new. Students think science is only at school. Activities that include everyday life should be planned.	LO3 is time-consuming and students need to learn concepts for exams. Students cannot link classroom work with outside world. Students should be given things to do outside the classroom.
Teaching NOS. (Explicit versus implicit approach)	The response about teaching NOS aspects was vague. Allowing students to observe is the best teaching approach. Elicit their pre-knowledge and use it with new.	Teacher showed no understanding of NOS. Lessons and prior knowledge to be linked. Lessons to include solving problems from outside school, debates, group-work and experiments.	NOS aspects never been taught as topic. Students should do science and be given freedom to work on their own. Students to work even outside the classroom. Exams and overcrowding are limiting factors.

4.2.1 Results from interviews

In trying to elicit whether the sampled teachers teach about NOS and plan for the achievement of LO3 in lessons other than the observed ones, some questions were asked during the interviews. The results are discussed below.

4.2.1.1 The teachers' teaching philosophy

The teachers' responses to the question on their teaching philosophy were silent as far as the value and status of scientific knowledge is concerned, probably because they did not understand the question. The following responses illustrate the point; Mrs Mafike said:

> … The way I teach the science, but I think, eh, I believe it's a good way of teaching." "Eh, I believe in myself and I have confidence…

However, she went on to indicate how she believed scientific knowledge is generated by saying that:

> … I make sure that my students understand that science is about research, it's about the environment…

The implication here could be that the teacher believes that scientific knowledge is generated through research. Mr Phiri's response was:

> …What is taught should be related to what the students know.

Mr Phiri believed in accommodating the students' prior knowledge in lessons. Mrs Luso's response reveals that constructivism is her teaching philosophy. She expressed this by saying:

> …constructivists' way of doing things…they discover on their own… [Or else] they will think science its absolute truth.

This quote implies she believes students should be given freedom to construct knowledge while doing inquiry type of activities. Such activities would help them pick up some of the NOS aspects. The three teachers' teaching philosophies can be summarised as promoting constructivism, research and students' prior-knowledge.

4.2.1.2 Teaching NOS aspects

Responses from all three teachers show that none of them teach and assesses NOS aspects as part of the content. Mrs Mafike and Mr Phiri gave vague answers to questions about teaching NOS aspects, suggesting that they did not have an understanding of what teaching about NOS is. Mrs Luso clearly stated that she had never taught and assessed NOS aspects as part of the content. However, the teaching approaches that the three teachers described as the best methods of teaching have some similarities with the approaches that Matthews (1998) as well as Khishfe et al. (2002) describe. They describe these approaches of teaching NOS as implicit rather than explicit. This appears to be supported by the following quotes:

Mrs Mafike:

> …it's to first observe, they come up, eh, or maybe I can use their own knowledge and then I can apply their knowledge into the new knowledge of science. I can use experiment…so that they can be able to know that science is everywhere, it's around them.

Mr Phiri's:

> …relate knowledge to what students know." "…lessons to include solving problems from outside the school…

Mrs Luso's similar response showed that she believed in inquiry type of lessons. She responded as follows:

> …to do science, they must do science. They must work like scientist, so they must do science…constructivists' way of doing things …I facilitate the teaching and then they discover on their own, hands on

It is evident from these responses that the teachers, even though they are not aware of it, do believe in teaching NOS using the explicit approaches. There were unfortunately no follow up probes on why the teachers do not teach NOS aspects.

4.2.1.3 Planning for LO3 achievement.

On the issue of planning for the achievement of LO3, the respondents showed lack of understanding of this learning outcome. Their responses to the question on problems experienced when planning for this learning outcome were vague. For example, Mrs Mafike's response was:

> …the way the new knowledge, the ethics, the attitudes and also the values, because in LO3 we are trying to incorporate science, the life science, science technology, the environment and the society, so sometimes we identify some barriers, the ethnic issue of the student…

She was also not clear about planning for LO3. She said:

> …we can use our own philosophy maybe our way of thinking, we can apply the existing knowledge that people have and then we can apply it into existing science and we can try to match them…

Mr Phiri stated in his response that he finds planning for LO3 to be difficult because he is not familiar with learning outcomes since they are new. He then indicated that when planning for LO3 achievement students are to be taught such that they are aware that science is not confined to the school environment only. His exact words were:

> …most of the students, neh, they are still eh, believing that the science is something that you do at school, they don't check at how they use it in the community…

He then suggested taking science out of the classroom. The activities he suggested are similar to the explicit approach described in Khishfe et al. (2002). He said:

> …their plans don't have to focus only in class or in a lab, some of the things they'll have to go out and do maybe at home… …activities that mostly include things that happen in every day's life… I like them discuss when they are in class and then sit in groups during experiments, debating…not only giving them class-work…

Mr Phiri might not be conversant with planning for the achievement of LO3, but his idea of how teaching should take place in the classroom is similar to explicit approaches of teaching NOS described earlier.

Mrs Luso concurred with Mr Phiri about students who only see science in the classroom when she said**:**

> …so they don't see the link between the classroom and the outside world.

She then went on to give an example of a lesson that needs to be conducted in order to achieve LO3. The lesson was an open inquiry type of a lesson.

It appears that all three teachers are not familiar with planning for the achievement of LO3. What they describe as the best teaching methods fit into the types of NOS lessons described in Matthews (1998) and Khishfe et al. (2002) as largely implicit approaches to teaching NOS as opposed to explicit approaches. In explicit approaches students are allowed to see and practise science outside the classroom, incorporate their ideas in the lessons, use argumentation to build knowledge and be involved in inquiry type of lessons with the aim of developing their NOS understandings but NOS aspects are neither taught nor assessed. The sampled teachers' teaching philosophies portray teaching methods with NOS elements (see table 4.2).

4.2.2 Results from classroom observations

In all three lessons there was no reference to NOS aspects in the introductions, the aim as well as the closure of the lesson. Not even during the course of the lesson were

NOS aspects ever mentioned. Furthermore, there was not even a reference to LO3 in the introductions and the aims of the lessons. If the development of desirable understandings of NOS aspects in students was targeted, it is not unfounded to conclude that the students were expected to pick these up while they were doing science. This would suggest that the teachers believe NOS aspects can be understood by merely involving students in scientific activities (Hodson, 1996). The methodology of the lessons had some elements of the explicit strategy of teaching NOS described by Matthews (1998) but lacked the deliberate aim to teach about NOS which is to teach and assess the NOS aspects. Advocates of explicit teaching of NOS, for an example, Bell (2001), would therefore, describe these lessons as implicit approaches to teaching NOS.

4.3 The nature of interactions between teachers' NOS understandings and their instructional practices

Results from classroom observations were used to establish whether the teachers' NOS understandings elicited during interviews do translate into their classroom practices. The classroom observations were followed-up by interviews again that were aimed at getting clarity on what was observed in the classroom. These results were also used.

