

**NATURAL SCIENCES TEACHERS' UNDERSTANDINGS OF THE NATURE OF
SCIENCE AND HOW THEIR UNDERSTANDINGS INFLUENCE THEIR
INSTRUCIONAL PLANNING: A CASE STUDY OF SIX TEACHERS IN
UMSUNDUZI CIRCUIT IN KWAZULU-NATAL**

Master Dissertation

Submitted in fulfilment of academic requirements for the Degree of Masters of Education
School of Science, Mathematics, and Technology Education
Faculty of Education, Edgewood campus
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(December 2015)

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Abstract

An adequate understanding of the nature of science (NOS) has become increasingly imperative for science teachers in South Africa as all-inclusive curricular developments over the past decade. The NOS is viewed as a central and critical component of scientific literacy in the science education reform. Therefore it is essential that teachers need to possess an adequate understanding of NOS so that the goals of the intended South African science curriculum of promoting scientific literacy is achieved. To achieve this vision, the introduction of Curriculum 2005 (C2005) in South Africa resulted in a shift from an outdated system of education of the apartheid era to Outcomes-Based Education (OBE), and it incorporated NOS as well. Therefore the purpose of this study is to explore Natural Sciences teachers' understandings of NOS, and how they translate their understanding into classroom planning.

This is a qualitative study. Using a case study approach, the research design for this study pivoted around the use of questionnaires Views of Nature of Science Form C (VNOS-C) and interviewing teachers for their NOS understandings using VNOS-C follow-up interview protocol. It also uses their instructional documents to see if their lesson planning shows any explicit links to NOS. This study also employed the case study method since it intended to focus on the particular group, namely Grade 9 Natural Sciences teachers and using a conceptual framework of the core aspects of NOS, teachers' naive and sophisticated understandings of NOS and explicit and implicit instruction to explore how teachers link their understanding and instructional planning. Therefore this study made use of qualitative data collection method and an interpretive analysis was then conducted. The purpose of the questionnaire was to probe Natural Sciences teachers' understanding of NOS. Interviews

were essential to probe the variety of instructional strategies planned to be used for NOS teaching and learning and documents were analyzed to probe a relationship between teachers' NOS understanding and their instructional planning.

The findings of the study suggest that even though the teachers possessed more adequate understandings of NOS, their planning for teaching was not influenced by their understanding of NOS. Another finding revealed that most of the teachers do not explicitly plan to teach NOS aspects it only happens incidentally and some of their teaching approaches can be described as implicit. The findings also suggest that teachers were not able to perceive NOS aspects stipulated in their work schedules. Teachers revealed that they are mostly depended on the textbooks including experimental procedures. Lastly this study concluded that the participants in this study have had little formal exposure to the NOS construct and its aspects.

DECLARATION

I, Barbara Duduzile Zulu declare that

- The work contained in this dissertation is my own original work, except where otherwise indicated and has not previously in its entirety or in part been submitted at any university for degree purposes.
- This dissertation does not contain other person's data, graphs or other information, unless specifically acknowledges as being adapted from other persons.

Signed..... Date.....

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ABBREVIATIONS AND ACRONYMS

NOS	Nature of Science
DOE	Department of Education
NCS	National Curriculum Statement
RNCS	Revised National Curriculum Statement
OBE	Outcome-Based Education
IKS	Indigenous Knowledge Systems
LO	Learning Outcome
NRC	National Research Council
PCK	Pedagogical Content Knowledge
GET	General Education and Training
VNOS	Views of Nature of Science
CAPS	Curriculum and Assessment Policy Statement

ACKNOWLEDGEMENT

I would like to give praises to God Almighty who sent His only begotten son Jesus Christ to die for me on Calvary. Through Christ I had strength to wake up and push forwards against all odds through this long journey of finishing this dissertation. He gave me power to press on especially during the times of depression, when I felt like giving up and tended to lose hope He never forsaken me.

I would also like to express my heartfelt gratitude and thanks to the following people:

To my supervisor Dr Nadaraj Govender and my ex- co-supervisor Dr J. Coleman for being patient with me, for their support, motivation, insightful advice, they will always be in my heart.

To the participants of this study for sparing their time in order to share their ideas openly and willingly with me, it meant a lot to me.

My Pastor M.W. Mfeka for all words of wisdom and encouragement they kept me going forwards one step at the time, I am grateful.

To my loving husband, Sibongiseni and my children, Ndumiso and Philani for your understanding, unconditional support, encouragement, patience and tolerance during the long hours spent in the library and at the computer, completion of this writing would not have been accomplished without you. God bless you.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

The investigation of Natural Sciences teacher in regard to the nature of understanding they have about Nature of Science, and how they translate their understanding into classroom planning is the major aim of this study. This chapter provide the general background to the study, it outline the purpose and focus of the study and describes the rationale behind the study. In this chapter the research design is briefly outlined. It also introduces the conceptual framework that underpins the study. It also gives out a brief summary of the design of the complete thesis.

1.2 Background of the study

The Nature of Science (NOS) is viewed as a vital and crucial constituent of scientific literacy (DeBoer, 2000) in the current status of science education reform (Lederman, 2007; Hanuscin, Lee & Akerson, 2011). Therefore it is essential for teachers to possess adequate understanding of NOS so that the goals of the intended South African science curriculum of promoting scientific literacy is achieved (Kurup & Webb, 2009). To achieve this vision, the introduction of Curriculum 2005 (C2005) in South Africa resulted in a shift from an outdated system of education of the apartheid era to Outcomes-Based Education (OBE), and it incorporated NOS as well. NOS generally “refer to the epistemology of science”

(Lederman, 2007, p.833) - meaning how do we know what we know? While there is no precise NOS definition agreed upon, some points of generalization regarding several aspects or uniqueness of the scientific activity that is acceptable are there (Lederman& Lederman, 2004 b). These aspects involve accepting that:

scientific knowledge is tentative (subject to change); empirically based (based on and/or derived from observations of the natural world); subjective (influenced by scientists' background, experiences, and biases); partly the product of human imagination and creativity (involves the invention of explanations); and socially and culturally embedded. Two additional aspects are the distinctions between observations and inferences, and the functions of, and relationships between, scientific theories and laws (Khishfe & Lederman, 2006, p.1).

The OBE curriculum was followed by the Revised National Curriculum Statement with change to the naming of subjects to Learning Areas and the subject known as General Science to Natural Sciences. There were new changes to the Natural Sciences curriculum (Grade R-9) which focused on both content and the processes of science (Department of Education, 2002; 2003). This new curriculum for the Natural Sciences included the intention to develop in learners an “understanding of science as a human endeavour in cultural contexts” so that a learner “compares differing interpretations of events; identifies ways in which people build confidences in their knowledge system; and recognises differing in explanations offered by the Natural Sciences Learning Area and other systems of explanation” (Department of Education, 2002, p. 20-21). These understandings embedded in the Revised National Curriculum Statement for the Natural Sciences (RNCS) are related to Nature of Science (NOS) and to Indigenous Knowledge Systems (IKS).

As teachers were not exposed to these areas of knowledge previously, they needed curriculum support in both to understand the NOS content themselves and to know how to enact the pedagogy to their learners. This meant that for the new curriculum, teachers are required to structure their teaching towards the achievement of outcomes called Learning Outcomes (LO's). It was anticipated that throughout their teaching plans and classroom instructional practices, teachers were to show evidence that they meet these requirements. Teachers, therefore, were required to assess whether learning was successful or not through the use of the LO's.