4.3.1. The teachers' classroom practices: results from lesson observations

As said in Chapter 3, the classroom observations focused on whether teaching NOS is done the way it is described in Bell (2001); Khishfe et al. (2002) and Matthews (1998). Four major factors were considered, namely:

- teaching and assessing of NOS aspects.
- the type of lesson presented;
- the type of problem being solved by students; and
- classroom environment.

In one of the observed lessons, which is Mrs Mafike's class, each student was given a copy of an extract. The extract was based on the section of the syllabus on light, waves and sound. The aim of the lesson was stated as being to teach the students about the uses of the knowledge of sound, waves and light to benefit human life and the environment. The teacher selected two students to read the extract out loud to the class. At intervals she would interrupt the readers to help them with pronunciation of words. Examples of how total internal reflection, a phenomenon about light, is used to benefit human life were given in the extract. The students were then told they were to argue for or against the use of this knowledge and the impact it has on human life and the environment. Students were required to also mention and describe other examples where the knowledge of light has impacted on human life. Half the class was instructed to take a position for this knowledge and the other half against it. Members of each group were into discussions for about ten minutes then the teacher called for responses. The teacher wrote the ideas from both teams on the chalkboard and when all seemed to have been said she asked several students to select and explain their individual positions but this time based on the ideas written on the board. She would at times ask one student to comment about another students' position. The students had the freedom to express their opinions and listen to others as well but eventually agree to disagree since they were told to copy all what was written down at the end of the lesson. The lesson seemed to be aimed at highlighting the existence of multiple truths and realities as well as creating a constructivist environment described in Tsai, (2000). However, there was no mention of these NOS aspects in the introduction, the closure or at anytime during the lesson.

In Mr Phiri's introduction the aim of the lesson was stated as to mark the previous day's homework. The students had to solve a mathematical problem. They were, however given the freedom to argue about the solution to the problem. Students selected by the teacher stood up and told the teacher the steps of the solution to write on the chalkboard and others were allowed to argue at the end whether the solution was correct or not. One student was given a chance to write on the chalkboard a method that she had used to solve a second problem. The method was ruled out as incorrect by other students and the teacher. At the end students were told to copy the solution that was agreed upon. The period ended whilst the students were still copying the solution and the class was dismissed (see appendix C). At no stage were NOS aspects mentioned.

In Mrs Luso's classroom the lesson was started by an announcement that students were to sit as groups that had been previously arranged and start with their planning which became evident later that it was a planning of an investigation they seemed to have been briefed about earlier. They seemed to know what they were supposed to do because they quickly settled down and there was some talking and writing amongst group members. The groups consulted with the teacher now and then until the end of the period. On several occasions during the lesson the teacher stopped the discussions and explained to the class what a problem statement and what a hypothesis is. It became evident that each group was given the freedom to plan an investigation on their own. The lesson was, therefore, an inquiry type of lesson. As with the other two teachers' lessons NOS aspects were never mentioned during the lesson. Table 4.3 below summarises the observations made in each of the teacher's lessons.

Table 4.3: Results of the classroom observation for each teacher

Major ideas	Mrs Mafike	Mr Phiri	Mrs Luso
NOS content	NOS aspects not taught as content.	NOS aspects not taught as content.	NOS aspects not taught as content.
Lesson type	Debate.	Mathematical calculation.	Inquiry activity.
Type of problem	Socio-scientific.	Mathematical	Socio-scientific.
Classroom environment.	Students' ideas and opinions produced knowledge.	Students given freedom to suggest solutions and argue.	Students planning an investigation on their own.

The results in table 4.3 above reveal that the three lessons were characterised by what Tsai, (2000) describes as a constructivist environment where students produced knowledge through discussions and doing inquiry exercises. The interactions in the classroom did not portray the teacher as the source of knowledge or a dictator of the process of acquiring knowledge but a facilitator of discussions. Students were learning to solve problems through arguing until a consensus was reached. The lessons were characterised by discussions where students had freedom to express their views and at the same time respect others' views. That is a sophisticated understanding on processes of acquiring knowledge where disputes are solved by agreeing to disagree. Furthermore, by allowing students to comment on others' views, both Mrs Mafike and Mr Phiri portrayed the sophisticated NOS understanding that there is no fixed reality but there are multiple truths, an understanding that was also reiterated by Mrs Luso when she said "… in this new curriculum…there are no absolute truths…" This is one of the NOS aspects elicited through the interviews where the teachers' understandings were found to have a mixture of naïve and sophisticated elements. The fact that students were conducting an investigation in Mrs Luso's lesson also portray an understanding that investigations play an important role in acquiring scientific knowledge but their objectivity could not be checked in the one lesson observed.

The lesson types as well as the types of problems solved in two of the lessons were socio-scientific problems that according to McComas et al. (1998) make students appreciate and understand that science, technology and society are interrelated. This, according to Driver et al., (1999); Lederman (1999) and Kolsto (2001) would make scientifically literate citizens and is a requirement for the achievement of LO3. Once more one can sense the teachers' attempt to address NOS through achieving LO3 in the type of lessons and type of exercises done in the classroom but a contradiction arises when they portray a lack of understanding of the two concepts namely, LO3 and NOS.

The fact that NOS aspects were never mentioned in the three lessons' aims, introductions and closures suggests that the teachers in this study did not explicitly teach about NOS in the lessons observed. If there were NOS aspects targeted then they were taught implicitly.

It can then be concluded, then, that some of the NOS aspects elicited during the interviews were sensed in the lessons observed. This suggests that there was a translation of some of the elicited teachers' NOS understandings into their lessons. However, because of the nature of the lessons and the fact that only one lesson was observed for each teacher, some of the elicited NOS aspects, for an example the scientific method and that investigations are never objective, could not be checked.

4.3.2 The post-classroom observation interviews

From these interviews, the teachers indicated that they neither planned for the achievement of LO3 nor had they targeted any NOS aspects in the lessons observed. For an example, Mrs Mafike's response in line 4 of the interview schedule was:

> No ma'am I didn't plan to achieve LO3…

A similar response was given by Mr Phiri but Mrs Luso's response was different.