There has been another recent shift of the South African Natural Sciences curriculum through the introduction of Curriculum and Assessment Policy Statement (CAPS) in 2011. However the emphasise of both RNCS and CAPS curriculum has been to promote scientific literacy in learners from Grade R to Grade 9 (Department of Education, 2002, 2003; Department of Basic Education, 2011). This is the major goal for the revised South African science curriculum and is explicitly stated in the statement that "Natural Sciences in the Senior Phase is compulsory for all learners. It is therefore critical in promoting and developing scientific literacy, as learners may elect not to continue with one of the science subjects beyond Grade 9" (Department of Basic Education, 2011, p. 12). To be able to achieve this, South African teachers have need of possessing sufficient understandings of NOS as studies have argued for the adequate understanding of NOS as a prerequisite for achieving scientific literacy (Lederman, 1999; Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2009; Schwartz & Lederman, 2002).

For successful learning and teaching in Natural Sciences, teachers require curriculum support and materials. It is tempting to suggest that teachers that have NOS understanding and were exposed to NOS practise of teaching will then expose their learners to NOS instruction. However, in Lederman's study (1999), five teachers who held sophisticated views of NOS did not translate their

understandings to similar NOS understandings for their learners. Therefore the link between teachers' understandings of NOS and learners' views of NOS is a complicated one and requires further exploration (Lederman, 2007).

Teachers are viewed as agents of curriculum implementation and transformation. Therefore, they need to be alert of the significant role of NOS, IKS and update their knowledge of the new curriculum in creating a scientifically literate society (Webb, Cross, Linneman & Malone, 2005). If learners are to develop adequate understandings of NOS, teachers themselves must have a deep understanding and experience of NOS since they play a pivotal role in developing learners' overall understanding and interest in science.

Studies conducted nationally (Dekkers & Mnisi, 2003; Dudu, 2014; Linneman, Lynch, Karup, Webb & Bantwini, 2003; Kurup, 2014; Kurup & Webb, 2009) reveal that teachers in South African do not have sufficient understandings of NOS and the instructional strategies they are using do not include the core components of NOS as outlined by RNCS (Naidoo & Govender, 2010). These studies have focused on teachers' perceptions and misconceptions on aspects of NOS (Dekkers & Mnisi, 2003; Dudu, 2014; Kurup, 2014; Kurup & Webb, 2009), and what is known about how their understandings of NOS *impact on their classroom lesson planning* is very little. This is a crucial link between teachers' knowledge and actual teaching in classroom. While current pre-service science teachers and some post-graduate science teachers may have been taught about NOS, many practicing teachers in the field have not yet been exposed to NOS in their teaching training, yet there is the expectation in the RNCS that teachers should have adequate understanding of NOS and that this understanding ought to translate into effective practise. Even international studies reveal a gap between teachers' NOS knowledge and classroom implementation of NOS (Herman, Clough, &

Olson, 2013; Lederman, 2007). As a consequence of this gap, I have explored science teachers' NOS understanding and their preparation of lessons plans with a view to implementation in the classroom.

1.3 Purpose and focus of the study

The purpose of this research is to scrutinize Natural Sciences teachers with regard to how much NOS understanding they have, and how they translate their understanding into classroom planning.

The following research questions are posed:

- What do Grade 9 Natural Sciences teachers understand about the Nature of Science (NOS)?
- How do Grade 9 Natural Sciences teachers plan to teach Nature of Science (NOS)?
- How do Grade 9 Natural Sciences teachers' understandings of Nature of Science (NOS) influence their instructional planning?

The focus of the study will be Grade 9 Natural Sciences teachers in the UMsunduzi circuit, UMgungundlovu district of KwaZulu-Natal, South Africa.

1.4 Rationale for this study

Ensuring that South African citizens are scientifically literate is the chief objective of the Natural Sciences curriculum (Revised National Curriculum Statement, Natural Sciences, DoE, 2002). The NOS understanding is recognized as an imperative constituent of the science programme of study in expanding a society that is scientifically literate (Akerson, Buzelli, & Donnelly, 2008; Bell, Lederman & Abd-El-Khalick, 2000; Lederman, 2007). One goal in the Natural Sciences curriculum is that "Science learnt at school should produce learners who understand that school science can be relevant to their lives outside of school" (Department of Education [DoE], 2011, p. 11). This implies that learners need to make explicit connections between science learnt at school and what is taking place

in the real world. A learner who cannot make connections between science learnt in school and what takes place in the real world may find it difficult to use the acquired knowledge of science outside school. Therefore science classrooms should present all learners with NOS understandings relevant to their level of education.

According to Lederman (2007), NOS refer to the epistemology of science - meaning how do we know what we know? Rather than focusing only on “what” we know, researchers suggest that science educators should emphasise more on “how” scientific knowledge is attained. As active members of society, learners will be faced with decisions daily that requires scientific knowledge. These decisions can be made individually and /or may also involve the role of scientific knowledge in policy decisions at the local, regional or national level. Therefore understanding of NOS will prepare learners to be critical in assessing and integrating scientific knowledge relating to their daily life. Bell, (2008) present a notion that “using scientific knowledge in decision-making involves understanding not only the products of science, but also the process by which these products are generated and the grounds for confidence in them” (p. 1). What Bell suggests is in line with the focus of the Natural Sciences curriculum referred to previously, where its substance and the procedures lay the basis for the curriculum and teachers should support learners to be able to discover traditions in which people put together assurances in their knowledge system.

The ability to use scientific knowledge in decision making is a characteristic of scientific literacy and NOS is a vital constituent of scientific literacy. Scientific literacy is defined by National Research Council (NRC) as:

Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles

about science in the popular press and to engage in social conversation about the validity of the conclusions. (National Research Council [NRC], 1996, p. 22)

The Learning Outcome 3 (LO3) in Natural Sciences RNCS is Science, Society and the Environment. This LO is about developing learners' understandings of the NOS and the relationships between science and technology, society and the environment. Therefore when assessing, teachers are expected to assess whether this LO3 has been achieved or not by their learners. It clarifies that achievement would be evident if learners demonstrate understanding of "science as a human endeavour in cultural contexts" through being able to "compare differing interpretations of events"; identifying "ways in which people build confidences in their knowledge system"; and recognise "differing in explanations offered by the Natural Sciences Learning Area and other systems of explanation" (Department of Education, 2002, p. 21). Linking this to scientific literacy means in order to be scientifically literate citizens, learners should be taught to be able to formulate well-versed decisions about scientific claims and facts (Lederman, 1999) and also contribute meaningfully to debates on socio-scientific issues (Nuangchalerm, 2010).

A significant view of teaching is that teachers cannot translate to learners what they do not know or comprehend and the subject matter that teachers present and how they present it has an impact on learners' views of science and of the world (Akindehin, 1988). Many studies, such as, Abd-El-Khalick and Lederman (2000), DeBoer (2000), Khishfe and Lederman (2006), Laugksch (2000) and Lederman (2007) argue that developing learners' NOS understandings is a major objective of science curriculum and has now effected throughout the world. Due to this reason, teachers' understandings of the NOS have become vital for both the practice of science education and for research in South Africa as well. Therefore it is practical to assume that Natural Sciences teachers can teach the concepts of NOS in a desirable way that can lead learners to understand it only if they

interrogate, understand, and reflect on the ideas and concepts that have been developed by NOS research and teaching and learning.