The vague answers given by the teachers about teaching NOS aspects could be taken to mean that they had no understanding of the NOS concept. For an example Mrs Mafike's response in line 6 is evidence to that. Asked if she knew anything about NOS she said:

> …it is because it is based on the knowledge, scientific knowledge whereby now, eh, we can also include indigenous knowledge…

Mr Phiri's response also conveyed an understanding that he is not familiar with the NOS concept. His response was:

> …I find it difficult…because maybe it's just something that's even new to us…Nature of science neh, I can, according to the way I can explain it, it's how eh, science can be used in nature or how… how does it apply in nature…

Although Mrs Luso claimed she had planned for the achievement of LO3 in her lesson she indicated that she had never taught NOS aspects. She said:

> …Yes, I planned because I wanted them to understand, because nature of science is involved, and that to observe and to use what they observed and then relate it to the real world. I've never taught the

> topic nature of science but in my teaching I tell them what science is…with this new curriculum that we need to understand there are no absolute truths…

The results from the interviews indicate that the teachers did not plan to teach NOS aspects and achieve LO3 in the observed lessons as well as in all other lessons. This conclusion is drawn from their vague responses about NOS and LO3 which suggest a lack of understanding of the concepts. This is in contradiction with what was observed in the classroom where lessons portrayed some sophisticated NOS understandings.

4.4 Conclusion

In conclusion, the findings of this study indicate that:

- The teachers in this study hold a mixture of naïve and sophisticated NOS understandings but they are largely naïve.
- The teachers teach NOS implicitly but without any of them being aware of it.
- There is interaction between their NOS understandings and their instructional practises even though it is not done consciously.

Additionally it is also evident from pre-classroom observation interviews that: (for an example: line 70)

- The three teachers do not teach NOS explicitly in their other lessons as well.
- None of the teachers plans for the achievement of LO3 in all their lessons.

CHAPTER 5

Conclusions, Implications and Recommendations

5. Introduction

This study set out to investigate: the understandings about the NOS that are held by the teachers; how teachers teach about NOS; and the nature of interaction between teachers' NOS understandings and their instructional practices. From the results in Chapter 4 it is concluded that:

- On the selected NOS aspects, the teachers who participated in this study hold a mixture of naïve and sophisticated NOS understandings. These understandings are however, largely naïve;
- The participating teachers do not explicitly teach students about the NOS; and
- While there is some interaction between teachers' NOS understandings and their instructional practises with respect to NOS teaching, the interaction itself is not consciously recognized by the teachers.

Furthermore it is evident that none of the teachers plans for the achievement of LO3 in their lessons.

These conclusions are further discussed below, together with implications and recommendations coming out of this study.

5.1 Teachers' understandings about NOS

The results of the interviews provided more evidence to the claims by authors such as Abd-El-Khalick et al. (2002); Dekkers et al. (2003) and Lederman (1992) that science teachers harbour naïve understandings of NOS. The three teachers interviewed for this study believed that there is a scientific method for school science, not for professional scientists though. Abd-El-Khalick et al. (2002) has noted that this is one of the most widely held misconceptions about the nature of science. The finding in this study is, therefore, not surprising. Unfortunately, this view of the scientific method is still being popularized in school textbooks and science classrooms. It is important for teachers to understand and teach the idea that there can never be one single method that would guarantee the development of knowledge (Abd-El-Khalick et al., 2002; Lederman, 1998).

By expressing the view that experiments and investigations are what separate science from other disciplines, teachers in this study showed that they hold very naïve understandings about what science is. Scientific knowledge does not always depend on what is observable to be accepted. Creativity and imagination do play roles in creating scientific knowledge. Again this is not a surprising finding as it is in line with earlier studies (Lederman, 1992). Science is believed, by the teachers who participated in this study, to be a collection of correct indisputable facts, an idea that is naïve. They also don't seem to understand the difference between theories and laws. Theories are beliefs and explanations guiding investigations, thus resulting in different explanations for the similar observations. The development of this understanding among students could be difficult for school science due to factors such as time constraints, to mention but one.

The teachers also expressed the view that experiments and investigations are used to prove what is already known. They revealed an understanding that experiments are conducted to validate or discover instead of falsifying (Popper, 1972). In their explanations they used the terms, prove and discover to explain the role of experiments in science. They seemed to understand scientific knowledge as a representation of a fixed reality and had the idea that all what scientists have to do is conduct experiments and uncover or unveil this reality. They were obviously not aware of the NOS idea that scientific knowledge is also the product of inference, human imagination and creativity (Abd-El-Khalick et al., 2002).

The notion that scientific knowledge can be proved or demonstrated in the laboratory has also been identified as a misconception among teachers in South Africa by Linneman et al. (2003). These understandings are described as positivist views in Wellington (2000). The teachers' responses to the questions on how scientific knowledge is acquired also show a strong commitment to the idea that scientific knowledge is acquired solely through experiments and investigations. The responses from two of the teachers emphasized the importance of experiments as confirming and proving what is observed. The other teacher expressed the view that all the knowledge that scientists have, had been acquired through experiments. These ideas suggest that the teachers in this study harbor one of the myths of science as stated in McComas et al. (1998). This is the myth that experiments and investigations are the principal route to scientific knowledge. Similar findings are reported by Ogunniyi (2006).

Although the teachers showed awareness that scientific theories change, their responses were also naïve and some of their responses to questions about laws were vague. For an example, they had the notions that new evidence always result in a theory being changed instead of saying new evidence either confirms or falsify a theory. The role of theories as starting research and guiding it is a sophisticated understanding identified in the three teachers but it did not come out in the teachers' explanations when they were asked about solving different results in a classroom. Surprisingly the teachers seemed to believe that these ideas did not apply in classroom situations where students conducted experiments. When different results come out in an experiment, the procedure in doing experiments is blamed. The results are taken as wrong and the solution would be to re-do the experiment until similar and expected results come out. This implies that all experiments in the classroom are supposed to come out as expected so the idea of the investigator being influenced by an investigator's theories was not used as an explanation.

In conclusion one can say that, the sampled teachers generally hold naïve understandings of NOS.

5.2 Teaching about NOS

It also came out that the sampled teachers do not explicitly teach about NOS. They conducted lessons where there was no reference to NOS aspects in the introduction, aim and closure of the lessons. Their lessons can be described as following the implicit method of teaching NOS as explained in for an example Khishfe et al. (2002) and Lederman (2006) since there was no deliberate effort to teach and assess NOS even though the types of lessons had NOS elements in terms of lesson type, type of problem solved, teacher-student role, and classroom environment. Indications from interviews were that those methods were chosen because they are the best methods of teaching science, and there was no reference to targeting NOS made. The results of the interviews also revealed that none of them teaches about NOS tenets in other lessons as well since their responses showed that they are not even familiar with the concept of NOS. Linking this to their largely naïve NOS understandings the possibility of their choice of these teaching methods being influenced by factors not related to NOS cannot be ruled out.

5.3 The interactions between NOS understandings and practices.

The findings about the teachers' instructional practices match those made internationally and reported in, amongst others, Abd-El-Khalick et al. (1998). The teachers did not refer to their NOS understandings, whether naïve or sophisticated, in the content they taught in the classroom but they portrayed them in the teaching methodology. The interviews conducted after the classroom observations revealed that teachers do not include their NOS ideas during planning and instruction of other lessons as well. It can be concluded then that even though during instruction there were elements of NOS aspects in the teaching methodology, these could have been coincidental because teachers displayed lack of knowledge of the concept of NOS. The curriculum demands that for the achievement of LO3, students should be able to critically evaluate knowledge claims. This was not seen to be in the general practice of the participating teachers. So, interactions were found to exist between the teachers' NOS understandings and their instructional practice but they were not planned or done consciously.

5.4 Implications and recommendations

The findings of this study have implications for teaching and implementation of the new science curriculum. These are outlined below.

The study has revealed that teachers have a mixture of naïve and sophisticated views about NOS. However they do not teach what they believe because of some limiting factors such as exams. It would be important for teachers to be work shopped so they can know how to teach about NOS. The results show that the participating teachers do not know much about NOS, a finding also made by Linneman et al. (2003). The teachers displayed some misconceptions about NOS aspects. Previous research has revealed that student' NOS understandings are influenced by teachers' views (Abd-El- Khalick et al., 2000). Does it mean then that the teachers are portraying the same misconceptions about science to their students? Further research is required on this issue. If teachers can be more knowledgeable about NOS and have their NOS understandings made to be more sophisticated, this would greatly benefit science teaching.

The curriculum demands that for teachers to teach NOS, they should amongst other things aim for the achievement of LO3. For this learning outcome to be achieved a student should be able to critically evaluate different knowledge claims as well as the impact of this knowledge on the society and the environment. This learning outcome is about teaching NOS. If teachers can say they do not plan for the achievement of LO3 then it means they are not implementing that part of the curriculum. This suggests that teachers have not understood what is expected of them in terms of the curriculum.

The present study has revealed some scope for future research. Since the results are limited to the three teachers that were the participants they cannot be generalized to the whole of South Africa. But what is learnt here is that more research needs to be conducted on more South Africa's teachers in order to see if these findings can be confirmed or not. The findings of this study could have been influenced by the nature of the topics that the teachers were teaching. It is necessary to have more research with teachers teaching different topics.

5.5 Limitations of the study

The use of semi-structured interviews was strength in this study because the respondents were asked the same questions but their responses guided probing. The small sample was both strength and a weakness. It was strength in the sense that the data collected was manageable. It was a weakness because the results cannot be generalized to all science teachers in South Africa.

Interviewing is a skill and if the interviewer is not experienced then some of the responses will not be probed enough and some useful data will not be acquired. In this study there were many instances where more probing could have been done to get more insight into the teachers' responses. If this study was to be repeated this should be borne in mind. The number of classroom observations could have been more. This was mainly due to time constraints.

5.6 Conclusion

The findings of this study suggest that teachers in South Africa hold NOS understandings that are largely naïve. These findings are consistent with earlier findings made in South Africa by Dekkers et al. (2003). The study revealed and further suggested that the teachers barely understand what NOS is and they do not teach NOS explicitly but their teaching approaches can be described as implicit. Their NOS ideas are not evident in their teaching practices.

References

Abd-El-Khalick, F., Bell, R.L. and Lederman, N.G. (1998). The Nature of Science and Instructional Practice: Making the Unnatural Natural. *Science Education*, 82, 417-436.

Abd-El-Khalick, F. and Lederman, N.G. (2000). Improving science teachers' conceptions of nature of science: a critical review of literature. *International Journal of Science Education,* 22(7), 665-701.

Abd-El-Khalick, F., Lederman, N.G., Bell, R.L. and Schwartz, R. S. (2002). Views of Nature of Science Questionnaire (VNOS): Towards Valid and Meaningful Assessment of Learners' Conceptions of Nature of Science. *Journal of Research in Science Teaching,* 39(6), 497-521

Akerson, V.L., Buzzelli, C.A., and Donnelly, L.A. (2010). On the Nature of Teaching Nature of Science: Preservice Early Childhood Teachers' Instruction in Preschool and Elementary Settings. *Journal of Research in Science Teaching*, 47(2), 213-233.

Bell, R. (2001). Implicit instruction in technology integration and the nature of science: There's no such thing as a free lunch. *Contemporary Issues in Technology and Teacher Education,* 1(4), 1-7.

Breakwell, G.M., Hammond, S. and Fife-Schaw, C. (1995). *Research Methods in Psychology*. London: Sage.

Bruner, J. S. (1966). *Toward a theory of instruction*. Cambridge Mass: Harvard University Press.

Clough, M.P. and Olson, K. J. (2008). Teaching and assessing the nature of science: An introduction. *Science & Education,* 17(2), 143-145.

Cohen, L. and Manion, L. (2000). *Research Methods in Education.* London: Routledge.

DeBoer, G.E. (2000). Scientific literacy. Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching,* 37(6), 582-601.

Dekkers, P. and Mnisi, E. (2003). The nature of science- do teachers have the understanding they are expected to teach? *African Journal of Research in MST Education,* 7, 21-34.

Dekkers, P. (2005).Teaching teachers NOS- Practical examples and classroom experiences. *Science Education International,* 18, 193-210.

Dekkers, P., Oguniyi, M.B., Mosimege, M. and Kadjeo-Marenga (2005). Teachers' understanding of NOS-design of, and preliminary data based on a contextualized instrument. In C. Kasanda, L. Muhammed, S. Akpo & E. Ngololo (Eds.), *Proceedings of the 13 Annual Conference of the Southern African Association for Research in Mathematics, Science and Technology Education(SAARMSTE),* 164-171.

Dekkers, P. (2006). Reconstructing the creature- developing understandings of NOS through inquiry and reflection. *African Journal of Research in SMT Education,* 10(1), 81-92.

Department of Education (2003). National Curriculum Statements Grades 10-12 (General) Policy: Physical Sciences. Pretoria: Government Printers.

Driver, R., Newton, P. and Osborne, J. (1999). Establishing the norms of scientific argumentation in classrooms. *Science Education,* 84, 287-312.

Eick, C.J. (2000). Inquiry, Nature of Science, and Evolution: The Need for a More Complex Pedagogical Content Knowledge in Science teaching. *Electronic Journal of Science Education,* 4(3), 1-14.

Gall, D.G., Borg, W.R. and Gall, J.P. (1996). *Educational Research: an Introduction.* New York: Longman.

Gallagher, J.J. (1991). Prospective and Practicing Secondary School Science Teachers' Knowledge and Beliefs about the Philosophy of Science. *Science Education,* 75(1), 121-133.

Griffiths, M. (1998). *Educational Research for Social Justice: getting off the fence.* Philadelphia; Open University Press:

Guerra-Ramos, T., Ryder, J. and Leach, J. (2010) "Ideas about the nature of science in pedagogically relevant contexts: insights from a situated perspective of primary teachers' knowledge". *Science Education.* 94(2), 282-307.