There has been a focus of NOS research in South Africa due to the science education curriculum imperatives. While the majority of studies done in South Africa have focused on exploring and describing teachers' NOS understandings, attempts to look at the nature of interaction between teachers' NOS understandings and their instructional practices are very scarce (Dekkers and Mnisi, 2003; Linneman et al., 2003). Further, there is little done in research in assessing how teachers plan to teach or how do they integrate NOS in their lesson planning. Therefore, because of this gap in the research, the major focus of this study is based on exploring how teachers integrate NOS into their instructional planning documents. By instructional planning this research means the development of units of instruction, lesson plans, differentiated learning activities, and assessment methods by a team of teacher(s) prior to the delivery of instruction (Academic Development Institute 2012). This case study will then contribute to a deeper understanding of how lesson planning and lessons are prepared by Natural Sciences teachers.

According to Kang and Wallace (2005), teachers' naïve ideas about NOS are revealed in their teaching practices and that has developed an assumption that the way teachers present their lesson plans and teach NOS depends on their NOS understanding and pedagogical exposure. This assumption is supported by research evidence that has revealed that in many parts of the world, in both primary and secondary schools, teachers have inadequate understandings of the NOS (Abd-El-Khalick et al., 2000; Lederman, 1992; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Kurup, 2014). Naturally, this is a serious concern, and has pedagogical implications in how we prepare our teachers especially when new themes are incorporated into curriculum documents. In this regard, Lederman and Abd-El-Khalick (2000) suggest that even in situations where teachers do acquire

sufficient knowledge of NOS, there is little explicit reference to it in their planning and teaching practices. Lederman (1992), Herman et al. (2013) and Kurup (2014) argue that teachers were unable to decode their NOS understanding into teaching practices due to the fact that the decoding of NOS understandings in teaching practice is impeded by many factors such as curriculum and administrative constraints and the availability of time and resources. The majority of studies conducted internationally and nationally on the teachers' understandings of NOS have been mainly conducted on Physical Science teachers and Biology teachers (Lederman & Zeidler, 1987; Lederman, 1999; Naidoo & Govender, 2010) and there is no study that I am aware of conducted specifically focusing on NOS inclusion in lesson planning by Grade 9 Natural Sciences teachers in South Africa. Therefore very little is known about how much these teachers understand about NOS and how do they plan their lesson. The research question is thus currently relevant: How do teachers plan lessons so that they will be effective in developing their learners' understanding of the NOS within scientific literacy? The current study therefore makes a contribution on how Natural Sciences teachers' NOS understandings are translated into their classroom lesson planning in preparation for teaching.

Although there is no existence of any explicit mention of NOS in the RNCS curriculum (Dekkers, 2006), the science curriculum policy documents in South African context will be cross-examined in this research to spot the fundamentals of NOS entrenched in it. Teachers' NOS understandings and the way they integrate it into their classroom lesson planning are examined. Its findings may help teachers, educators and students who are interested in NOS and scientific literacy in order to gain deeper insights of Natural Sciences teachers' understandings of NOS and lesson planning in NOS from this study.

1.5 Research design outlined

Using a case study approach, the research design for this study pivoted around use of questionnaires and interviewing teachers for their capturing their NOS understandings. It also uses their instructional documents to see if their lesson planning shows any explicit links to NOS. An interpretive analysis was then conducted on the data captured (Gall, Borg & Gall, 1996).

Six grade 9 teachers from six high schools in UMsunduzi circuit in Pietermaritzburg in the KwaZulu-Natal province were involved in this study. They were asked to write their responses on the open-ended questionnaires Views of Nature of Science form C [VNOS-C] (Abd-El-Khalick, 1998; Lederman, Schwartz, Abd-El-Khalick & Bell, 2001; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). The study made use of VNOS-C to survey participant's understanding of seven targeted NOS aspects. They were also individually interviewed.

The VNOS-C questionnaire together with a follow-up interview protocol (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002) was utilized by the interviewer as an interview schedule. Their planning documents were analysed with the aim of seeing how their NOS understandings interacted with their instructional planning of the Nature of Science lessons. The VNOS-C questionnaire has also been used successfully in South Africa (for example, Dekkers and Mnisi, 2003). Interviews to investigate teachers' understandings of NOS have been used successfully by other researchers (Lederman et al., 2002; Dekkers & Mnisi, 2003; Linneman et al., 2003). Grade 9 Natural Sciences teachers were selected on the basis that grade nine is an exit point in the General Education and Training (GET) band. They were also chosen because unlike in primary schools where most of the teachers are expected to teach every learning area, grade nine educators are specializing in Natural Sciences as a learning area.

1.6 Brief outline of the Conceptual framework of NOS

The conceptual framework of NOS in this study draws from the seven NOS aspects, teachers' naïve and sophisticated understandings of NOS and explicit and implicit instruction. The literature on the NOS and the collection of data from the Natural Science teachers guided by the NOS aspects supports the lens through which this study is examined. NOS refer to the “epistemology of science” (Lederman 2007, p. 833) or “principles and beliefs inherent to the development of scientific knowledge” (Lederman, 1992, p. 331). It is also about how scientists build up and rationalize “knowledge claims about the natural world” (McComas, Clough & Almazroa 1998, p. 4). However, there are disagreements about the definitions of NOS among the philosophers of science, historians of science, sociologists of science, scientists and science educators (Akarsu, 2007, 2010; Bell, Lederman & Abd-El-Khalick, 1998; Duschl, 1994; Lederman & Abd-El-Khalick, 2000). Despite these disagreements, there appears to be agreement within the science community about what core aspects should be used to describe the NOS (Lederman & Lederman, 2004a). These involve accepting scientific facts as presented in Lederman & Lederman (2004a, p. 37) that there is:

the crucial distinction between observation and inference, the distinction between scientific laws and theories, all scientific knowledge is, at least partially, based on and/or derived from observations of the natural world, it nevertheless involves human imagination and creativity, scientific knowledge is at least partially subjective, science is socially and culturally embedded, scientific knowledge is subject to change.

When looking to NOS understanding Lederman, Abd-El-Khalick, Bell and Schwartz (2001) uses the term inadequate as same as naïve and the term adequate as similar to sophisticated. On the other hand Tsai (2003) uses the term positivist and constructivist to differentiate the NOS

understandings. It is important to note that naïve and inadequate views correspond with the positivist view and the sophisticated and/or adequate view goes with constructivists' views as described in Tsai (2003) and Kang and Wallace (2005). Therefore the teachers' NOS understanding described as inadequate/naïve and adequate/sophisticated are used in this study as a frame to explore and analyse teachers' views about NOS. These understandings are also used to analyse teachers' teaching lesson plans as the study is also about exploring how teachers explain scientific ideas and organize information when planning for teaching.

This study also focuses on differences between explicit and implicit approach based on how NOS core concepts are embedded into lesson preparation. Abell, Martini and George (2001) identified the value of being precise when teaching of NOS than being implicit. Further, the use of explicit rather than implicit curriculum instructional approaches has been recommended for the development of learners' understandings of the NOS (Dekkers, 2006; Linneman et al., 2003; Vhurumuku, Holtman, Mikalsen & Kolsto, 2006). Vhurumuku (2010) assert that core curriculum and teaching approach are considered precise or explicit when the subject matter, method of teaching and learners' evaluation or assessment tasks intentionally seek to develop learners' NOS conceptions. In the explicit approach, teachers should plan for NOS teaching and should deliberately attracts learners' interest to NOS aspects through conversations, channelled suggestion, and explicit questioning during class "activities, investigations and historical examples" (Schwartz, Lederman & Crawford, 2004, p. 614). On the other hand implicit approach assumes that NOS understanding is minimally a result of partaking in science inquisition (Akerson & Hanuscin, 2007). Research (Lederman, 2004; Clough, 2011; Lederman & Abd-El-Khalick, 1998) supports the view, to which I concur, that for a teacher to address NOS aspects explicitly in the classroom, he/she should develop lesson plans that explicitly show how he/she is going to present NOS in a lesson. This may include what aspects of NOS the teacher intend to address and what approach is going to be used.