Gwimbi, M.E. and Monk, M. (2003). Study of Classroom Practice and Classroom Contexts Amongst Senior High School Biology Teachers in Harare, Zimbabwe. *Science Education,* 25(4), 467-488.

Hashweh, M.Z. (1996). The effects of science teachers' epistemological beliefs in teaching. *Journal of Research in Science Teaching,* 33(1), 47-63.

Hatch, J. A. (2002). *Doing qualitative research in educational settings.* New York: SUNY

Hodson, D. (1996). Practical work in school science: exploring some directions for change. *International Journal of Science Education,* 18(7), 755-760.

Irez, S. and Cakir, M. (2006). Critical Reflective Approach to Teach the Nature of Science: A Rationale and Review of Strategies. *Journal of Turkish Science Education,* 3(2), 7-23.

Kang, N. and Wallace, C. (2004). Secondary science teachers' use of laboratory activities: Linking epistemological beliefs, goals and practices. *Science Education,* 89(1), 140-165.

Khishfe, R. and Abd-El-Khalick, F. (2002). Influence of Explicit and Reflective versus Implicit Inquiry-Oriented Instruction on Sixth Graders' Views of Nature of Science. *Journal of Research in Science Teaching,* 39(7), 551-578.

Khishfe, R. and Lederman, N. (2006). Teaching Nature of Science within a Controversial Topic: Integrated versus Nonintegrated. *Journal of Research in Science Teaching,* 43(4), 395- 418.

King, K., Shumow, L. and Lietz, S. (1999). Science Education in Elementary School: Case studies of teacher beliefs and instructional practices. *Science Education,* 85(2), 89-110.

Kolsto, S.D. (2001). Scientific literacy for citizenship: tools for dealing with the science dimension of controversial socio-scientific issues. *Science Education,* 85(3), 291-310.

Laugksch, R.C. (2000). Scientific Literacy: A Conceptual Overview. *Science Education,* 84, 71-94.

Lederman, N. G. and Zeidler, D. L. (1987). Science teachers' conceptions of the nature of science: Do they really influence teaching behavior? *Science Education*, 71, 721 – 734.

Lederman, N. G. (1992). Students and teachers conceptions of the nature of science: A Review of Literature. *Journal of Research in Science Teaching,* 29(4), 331-359.

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching,* 36(8), 916 – 929.

Lederman, N.G. and Lederman, J.S. (2004). Project ICAN: A Professional development project to promote teachers' and students' knowledge of Nature of Science and Scientific Inquiry. In Buffer, A., and Laugksch, R. (Eds) (2004).

Proceedings from the 12th Annual Conference of the Southern African Association of Research in Mathematics, Science and Technology Education, Durban, SAARMSTE.

Lederman, N.G. (2006). Research on Nature of Science: Reflections on the Past, Anticipations of the Future. *Asia-Pacific Forum on Science Learning and Teaching,* 7(1), 1-11

Linneman, S.R., Lynch, P., Kurup, R. and Bantwini, B. (2003). South African Science Teachers' conceptions of the Nature of Science. *African Journal for Research in MST Education,* 7, 35-50.

Liu, S. and Lederman, N.G. (2007). Exploring Prospective Teachers' Worldviews and Conceptions of Nature Science. *International Journal of Science Education,* 29(10), 1281-1307.

Matthews, R.M. (1998a). In Defense of Modest Goals When Teaching about the Nature of Science. *Journal of Research in Science Teaching*, 35(2), 161- 174.

McComas, W.F. (1998). *The nature science in science education: Rationales and strategies,* Dodrecht: Kluwer Academic Publishers.

McComas, W.F., Clough, M.P. and Almazroa, H. (1998). The role and character of the nature of science in science education. In: McComas, W.F. (ed.) *The nature of science in science education- rationales and strategies*, Dodrecht: Kluwer Academic Publishers, 3-39.

McComas, W.F. and Olson, J.K. (1998). The Nature of Science in International Science Education Standards Documents. In: McComas, W.F. (ed.) *The nature of science in science education- rationales and strategies,* Dodrecht: Kluwer Academic Publishers, 41-51.

Mellado, V. (1997). Preservice Teachers' Classroom Practice and Their Conceptions of the Nature of Science. *Science and Education,* 6, 331-354.

Ogunniyi, M. (2006). Effects of a discursive course on two science teachers' perceptions of the nature of science. *African Journal of Research in MST Education*, 10(1), 93-102.

Popper, K. (1972). Objective Knowledge: An Evolutionary Approach. Oxford, Clarendon Press. 24, 41-52.

Romiszowski, A. J. (1984). *Producing Instructional Systems*. New York, Nichols

Southerland, S. A., Gess-Newsome, J., & Johnston, A. (2003). Defining science in the classroom: The manifestation of scientists' beliefs in classroom practice. *Journal for Research in Science Teaching*, 40(7), 669–691.

Tsai, C. (1998). An analysis of scientific epistemological beliefs and learning orientations of Taiwanese eight graders. *Science Education*, 82(4), 473-489.

Tsai, C. (2000). Relationships between student scientific epistemological beliefs and perceptions of constructivist learning environments. *Educational Research*, 42(2), 193-205.

Tsai, C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning and science. *International Journal of Science Education*, 24, 771-783.

Tsai, C. (2003). Taiwanese science students' and teachers' perceptions of the laboratory learning environments: exploring epistemological gaps. *International Journal of Science Education*, 25(7), 847-860.

Tsai, C. (2006). Teachers' Scientific Epistemological Views: The coherence with Instruction and Students' views. *Science Education*, 91, 222-243.

Vhurumuku, E. (2004). An investigation of Zimbabwe A-level Chemistry Teachers' Epistemological Beliefs, laboratory Instructional Practices and Students' Images of the Nature of Science. Unpublished Doctoral Dissertation, University of the Western Cape, South Africa.

Vhurumuku, E., Holtman, L., Mikalsen, O. and Kolstø, S. D. (2006). An investigation of Zimbabwe high school chemistry students' laboratory work-based images of the nature of science. *Journal of Research in Science Teaching*, 43(2), 127-149

Vhurumuku, E, and Mokeleche, M. (2009). The nature of science and indigenous knowledge systems in South Africa, 2000-2007: a critical review of the research in science education. *African Journal of Research in Mathematics, Science and Technology Education.* Special Issue 1, 96-114.

Wellington, J. (2000). *Teaching and Learning Secondary Science. Contemporary issues and practical approaches.* London: Routledge.

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APPENDIX A

TEACHER INTERVIEW SCHEDULE

Teachers' understandings of NOS

A. What is science?

a) What, in your view, is science?
b) What makes science (a scientific discipline such as physics or biology) different from other disciplines e.g. religion; art?