1.7 Outline of chapters

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. NOS perspectives and its characteristics are clarified for the study. The rationale, purpose of the study and the brief explanation of the conceptual framework of NOS and research design is given. The outline for the chapters to follow is also given.

Chapter 2: Literature Review.

A detailed review of literature relevant to the study is given in Chapter 2. This includes the literature reviewed on the description of Nature of Science, the relationship between the NOS and scientific literacy, the importance of the NOS. This is followed by a review of studies related to teachers' NOS understandings conducted internationally as well as nationally. The NOS in South African curriculum is then presented. The conceptual framework for the study is also articulated in this chapter.

Chapter 3: Research Design.

The research design is explained and discussed in Chapter 3. This includes the research methodology, the selection of participants, the instruments and methods used to collect data, data analysis methods, issues of validity, trustworthiness and ethical considerations.

Chapter 4: Data Analysis.

In Chapter 4, the results of the study are analysed and discussed. The analysis and discussion of the results is categorized according to themes based on the aspects of NOS. This is sub-divided in terms of teachers' NOS understandings; how they plan to teach about NOS and the relationships between their NOS understandings and their intended teaching strategies.

Chapter 5: Results, Conclusions, Implications and Recommendations.

The final chapter presents the conclusions of the study. The chapter also outlines recommendations for teaching, for curriculum implementation and for future research drawn from the study. Limitations of the study will also be discussed.

1.8 Conclusion

An exploration of the relationship between teachers understanding of NOS classroom planning is of relevance in South Africa's education system research because of the stipulations of the new curriculum. The next chapter of this study present the reviewed literature related to this topic on research conducted internationally and nationally.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

In this chapter the key concepts in this particular study are conferred in thematic approach. These concepts are the NOS and scientific literacy. A review of studies related to teachers' understanding of NOS conducted internationally and nationally and the methods of teaching and learning related to NOS will follow. The NOS content that appears in the South African curriculum is also presented.

2.2 Nature of Science (NOS)

The concept NOS has been defined in many ways. However it is important to understand what science is before understanding what nature of science is. Lederman (2007) defines science as the “body of knowledge”, “method”, as well as “way of knowing” (p. 833). Science does not consist of only laws, theories, and facts but it also involves the processes of the science that the scientific literate person should understand and also know the relationships between science, technology and society. In summary, Wisconsin Department of Public Instruction as cited in Meichtry (1992) assert that:

science is a human activity through which problems and questions dealing with natural phenomena can be identified and defined, and solutions proposed and tested. In this process, data are collected and

analysed, and available knowledge is applied to explaining the results. Through this activity, investigators add to the store of knowledge, thereby helping people better understand their surroundings. Applications of this knowledge also may bring about changes in society and the cultural order and may have a direct bearing on the quality of life. (p.3)

NOS refer to the “epistemology of science, science as a way of knowing” (Lederman, 2007, p. 833), or “the value and beliefs inherent to scientific knowledge and its development” (Lederman & Zeidler, 1987; Lederman, 1992, p. 331; Lederman & Lederman, 2004a, p. 36).

There are disagreements about the definitions of NOS among the philosophers of science, historians of science, sociologists of science, scientists and science educators (Akarsu, 2007, 2010; Bell, Lederman & Abd-El-Khalick, 2000; Duschl, 1994; Lederman & Abd-El-Khalick, 2000). Despite these disagreements, there appears to be agreements within the science community about what aspects should be used to describe the NOS (Lederman & Lederman, 2004a). Most agree that science is tentative, subjective, empirically based, socially embedded, and dependent on human imagination and creativity. In addition, it is important to recognize the distinction between observation and inference and between theories and laws (Khishfe & Lederman, 2006; Lederman & Lederman, 2004a). Therefore, according to Abd-El-Khalick et al. (1998), a person has adequate understanding of the NOS if this person understands that scientific knowledge is "tentative (subject to change); empirically based (based on and derived from observations of the natural world); subjective (theory-laden); partly the product of human inference, imagination and creativity (involves the invention of explanation); and socially and culturally embedded" (p. 418). Further, Dekkers and Mnisi (2003) asserts that a person with an adequate understanding of NOS “should distinguish between observations and inferences, and understand that scientific laws are not 'experimentally proven' theories, but categorically different, laws express relations among observable quantities

and/or qualities, theories provide explanations for events and phenomena, while both are equally tentative” (p. 22).

2.3 Scientific literacy

Scientific literacy has become a slogan and “a rallying cry for scientific reforms” (Bybee, 1997, p.71). It has been understood in different ways by different science scholars. Durant (1993) labels scientific literacy as what the broad-spectrum of community must understand about science. It is an admiration of the natural world, aims and common boundaries of science connected with how some researchers define “scientific literacy relation to language literacy” (Akgul, 2004, p. 1). For example, Koch and Eckstein (1995) consider scientific literacy as a vigorous and vital commitment of the reader in the interpretation of the meaning of a science text. The similar consideration has been proposed by Sutman (1996) that scientific literacy is independent upon any science content or process knowledge, it only consists of the motivation to continue to learn science content, to develop science processes independently, and to communicate the results of learning to others. However, Mayer’s (1997) argument contradicts Sutman’s idea as he sees scientific literacy as dependent upon specific amounts of science content knowledge. He considers scientific literacy as the having content and how it affects the interrelationships among people and how their activities influence the world around them.

The Project 2061 describes scientific literacy as:

the capability to use scientific knowledge and ways of thinking for individual and communal purposes. It involves being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology and the sciences depend upon each other; understanding some of the key concepts and principles of science; having a capacity for scientific

ways of thinking; knowing that science, mathematics and technology are human enterprises, and knowing what that implies about their strengths and limitations.

(American Association for the Advancement of Science, 1990, pp. xvii-xviii)

In line with Project 2061, Norris and Philips (2003, p. 225) conclude by defining scientific literacy as:

awareness of substantive substance of science and the capacity to differentiate from non-science; understanding of science and its allegations; capacity to utilize scientific knowledge in problem solving; capacity to think critically about science and to deal with scientific expertise; ability to think scientifically; knowledge of what count as science; independence in learning science; knowledge needed for intelligent participation in science based issues; understanding the nature of science, including its relationship to culture; appreciation of comfort with science including its wonders and curiosity; and the knowledge of risks and benefits of science.

Scientific literacy has been described as the ability to “understand media accounts of science, to be familiar with and realize the roles of science and be able to utilize science in decision-making on both everyday and socio-scientific issues” (Bell, 2011, p. 1). This means that a person who is scientific literate would be able to understand science articles in media and be able to make democratic decision regarding science issues. According to Anderson (2007) scientific literacy is a term that can be used “to select the science related knowledge, practices, and value that we hope students will acquire as they learn science”(p.5). Studies (Hodson, 2010; Hodson & Wong, 2014; Laugksch, 2000; Miller, 1998; Miller, 2012; Shen, 1975) present three classes of scientific literacy, namely, Practical, Civic and Cultural scientific literacy. Practical scientific literacy which covers the aspects solving practical problems of day-to-day life, for example, conservation, eradication of polio, HIV/AIDS and other communicable diseases; Civic scientific literacy that contribute to the awareness of science and science related issues of civic importance, such as HIV/AIDS, developing nuclear energy, to name

the few while Cultural scientific literacy includes the knowledge and achievement of science as a human enterprise, for example green revolution, life saving drugs, and so forth.