B. The role and purpose of experiments in science.

a) What is an experiment?
b) Why do scientists do experiments?
c) Does the development of scientific knowledge require experiments? Explain why.
d) Is there a step-by-step procedure of doing scientific investigations?

C. The nature of scientific theories.

a) Is there a difference between a scientific theory and a law? Give examples to illustrate your answer.
b) After scientists have developed a theory (e.g. the atomic theory) does the theory ever change? If no, explain why. If yes, explain why.

D. How scientific disputes are settled.

a) Some astrophysicists believe that the universe is expanding while others believe that it is shrinking, still others believe that it is in a static state with no expansion or shrinkage. How are these different conclusions possible if all these scientists are looking at the same experimental data?

(Adapted from: Abd- El-Khalick, et. al., 2002)

Teachers' instructional practices in relation to their understandings of NOS

CONTEXTUALIZED QUESTIONS

a) Students are doing experiments with circuit boards. With two lamps in series, many find that one is lit brightly whilst the other appears to be unlit. What would you do?

b) A class of 15-16 year old students is heating magnesium ribbon in a crucible with a lid. The purpose of the lesson is to test the consequence of the oxygen theory that materials gain mass when burnt. At the summary at the end of the lesson four groups report a loss in mass, two groups report no difference and two groups report a gain in mass. What would you say to the students? **(Adapted from: McComas, 1998)**

DECONTEXTUALIZED QUESTIONS

A.PRE OBSRVATION

a) What in your opinion is the best way to teach students science? Why?

b) What can you say is your science teaching philosophy?

c) Can you give reasons for teaching science the way you do?

d) What problems do you face in trying to achieve LO3?

e) In your opinion how should teachers plan for and teach for the achievement of LO3?

B.POST OBSERVATION

a) Did you plan for achieving LO3 in this lesson? If yes, what aspects of NOS were you targeting? Can you evaluate your success?

b) Why did you choose the approach and methodology you used in your lesson?

c) Were you able to teach the students about some aspects of the NOS? Explain your answer.

APPENDIX B

SUBJECT INFORMATION SHEET

I, *Nondyebo. Julia. Beauchamp,* a student at the University of Witwatersrand, invite ____________________ to be a participant in a research that I wish to conduct.

My research is **a case study of South Africa's teachers' understandings of the nature of science and classroom instructional practices**.

I will use the data collected to compile a research report to be submitted at the abovementioned institution towards a partial fulfillment of requirements for my Masters degree in Science Education.

For my study I need grade 10 teachers who have attended the training on NCS and are in their second year of teaching grade 10 in the current year.

My data collection procedures entail conducting individual interviews as well as observing lessons in progress.

I will use an audio-tape to record the interviews and will take notes manually when observing lessons.

I will need approximately 30 minutes of your time after school for the interviews and the duration of the science period at your school for observing the lessons. I will further request a few minutes of your time after school on the day of observing the lesson to make a short interview about the lesson observed.

Participation in this study is entirely voluntary. The choice not to participate will not have negative consequences on you in any way.

Should you agree to participate: you are free to decline to answer some questions and may withdraw at anytime during the process should you wish to do so.
You do not risk losing your job or sanctions from institutions because of your participation.

I will not use your real name in my transcripts and research report but I will use pseudonyms to ensure that you remain anonymous.

The data that I collect will only be viewed by me and my supervisor.
When my research report is complete I will shred the data.

Signed: ________________ Date: ____________

APPENDIX C

EXAMPLE OF LESSON OBSERVATION NOTES SUMMARY

LESSON OBSERVATION 1(for Mr Phiri)

The teacher and the observer come into the classroom, greeted the students and the students responded. Students fiddled with their school bags and eventually took out some exercise books while the teacher was writing on the chalkboard. This activity took about three minutes. There was a buzz in the classroom at the same time, students talking to each other. Summary notes as well as two physical science questions to solve were written on the chalkboard. The teacher talks or lectures for about seven minutes, asking questions in-between. Students were answering questions orally. After a while the teacher asked the students to tell him what to write on the chalkboard in order to solve one of the problems. A student would raise a hand and tell the teacher what to write and the teacher would do so. At some stage some students expressed disagreement with what the teacher had written on the chalkboard. The noise level went higher than it had been because of an argument in the classroom. One student raised her hand and asked the teacher why the last step was written the way it was. The teacher replied to say that someone in class told him to do so, the student tells the teacher to erase that step, the teacher does so, she then told the teacher what to write and the teacher did so. The whole class seemed to be satisfied because some started uttering the word “yes”. The teacher confirms that the step is correct, the exercise continues until the end. This exercise took about fourteen minutes. The teacher told the students to write the solution to the second problem in their class work books. Students are quiet for about six minutes. The teacher chooses one of the students in the classroom to go to the chalkboard and write the solution. The student does as instructed. The bell rings while the student is still busy, she continues with her solution. One student points out that he disagrees with one of the steps, the writing student refuses to listen and writes it till the end. Another teacher appears at the door, the teacher quickly wrote a correct solution on the chalkboard. The teacher and the observer went out while the students were still writing. The observer thanked the teacher who then went to another classroom.

APPENDIX D

EXAMPLE OF TEACHER INTERVIEW TRANSCRIPT

Teacher 1 (Mrs Mafike)

Key: Int: = interviewer
Resp: = respondent

1. Int: What, in your opinion, is science?

2. Resp: Mhh… eh! According to my understanding, science is a theory which has been investigated by scientists, and they were also discovered, they made some, eh, investigations, and then they made some discoveries, and then the collection of all the principles and the laws is described ad science.

3. Int: Right my second question is what makes science, or a science discipline such as biology or physics, what makes it different from other disciplines such as religion or art?

4. Resp: Ok, Eh, I think the difference is in science we discover, eh (pause) we conduct an investigation and then you test a hypothesis, and then you discover something after that you….the investigation that has been applied and then that's where you get um eh results based on (pause) results are based on the research that was done. That makes it eh that makes it different from other theories.

5. Int: Ok, so you say basically it's because of the discoveries?

6. Resp: The discoveries.

7. Int: The discoveries that, that they have, do they discover something new through these investigations?

8. Resp: Yes. Eh science, I can say it's a principle because it can change over time based on the new investigations that are done. It is based on the investigations and then the (pause) the acquired knowledge and the results that are obtained ch... They are principles, we cannot say they are laws; they are based as principles because they can change over time when new discoveries are made.

9. Int: Our next question then will link to the answer that you have just given. What is an experiment?

10. Resp: To me an experiment, you first identify the problem, the problem statement, and then you design eh eh an an investigation whereby you to formulate a hypothesis and then which can be tested, and then therefore you

conduct an investigation by following instructions, that's how I think an experiment, which are based on the results.

11. Int: Ok, you say, Ok, why do scientists do experiments?

12. Ok, in order to….to, to test and to make discoveries.

13. Int: Both for testing and for making discoveries?

14. Resp: Mh

15. Int: So does it, where do the initial ideas come from, for the experiment, is it something that was there before you are testing?

16. Resp: Yes ma'am.

17. Int: Are they looking for something that was there, or that wasn't there?

18. Resp: I think eh... I can say both because eh science is based on the previous knowledge, and then you can use and can apply previous knowledge on a new situation, eh, and then I think it is linked to the, you can link the new discoveries, then you can start eh to conduct new investigations whereby you have to check or to find out if something really exists or not.

19. Int: So, Ok. The next question is also linked to what you have just said, I just need more clarity. Does the development of scientific knowledge require experiments, or was the scientific knowledge, the knowledge that they have, did they get it through experiments?

20. Resp: Yes, I can say yes and no because some of the knowledge that, eh, let me start by saying this, previously, eh, the scientists they only used maybe, eh, things like mathematics and other applied knowledge, as a knowledge but now we also have, eh, our knowledge, African knowledge that can be implemented together with the knowledge that pre-existed, so we can say, ehm, to answer your question, I can say, eh(pause) the knowledge can be tested based on experimenting, eh, maybe discovering the new ideas but taking into consideration the previous knowledge whereby you can also incorporate, incorporate our African knowledge which is indigenous knowledge to make new discoveries.

21. Int: And then as soon as they get the new ideas what do they do with them, the new ideas after the experiment?

22. Resp: Eh I think, eh, immediately they get new ideas or the new discoveries, eh, what scientists do they(pause)

23. Int: What do they do with the discoveries; you said that there was previous knowledge, now they discover something new, what do they do with the new information?

24. Resp: The new information, eh, it’s applied in different, eh, I can say in different, eh, different situations, eh, eh, it can be applied but it is not, eh, it is not conducted as, ehm, as a rule. I can say it’s just a principle because, eh, science we keep on discovering new ideas so as soon, eh, we say put it in principle and it can be applied, eh, if new discoveries are discovered and then we can maybe make some changes, eh, and implement new theories just like that.

25. Int: Do they follow a specific procedure, scientists, when they do experiments?

26. Resp: Yes, eh ma’am if we do experiments we need to follow procedures, there are steps that are conducted in order to perform an experiment. Eh, you must first, eh, identify the problem, I think that is the main point, and then you set a control, and then try to formulate a hypothesis, it’s then that you can, and then you set a control, and also, in order to conduct your experiment, whereby you have to identify the variables and the independent variables and then you need to follow, eh, the steps when you are conducting your method in order to get good results because if you, you fail to follow steps you may not get good results.

27. Int: By good results meaning?

28. Resp: I mean you get(pause)

29. Int: meaning getting something that you were looking for?

30. Resp: Yes.

31. Int: There was an answer that you wanted?

32. Resp: The hypothesis that you have formulated, that you need to test, I think you are looking forward to get an answer, so you need to follow steps.

33. Int: Is it an answer that you already know?

34. Resp: No ma’am, it’s a guess, just, just like I’ve said you formulate a hypothesis, eh, I think there is a, eh, a doubt in your hypothesis, you were not sure so if you, you formulate a hypothesis it’s either you get a good, the, the response, eh, it’s either the response agree with the hypothesis that you have formulated or disagree.

35. Int: Moving on to the next question, it’s about theories and laws. Is there a difference between a scientific theory and scientific law?

36. Resp: Ehm, to me a theory it’s eh, it’s a way of thinking, it’s a belief, a theory it’s eh, no ma’am, to me a theory it’s, eh, knowledge that has been accumulated by the scientists and then it was applied by the scientists, eh, you said theory and (pause) law?

37. Int: Law?

38. Resp: Law, but a law, I think it’s a procedure, it’s a law that has been formulated to follow when you are conducting, eh, eh, a specific or, eh, particular investigation, you need to follow some laws, you have to apply those laws.

39. Int: Are there any examples that you can think of, of a theory or a law?

40. Resp: Ehm, like ehm(silent)

41. Int: Ok, maybe you can, will remember as we move on. After scientists have developed a theory, for instance the atomic theory, does the theory change or remain the same after they have developed it? Or the theory of evolution, does it change or does it remain unchanged?

42. Resp: I can say, ehm, it cannot change but I think as I’ve already indicated that if there are some new evidence, that can be acquired I think it can change but it cannot change a theory without a new evidence.

43. Int: So can you still think of an example of a law?

44. Resp I’ll think of something.

45. Int: Alright. Let’s move on to another one of how scientists reach a consensus. For instance some astrophysicists believe that the universe is expanding while others believe that it is shrinking, still others believe that it is static with no expansion or shrinkage. How are these different conclusions possible if all these scientists are looking at the same experimental data?

46. Resp: I think it’s because, ehm, scientists are conducting investigations, and then someone can come again, another scientist can come with new ideas which are different from those ones that you have just mentioned because everyday they are experimenting, scientists conducting some investigations, eh, in order to find out, eh, which one is good or it’s true, so, ehm, I believe the scientists are different because there are (pause) but, but some maybe I can say maybe they’ve got some belief or their way of thinking, eh, maybe their philosophy, I can say their philosophy it’s the one that guided their belief, and then again I can also say, eh, when the scientists are not getting the same thing, it means, eh, they are not conducting their investigations in the same way, eh, others they believe they’ve got their own theories of belief. I mean their investigations are based on a particular theory.

47. Int: So is that acceptable that they get different results?

48. Resp: Yah, I think it is acceptable and that it also proves a question of, eh, maybe if you can make new discoveries, maybe you can start to experiment and investigate, maybe you can find out which one it’s right or which one it’s true.

49. Int: Ok let me (pause) still on the same thing let me come with examples. Let's say students in a classroom are heating magnesium ribbon in a crucible with a lid. The purpose of the lesson is to test the consequence of oxygen theory that materials gain mass when burnt. At the summary at the end of the lesson four groups report a loss in mass, two groups report no difference and two groups report a gain in mass. What would you say to the students?

50. Resp: I can say that eh, eh, it is based on the observations, what they have observed. Eh, maybe they didn't follow maybe the correct steps or the steps that they were supposed to follow in to test for something and you find that there are new observations that were never expected from the students, I can say, eh, the, the investigation is based on their observations, they have to stick on what they have observed.

51. Int: So would you make them change what they have observed, what they discovered?

52. Resp: Yes I can make them change ma'am because I can explain to them that if you do an experiment or an investigation, you need to conduct it in such a way that, eh, you follow the steps. Sometimes maybe the environment that, eh, you are conducting that particular investigation it's not, eh, eh. It's not good for that particular, eh, experiment.

53. Int: Ok, there's another one. It's a contextualized question. Let's say students are doing experiments with circuit boards. With two lamps in series many find that one is lit brightly whilst the other appears to be unlit. What would you do?