2.3.1 What it means to be scientifically literate?

Duschl (1990) describes a person that is scientific literate as one able to see the changing nature of scientific information and stay unaffected as long as he or she is familiar with the developing character of scientific inquiry. Further without proper understanding of the motive behind scientist use to change techniques, viewpoints, and procedures, people might not admit scientists' views as sound and as an end result of a method on which transformations are both natural and expected (Duschl, 1990). Being scientifically literate means to be conscious with the reality of science, mathematics and technology being inter-reliant people endeavours that has its strong points as well as restrictions; being aware of crucial ideas and ideologies of science; possess well-versed comprehensions about the nature also recognizes both its multiplicity as well as accords, lastly use both scientific understanding as well as scientific techniques of judgment for personal and societal reasons (Rutherford & Ahlgren, 1990).

In 1996 the National Research Council (NRC) in America expressed that the target of national science education standards is to put together idea for scientifically literate person that will serve to channel science education system toward its goal of scientifically literate citizenry in productive and social responsible way. That person can “identify scientific issues underlying national and local decision and express positions that are scientifically and technologically informed, be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it and have the capacity to pose and evaluate arguments on evidence and to apply conclusions from such arguments appropriately” (NRC, 1996, p. 22). Koch and Eckstein (1995)

emphasize that a scientific literate person should take critical stance towards science texts and develop the ability to interpret them from a theoretical perspective. A scientifically literate citizen is supposed to possess knowledge of scientific theory, laws, principles, concepts, technology and relationship to society and should reveal the NOS understandings (Akarsu, 2010).

Basing on the presented literature above, one may argue that to be scientific literacy includes three dimensions, that is “(a) science content pertaining to the understanding of facts, laws, concepts and theories; (b) scientific inquiry which draws on the understanding of the scientific approach to inquiry, it calls for the ability to define scientific study and to discriminate between science and non-science; and (c) social enterprise meaning the understanding of science as a social enterprise” (Driver, Leach, Millar & Scott, 1996, p.13). Being conversant with the above dimensions, calls for ones NOS understanding.

Nature of Science is defined in McComas, Clough and Almozroa (1998) as a

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

It is also about the way scientists build up and validate their arguments based on their understanding of the natural world (McComas et al., 1998). In simple terms “NOS is knowledge about how scientists use and develop scientific views, how they determine the question to investigate and how they collect data and analyse their findings from observation of scientific facts about the world around us” (Akarsu, 2010, p.100). It can be argued that based on what has been presented above that NOS is the enhancer of scientific literacy and without its adequate understandings, being

scientific literate is a goal too far to achieve. Therefore it is important for one to possess sufficient NOS understanding.

2.3.2 The relationship between the Nature of Science and scientific literacy

NOS are viewed as a vital and crucial building block of scientific literacy (DeBoer, 2000) in science education reform (Hanuscin, Lee & Akerson, 2011). Norris and Philips (2003) define scientific literacy as “knowledge of the important content of science and ability to differentiate from non-science, understanding of science and its relevancy, knowledge of what count as science, ability to solve problems using scientific knowledge and understanding of the nature of science, including its relationship with culture” (p. 225). According to Nuangchalerm, (2010) scientific literacy is the capability to understand science and to apply that science understanding in formulating decisions on daily life and socio-scientific problems. These two definitions put an emphasis on the understanding of science and its relevancy on our everyday life. Therefore the promotion of scientific literacy calls for “curricular attention to the moral and ethical implications of socio-scientific issues. The socio-scientific issues offer way to explore the nature of science, bridge student and scientific literacy, interdependence of science and society movement, and democratizing science in society” (Nuangchalerm, 2010, p. 36). Since it is clear that NOS is the central component for scientific literacy, its adequate understanding by teachers is essential so that the ultimate goal of the intended South African science curriculum which is based on moving away from “teacher-centred and examination based education to one that promote scientific literacy is achieved” (Kurup& Webb, 2009, p.53).

2.4 The importance of teaching and learning about NOS

Being able to understand and teach about NOS is very important. Therefore providing teachers with a functional NOS understanding is a “prerequisite to any hope of achieving the vision of science teaching and learning specified in various reform efforts” (Lederman, 1998, p. 2). This is because teachers are agents of change and one of their role is to “decode the paper curriculum into an outline ready for classroom relevance and decide what, how and why to learn” (McComas, Clough & Almozroa, 1998, p. 23). Therefore, understanding NOS is very important because it improves the knowledge of science content; NOS knowledge improves science understanding; NOS understanding improves curiosity in science; NOS knowledge improves the way one is making decisions and NOS knowledge improves way lessons are delivered (McComas et al., 1998).

Lederman (2006; 2007) when answering a question of why understanding NOS is important draws from five arguments provided by Driver et al. (1996) which are as follows : (i) utilitarian meaning the NOS understanding is essential to comprehend science and handle the technical things and practices in every daily life; (ii) democratic meaning in NOS understanding is needed for knowledgeable choice making on socio-scientific issues; (iii) cultural meaning in NOS understanding is required to realize the significance of science as element of current society (iv) moral meaning in NOS understanding assists in developing an understanding of the customs of the scientific society embodying ethical obligation which are common significance to the public; and (v) learning of science meaning in NOS understanding aids the knowledge of science themes under discussion. Therefore teacher understanding of the NOS is a requirement because while teaching, the teacher will be able to help learners to develop truthful ideas of what science is, involving what kinds of problems science can respond to and not, what makes science differ from other disciplines, and the strong

points and limitations of scientific knowledge (Bell, 2008). It creates a room for all learners to doing well in science (Quigley, Pongsanon & Akerson, 2010). It allows teachers to promote “life-long learning, and a valuing of the kind of knowledge that is acquired through a process of careful experimentation and argument, as well as critical attitude toward the pronouncement of experts” (Carey & Smith, 1993, p. 235). Life-long learning is one the seven roles of educators described in the South African education curriculum.

In summary, through the understanding of NOS teachers and learners will be capable of making sense of science and handle science practices in daily life, make decisions that are informed based on socio-scientific issues, value science as element of society, learn science content, and understand customs and principles that embody the moral commitment of the scientific society (Lederman, 2006; 2007; McComas, et. al., 1998). For all this to happen it requires effective planning on the side of the teacher. According to Burns and Lash (1988) the way teachers plan for instruction is influenced by their knowledge.

2.5 Instructional planning

Teaching begins before the teacher steps into the classroom. Prior to each lesson or unit, successful teachers identify what learners need to know, understand, and do, using the curriculum benchmarks. One of the teacher’s roles is to decode the paper curriculum. A curriculum portrays the skills, performances, knowledge, and attitudes learners are expected to gain knowledge of in school. The curriculum includes opportunities or learning outcomes, which are declarations of desired learners learning, and descriptions of the methods and materials that will be used to help learners achieve this. Therefore identifying appropriate curriculum, instructional strategies, and resources to address the needs of all learners, requires solid planning process that is also essential to a teacher’s

effort. In general terms, planning means the “act or process of making or carrying out plans” (Merriam-Webster, Inc. 2006. p. 1387). In short planning is preparation for action. Planning is an essential tool for effective teaching. Teaching is a multifaceted activity that entails cautious preparation and planning, both for short-term learning and long-term learning. Since teachers are agents of change and one of the changes they need to make is changing learners’ behaviour and that requires methods and processes. Therefore, the methods and processes essentially utilized to change learners’ behaviour may be called instruction. Then instructional planning can be described as a process whereby a teacher make use of appropriate curricula, instructional strategies, and resources during the planning process to address the diverse needs of the learners. It is the development of units of instruction, lesson plans, differentiated learning activities, and assessment methods by a team of teachers prior to the delivery of instruction (Academic Development Institute 2012). Instructional planning is a multifaceted and a mind challenging procedure (Fernandez & Cannon, 2005) that outlines the starting point for effective teaching and learners learning (Burns & Lash, 1988; Clark & Dunn, 1991; Reiser & Dick, 1996).