54. Resp: and they are still new?

55. Int: They are still new. The lamps are in series, they are supposed…

56. Resp: to have the same amount of light. Ok, ma'am, I can say sometimes can conduct an experiment and then you fail to get what you want, maybe what you were expected to find out and maybe there is a fault of connection or maybe there's a fault in one of the bulbs. I can say that to my students. It occurs most of the time.

57. Int: You wouldn't make them change what they observed?

58. Resp: Eh we can try to do another one, in order to make the change, maybe we can do it twice or three times in order to get some results because always when we do an experiment we must not do it once in order to get good results.

59. Int: The next questions are based on how you teach science. In your opinion what is the best way to teach students about science?

60. Resp: Ok ma'am, eh, I think the best way for me to teach science it's to first observe, they must come up, eh, or maybe I can use their own knowledge and then I can apply their knowledge into the new knowledge of science. I can use the experiment.

61. Int: then make them observe?

62. Resp: Uhm.

63. Int: Why do you think that is the best method?

64. Resp: I think it's the best method because if I use the information or the knowledge that students have and then and make them observe, I think that will be the, the good baseline. It's a good introduction for students and they will never forget, they can also be able to know that science is everywhere, it's around them.

65. Int: What is your science teaching philosophy?

66. Resp: Eh, I think it's the way I, the way I teach the science, but I think, eh, I believe it's a good way of teaching.

67. Int: Can you give me reasons why you teach science the way you do.

68. Resp: Eh, I believe in myself and I have confidence, I make sure that my students understand that science is about the research, it's about the environment, so it makes things easy for , it makes things easier for me.

69. Int: Now this question is based on the new curriculum. The NCS. One of the learning outcomes is LO3. What problems do you face in trying to achieve LO3?

70. Resp: Eh, I think, eh, eh, the philosophy (pause), the way (pause) the new knowledge, eh, the ethics, eh, the attitudes and also the values, eh, because eh in LO3 we're trying to, to incorporate, to incorporate science, the life science, science technology, eh, environment and the society itself, so sometimes there is, eh, we do identify some barriers, eh, the ethnic issue of the student.

71. Int: Why, why does it pose as a barrier?

72. Resp: Because sometimes eh, the beliefs of the, the students, since we are multicultural we are multicultural, some be (pause) there are beliefs ma'am and also their attitudes and values, they think maybe, eh, they are they are not identified, maybe are just accepted, yes.

73. Int: But what do you think those values (pause) what do you make them do with their values?

74. Resp: Eh, I make sure that my students they must learn to respect one another and they must make sure that they respect other people's values and attitudes, and then they must take into consideration, eh, some other, other people's way of thinking, or way of life and they shouldn't judge others as maybe they are wrong. They need to accept each other.

75. Int: So in your opinion how should teachers plan for teaching for the achievement of LO3?

76. Resp: Eh, I think, eh, they need to, LO3 it's covered, eh, the science that we have, it, it incorporate or maybe it, eh, covers the society, environment and also technology. Eh, we can use our own philosophy maybe our way of thinking, we can apply the existing knowledge that people have and then we apply it into the, the existing science and then we try to match them.

77. Int: Ok, thank you very much ma'am. That brings us to the end of our interview.

POST CLASS OBSERVATION

1. Int: These questions that I'm going to ask now are based on the lesson that I've observed in class. In that lesson did you plan for achieving LO3? Were you really planning to achieve LO3? Did you plan it consciously to achieve LO3?

2. Resp: Ma'am the lesson that you are talking about is the one that you….

3. Int: That I was……..yes.

4. Resp: Ok. No ma'am I didn't plan to achieve LO3 but, eh, in future I think I was still going to apply LO3 because I had to, eh, maybe to, eh, to give chance to the students whereby to have to apply the, the African philosophy or on how to cure some diseases or which are related to eye problem using light, but in that lesson I didn't plan for LO3.

5. Int: Ok. Eh, can you tell me anything about the Nature of Science, do you know anything about the Nature of Science because LO3 is about the Nature of Science.

6. Resp: Ja, yebo ma'am. I can say, eh, LO3 yes it is because it is based on the knowledge, scientific knowledge whereby now, eh, we can also include indigenous knowledge or maybe African way of thinking, eh, it is also included maybe it's given chance maybe whereby we can combine the two knowledge as a scientific knowledge. Knowledge of, eh, African people it is also incorporated.

7. Int: Ok. Now, eh, well you said you did not consciously plan for LO3 in that lesson but can I just ask you that (pause) can you evaluate your success in teaching in that classroom. Do you think you achieved what, what you had planned to achieve?

8. Resp: Yes ma'am, yes ma'am. I think so because, eh, it's not always; it's not always the case whereby you have to apply LO3. Sometimes you can only, eh, apply LO1, LO2 and also the assessment standards there, so I wanted, eh,

the learners, eh, to use the applied, I mean I wanted the students to apply the knowledge that they read there on how the operation of the eye is conducted and then into, eh, LO number 2 whereby you have to evaluate or maybe to assess, eh, which method it's, it's good or it's best.

9. Int: Ok. Again, eh, still on the same lesson, I saw you were using a debate, students were debating in class, Why did you specifically choose that, that method, why did you make students debate in class?

10. Resp: I think that is the best method of teaching whereby you have to listen to your students to give their own opinions, eh, to give their views. I'm not supposed to tell the students eh this and that, I have to let the students, I must give students information and then they must apply the knowledge that they just heard now into general situation and everyday situation.

11. Int: Ok, eh, so the next question again is still about the Nature of Science. Do you plan to teach students about the Nature of Science? Do you consciously plan to teach them explicitly?

12. Resp: No, not always, you cannot plan, sometimes you let the learners, eh students observe and then they come up with their own views and that's where you started to realize that you achieving goal that you have set.

13. Int: Ok. Alright, that brings us to the end of our interview, short interview. Thank you very much.

APPENDIX E

LETTER TO THE PRINCIPAL

Phineas Xulu Sec. School
P.O. Box 12470
Vosloorus
1475
13 March 2007

Dear Madam

Research Project:

A case study of South Africa's teachers' understandings of the Nature of Science and classroom instructional practices.

I, *Nondyebo*, *Julia*, *Beauchamp*, a physical science teacher, currently studying for my Masters in Science Education degree at the University of Witwatersrand, request permission to conduct the above mentioned activity as part of my research with the grade 10 physical science teacher(s) at your school. The objective of the study is to find out the teachers' understandings of the Nature of Science and the links, if there are any, between these and their instructional practices so as to find out how they are implementing the new curriculum.

Data for the research will be collected through individual interviews as well as observing lessons in progress.

Yours in education.

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N.J. Beauchamp (Mrs.)