Instructional planning has its own benefits as it is a method that assists the teacher design instructions systematically. According to Duke and Madsen (1991, p. 11) instructional planning provides the teacher “with some control over what is going to happen as opposed to reacting only to what has happened.” There has been a number of instructional planning models developed (Dick & Reiser, 1989; Dick & Carey, 1996; Seels & Glasgow, 1990) aiming at improving teacher instruction.

According to Reiser and Dick (1996) instructional planning consists of the six following phases: goals, objectives, instructional activities, assessment, revision, and implementation. In their study Kitsantas and Baylor (2001, p. 97) presented four key principles underlying these six instructional planning phases: (a) identifying goals and objectives that students will be expected to attain; (b) planning instructional activities that correspond with the objectives; (c) developing an assessment

instrument to measure attainment of objectives; and, (d) revising instruction based on student performance and attitudes. Therefore, teachers need to plan before hand as planning assists teachers allocate instructional time, decide on suitable activities, relation individual lessons to the curriculum, compile a series of activities to be presented to learners, set the pace of teaching, select the homework to be given to the learners, and identify techniques to assess their learning. Further Misulis commented “regardless of the teaching model and methods used, effective instruction begins with careful, thorough, and organized planning on the part of the teacher” (Misulis, 1997, p. 45).

It is vital that teachers have adequate understanding of NOS as well ability to transfer that understanding into practice. In this case instructional planning is the focus. According to Hanuscin, Lee and Akerson (2011) teachers need to possess required pedagogical content knowledge (PCK) for teaching NOS which comprises adequate subject matter related NOS and having knowledge of instructional strategies, examples, and activities to reflect NOS in class. Therefore, planning as a deliberate process (Stronge, 2007) should “not leave to chance the stringing together of activities or tasks that may or may not address what students should learn” (Academic Development Institute, 2012, p. 56). The teacher should clarify explicitly their high expectations to the learners because studies have revealed that communicating instructional objectives has an optimistic effect on learner achievement (Marzano, 2011). In other words they need to state the intention of the lesson in explicit language that tells what the learners need to learn, how deeply to learn it, and how to demonstrate the new learning, (Moss, Brookhart & Long, 2011).

Unfortunately, based on decades of research, Lederman (2007) expresses his concerns that similarly teachers and students do not hold suitable NOS understandings and hence teachers’ NOS understanding does not directly decode into classroom teaching and teachers cannot present or assess information they do not possess (Lederman, 1998). The lack of this background invariably results in

teachers' espousing positivistic views of the science and will thus be tempted to embark and address only the content facets of science, lay emphasis on vocabulary instead of balancing knowledge claims with knowledge production as well as assessment, and attend to science as the only way of comprehending the world (Gess-Newsome, 2002). This may have negative long-term impact on learners and may lower the importance on enquiry-oriented and problem solving teaching methods in the classroom and affect the way learners develop conceptions of NOS (Gess-Newsome, 1999).

It is then important to look at what findings do research have to say about teachers' NOS understanding and the way they implement in their classrooms.

2.6. International Studies: Teachers' understanding of NOS and Pedagogy

Nature of Science has been places as a objective for learners over a period of five decades and many studies have been around assessing learners' understandings of NOS, which mostly indicated that what learners possessed was not what to be adequate conceptions of NOS (for example, Klopfer and Cooley, 1961; Lederman, 1986; Miller 1963). However, there has been a turn of focus in the last decade which resulted in the researchers paying attention to teachers' conceptions of NOS and the teaching of NOS. The researchers made an assumption that teachers must have an adequate amount of knowledge of NOS and what they are trying to teach to learners.

From historical records it appears that attempts to assess teachers' conceptions on NOS started in 1950 by Anderson (1950) who did a survey that included 58 biology and 55 chemistry teachers. The results of the study reflected that teachers possessed serious misconceptions about the nature of science.

There had been studies conducted on teachers' NOS understanding and how it influenced their classroom practice. Lederman and Zeidler (1987) investigated the connection between teachers' NOS understanding and their classroom practice. They involved 18 high school biology teachers from nine schools as a sample of their study. The result of the study showed the noteworthy connection between teachers' NOS understanding and classroom practice were not evident. Instead they noted a number of variables that hindered teacher's translation of NOS into their practice.

Abd-El-Khalick, Bell and Lederman (1998) conducted the study involving fourteen (14) pre-service secondary science teachers which described the factors mediating pre-service educators' conceptions about the NOS to be translated into planning of lessons and classroom practice. Open-ended questionnaires, student teaching, participants' lesson plans, classroom videos and portfolios, supervisors' weekly clinical observation notes were used to collect data. To validate open-ended questionnaire responses and to identify the factors to mediate the translation of their conceptions of the NOS into their classroom practice, participants were individually interviewed. The results revealed that the participants possessed sufficient understandings of a number of significant aspects of the NOS including the empirical and tentative character of science, the difference involving observation and inference, as well as the function played by subjectivity and creativity in science. Although many of the participants in this study mentioned that they teach NOS through science-based activities, the clear indications to the NOS were rarely identified in their preparation and teaching. Participants expressed a number of issues that led them to be deficient in attending to NOS. They consisted of looking at NOS as less significant than other instructional outcomes, concern with classroom management and everyday tasks, not having confidence with their own NOS understandings, the shortage of resources and experience for teaching the NOS, cooperating teachers' imposed restraints, and the limited time for planning.

In a study conducted by Wang (2001), the participants claimed that they had not taught about NOS explicitly due to some constraints. Wang studied ten primary science teachers in a year-long in-service program that included a series of intervention courses. Although teachers understood a number of aspects of the NOS before the intervention, they were not able to describe how to teach it. After the intervention, some teachers were able to incorporate NOS into lessons. Participants did not place teaching the NOS as significant as other parts of science. These results that Wang found from his participants based on constraints that hinder them to implement NOS in their teaching are similar to Lederman and Zeidler's findings. In summary, these constraints involved, demands to cover up subject content (Abd-El-Khalick, Bell & Lederman, 1998); lack of teaching experience (Lederman 1995); unsure of their NOS understandings; shortage of resources at schools and the teacher's inadequate experiences on how to assess learners' understanding of NOS (Abd-El-Khalick et al., 1998).

Lederman (1999) tried to place to an end the hypothesis that teachers' conceptions of NOS directly impacted on classroom practice through a case study including five high school biology teachers with different experiences. He collected data on teachers' conceptions and classroom practice. All the participants were his earlier students and were in possession of adequate understanding of NOS. The study collected data through the questionnaire, structured and unstructured interviews, classroom observations and instructional material. This was done over the full academic year course. However, the results showed that even though these teachers had a better understanding of NOS, their classroom practice was not affected because their lesson plans records exposed teachers by showing that they never tried to educate learners in regards to NOS therefore learners did not get the opportunity to gain understanding NOS because teachers were not determined to teach NOS.

The same results were highlighted in Akerson, Abd-El-Khalick and Lederman (2000) in their study which surveyed 25 undergraduate and 25 graduate pre-service primary school teachers registered in different methods courses. Their study focused on empirical, tentative, subjective, creative, and social/cultural embeddedness of scientific knowledge. It also focused on the differences involving observation and inference and also theories and laws. The courses explicitly addressed these aspects of NOS using the reflective, activity-based approach. The results of the study showed that granting NOS precise attention was a valuable means of improving teachers' NOS understanding. However, exposure to NOS activities did not mean these teachers were easily able to transfer their knowledge into practice.

The results of the case study pre-service teachers' NOS conceptions, conducted by Bell, Lederman and Abd-El-Khalick (2000) focused at educators' translations of facts into teaching plan as well as practice in classroom. The participants were 13 pre-service science teachers. The results showed that these teachers displayed adequate understanding of NOS but failed to integrate NOS explicitly. Jones (2010) study showed that many science preservice teachers viewed science knowledge as having proven ideas that cannot be changed. They viewed scientific knowledge as absolute and is knowledge that is discovered. They perceive scientists as applying a particular methodology, an experiment, and using induction to explicitly prove some concept or fact. They view data analysis, data interpretation, and establishing theories are to be devoid of any individual or societal bias or interference. However, these methods of science are not as straightforward and sterile as cultural norms and values play a role in the scientific endeavour. Indeed, many participants do not see scientific knowledge as constructed knowledge but rather as discovered only.

In their interpretive study of the fourth grade teacher who sought help from the researchers in teaching the inferential, tentative and creative aspects of NOS to her learners, Akerson and Abd-El-

Khalick (2003) used analytic induction from data collected over a period of the year. Observations, questionnaire and interviews were used. Although the teacher had the necessary prior knowledge to teach the chosen NOS aspects to her learners and its results revealed that her knowledge was not sufficient and she was not able to translate her knowledge she had into practice. The study indicates that the teacher had a problem about *when* to integrate NOS even with model lessons being taught by the researchers.

Koksal and Cakiroglu (2010) examined 47 elementary science teachers' NOS aspects understandings making use of knowledge test and open-ended questions in Turkey. Their study used quantitative research approach propped up by qualitative data and also NOS knowledge test and open-ended questions were used. The study revealed that science teachers exhibited many inadequate understandings about the aspects of NOS. They had the most tremendous naïve understandings concerning relationship between theory and law. The majority of the science teachers thought that there is a hierarchy among hypothesis, theory and law. When examining the individuals' answers to open-ended question, it appeared that a number of the teachers possessed more than one inadequate understanding for every aspect presented.

2.7 South African studies on NOS

A review of literature on studies conducted in South Africa in pursuit of teachers' understandings of NOS 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 that focused on in-service and pre-service science teacher in Limpopo Province was conducted by Dekkers and Mnisi (2003) to examine if science teachers in South Africa have the

understandings of the nature of science they are expected to teach. The study utilized the VNOS questionnaire and semi-structured interviews to collect data. The study shows that the teachers believe that science is dependent only on experiments and that experiment provide proof rather than supporting scientific claims. They believed that for nature and natural phenomena to be measured legitimately the elucidations need to be founded on power and they viewed experiments as the power in science. They collectively see law as certain and the ideas they about the tentative character of science seem not deep. The respondents possessed no fully understanding the dependence that science have upon imagination and creativity, the role of subjectivity and the social and cultural embeddedness of science. The understanding that scientific knowledge is objective was not in the conception of the participants. Therefore the authors concluded that the participants did not have NOS understandings needed for them to teach and will not be able to help learners understand the NOS as expected in Curriculum 2005 (C2005).

Similar results were presented in Linneman, Lynch, Karup, Webb and Bantwini (2003) who researched South African science teachers' perceptions of NOS. They used questionnaire and subsequent focus group interviews to collect data from the participants who were qualified, veteran Grade 4-7 primary school science teachers of Eastern Cape Province. The group interviews were used to clarify teacher' questionnaire responses to NOS prompts, to examine teachers' perceptions of the relationship of science to society and their beliefs on how scientific knowledge become reliable and their understanding of NOS in connection to HIV/AIDS. This study was basically based on what teachers view as the place of NOS in the South African science curriculum. Their results pointed out that the majority of the respondents did not consider NOS as a goal in their classroom practice and interview discussions suggested that the participants have had little formal exposure to the NOS construct. These two studies, then, made similar conclusions that: teachers in South Africa hold naïve understandings of NOS. As in other countries, the results presented above encouraged research on

teachers' instructional practice of NOS teaching in addition to only knowing teachers' NOS understandings. Lederman (1992) points out that the current research efforts made worldwide to assess teachers' NOS understandings are now focusing on the realities of the teachers' instructional practices and this seems to be the development even in South Africa.

The studies by Dekkers et al. (2003) as well as Linneman et al. (2003) assessed teachers' understandings of the NOS. Their findings match those made internationally which revealed that teachers harbour inadequate (e.g. Abd-El-Khalick et al., 2003) and that these understandings have an impact on how teachers teach about NOS.

The results of the study conducted by Webb, Cross, Linneman and Malone (2005) on part-time cohort in-service BEd (Science and Mathematics) degree students to investigate their perceptions of the cause of AIDS shows that teachers in the study were able to present clearly their understandings of the NOS and apply it to the context of HIV/AIDS in terms of falsification and verification of theories, the social aspects of the NOS, paradigmatic thought, the tentative nature of science and nature of scientific production. However, teachers in the study admitted not using NOS to discuss arguments on the causes of AIDS with their learners because they believe that the idea that scientific knowledge is tentative would contradict their primary message that AIDS kills.

Kurup and Webb (2009) conducted a comparative study on 92 practicing science teacher (designated as Bed NMMU group) who obtained explicit teaching on the NOS through a university accredited Bed in-service programme module and 41 practicing science teachers who did not receive such an intervention (designated as non-NMMU group) to study whether explicit teaching in NOS may enhance teachers' conceptions of NOS. The results from questionnaire items indicates that BED NMMU teachers possessed a more informed view of NOS in comparison to the non-NMMU group

although both thought that there is a linear process of doing science and that theories graduate to form laws. Both groups demonstrated problems in regards to the role of theories and laws in science. The results of the study implied that the two groups of teachers required supplementary support in building up skills in teaching NOS aspects to rally the desires of the new curriculum.

The results on both studies above reveal that teachers can acquire the understanding of NOS if they are exposed to it, however, that does not guarantee that their understanding will affect their teaching practice.

In a study conducted by Naidoo and Govender (2010) in KwaZulu-Natal shed light of Honours teachers' classroom experience of NOS teaching. The participants had exposure to some higher institution experience of NOS issues in science education. VNOS questionnaires, in-depth classroom observations and interviews were used to collect data. The results show that the participants had NOS understanding that is adequate and were able to teach the key concepts of NOS but they taught in a usual teaching-lecturing manner. The results also shows that teachers did not have prior knowledge of NOS and they only acquired it as a outcome of completing courses that covered NOS objectives, history of science and philosophy of science from a tertiary post-graduate programme.

Kurup (2010), in his doctoral dissertation, investigated 136science teachers perceptions of the NOS in the perspective of core curriculum transformations in South Africa and realized that almost all the participating teachers thought that the development of scientific knowledge is a rational, step-by-step process which specifies a well-built commitment to inductive methods. They also possessed the understanding that other than during the primary planning stages of an investigation, scientists make no use of imagination and creativity but depend exclusively on

experiments to authenticate their claims. Further, most of the teachers did not perceive a distinction in the functions of theories and laws in science rather they perceived that theories mature to become laws after continual and unbeaten experimental proof. Ninety percent of his participants documented no difference between science and technology signifying confusion between the roles of these two aspects of human endeavour. Lastly, more than a half of his participants also possessed the understanding that scientists are subjective to social, cultural and personal considerations.

A review of literature as outlined showed very few studies were conducted on how teachers' understandings of NOS in South Africa affect their classroom lesson planning and were mostly on gathering teachers' NOS understandings.

2.8 Nature of Science in South African curriculum

Worldwide, many western countries stated one of the major objectives of curriculum transformations in science education is promotion of scientific literacy (National Science Teachers Association, 1982; American Association for the Advancement of Science, 1993; National Research Council, 1996; Turkish Ministry of Education, 2005). Over the years, the science education researchers have been involved in considerable debates on the conception of scientific literacy (Fensham, 2003; Hodson, 2003; Laugksch, 2000; Yore & Treagust, 2006). They reached the common concurrence that match the needs of the twenty- first century, scientific literacy needs to be considered an significant target of science education. Following the world wide styles in curriculum transformations, the South African National Curriculum Statement also formulated its intention of scientific literacy clearly by stating:

The Natural Sciences Learning Area deals with the promotion of scientific literacy. It does this by: the development and use of science process skills in a variety of settings; the development and application

of scientific knowledge and understanding; and the appreciation of the relationships and responsibilities between science, society and the environment.

(Department of Education, 2002, p. 4)

The Natural Sciences curriculum clearly presents the National Curriculum Statements (NCS) purpose through its Learning Outcomes (LOs) with LO1 centred on scientific investigation, LO2 putting importance on the development and use of scientific knowledge and LO3 dealing with the social and cultural impacts of science and technology. For each Learning Outcome prescribed Assessment Standards are used to measure the achievement of the outcomes. Scientific literacy includes an understanding of the scientific processes, the nature of scientific knowledge and its social concerns. This emphasizes that an adequate NOS understanding is a requirement and a crucial factor for attaining scientific literacy (Khishfe & Lederman, 2006). In defining NOS, NCS views learning science as “the search to understand the nature of the world through observation, communicating, evaluating, codifying and testing ideas and has evolved to become part of the natural heritage of all nations” (Department of Education, 2002, p. 4).

Revised National Curriculum Statement (RNCS) is based on the transformation programme from the previous teacher-centred and assessment-focused curriculum to the one of learner-centred in promoting scientific literacy. This curriculum is grounded on outcomes that are lined on educational principles and seven critical and five developmental outcomes that can be reached throughout the eight Learning areas these includes Natural Sciences. RNCS also reveals the concepts of the nature of science that must be included in classroom instruction. These includes the:

- understanding of scientific knowledge and how it is produced;
- its tentativeness,

- scientific knowledge and understanding is a cultural heritage that answer questions about the nature of the physical world,
- understanding of science as a human activity,
- the understanding of the history of science and
- the appreciation of the relationship between science, technology, society and environment.

(Department of Education, 2002, p. 4-5)

The Learning Outcomes in the Physical Sciences NCS (Grade 10-12) document also states how the study of the NOS is important. The evidence is seen in the policy document of the NCS as it declares that “the nature of science forms the basis from which learning outcomes have been developed” (Department of Education, 2003, p. 12). It furthers by discussing how science is relevant in issues concerning science, society and the environment as part of evidence showing the importance of NOS. Moreover, the NCS emphasis that a Physical Sciences learner needs to build up an understanding of:

- The scientific enterprise and, in particular, how scientific knowledge develops;
- That scientific knowledge is in principle tentative and subject to change as new evidence becomes available;
- That knowledge is contested and accepted, and depends on social, religious and political factors;
- That other systems of knowledge, such as indigenous knowledge systems, should also be considered;
- The importance of scientific and technological advancements and to evaluate their impact on human lives.

(Department of Education, 2003, p.11)

Scientific investigation; development of scientific knowledge; nature of scientific knowledge and the social and cultural aspects of science and technology (STS) are NOS views presented in the RNCS policy document and these are further analysed below.

2.8.1 Scientific investigation

Scientific investigation is interrelated to NOS sights with line to the epistemological inferences of science procedures such as the subjective nature of observations and the elucidation and valuation of knowledge claims. Lederman et al. (2002, p. 499) state that “although there is overlap and interaction between science processes and NOS, it is nevertheless important to distinguish the two” and cautions in opposition to such a combination. Further there is a value of building up science process skills as a cognitive outcome in learners by explicitly stating teaching instruction in scientific inquiry (England, Huber, Nesbit, Rogers & Webb, 2007; Lederman, Lederman & Bell, 2004). The term ‘process skills’ is defined in RNCS as “learners’ cognitive activity of creating meaning and structure from new information and experiences” (Department of Education, 2002, p. 13). In comparison the term ‘scientific investigation’ in the past science curriculum in South Africa only focused on ‘closed problem-solving’ based on verifying recognized scientific realities using science worksheet-centred experiments whereas the new curriculum (RNCS) stresses the building up of process skills in learners by involving them in analytical exercises so that they are able to comprehend the physical world surrounding them as exemplified in the policy document “...from the learning point of view, process skills are an important and necessary means by which the learner engages with the world and gains intellectual control of it through the formation of concepts” (Department of Education, 2002, p.13).

The set of process skills to be dealt with transversely all three Learning Outcomes are stated in the policy document as:

observing and comparing, measuring, recording information, sorting and classifying, interpreting information, predicting, hypothesising, raising questions about a situation, planning science investigations, conducting investigations and communicating science information

(Department of Education, 2002, p.13-14)

2.8.2 Development of scientific knowledge

The sequence of the important science content knowledge needed for each Grade is provided in Learning Outcome 2. Although not explicitly stated, the RNCS curriculum supports constructivism as the way of teaching and learning as it require learners to make science knowledge through deducing and reviewing information and be capable of applying relevant understanding to resolve difficulties or problems in new situations (Kurup, 2010). Furthermore, learners are expected to build up higher order thinking skills such as analysis, synthesis and evaluation of scientific knowledge as they process from one grade to another. Moving away from the past content-driven curriculum “this Revised National Curriculum Statement does not want learners to memorise material which has no meaning or connections for them; however this Learning Outcome recognises that the ability to retrieve connected ideas is still a valuable intellectual skill” (Department of Education, 2002, p. 9)

2.8.3 Nature of scientific knowledge

Developing meaningful NOS understanding consist of recognizing the tentativeness of scientific information and it is experimentally founded, Lederman (2006). The RNCS policy document illustrates the vision of the nature of scientific knowledge by declaring that:

Knowledge production in science is an ongoing process that usually happens gradually, but occasionally knowledge leaps forward as a new theory replaces the dominant view. As with all other knowledge, scientific knowledge changes over time as people acquire new information and change their ways of viewing the world.

(Department of Education, 2002, p. 4)

The RNCS curriculum also acknowledges the empirical nature of scientific knowledge as it proclaims that the “the prevailing world view of science is based on empiricism...” (Department of Education, 2002, p. 11) and explain the strong points and restrictions of the science experiential foundation when stating that:

Empiricism fuelled the growth of modern science over the past 400 years and has been remarkably effective in generating accurate and reliable knowledge about the natural world. As an approach to understanding nature, it is used in research and science education in all countries of the world. It is challenged by those who argue that pure empirical science does not concern itself with questions of meaning and value, and is therefore too limited a way of understanding the world.

(Department of Education, 2002, p. 11)

Whilst recognising the triumph of the science experiential foundation, the RNCS policy document asserts the existence of the diverse techniques of understanding the physical world such as Indigenous Knowledge Systems (IKS). The importance of IKS as a means of understanding the natural world is highlighted in the text that follows:

Traditional technologies may reflect people’s wisdom and experience: Indigenous or traditional technologies and practices in South Africa were not just ways of working; they were ways of knowing and thinking. Traditional technologies and practices often reflect the wisdom of people who have lived a long time in one place and have a great deal of knowledge about the environment. Wisdom means

that they can predict the long-term results of decisions, and that they can recognise ideas which offer only short-term benefits.

There are other world-views. For example in South Africa many people hold a strong world-view which says that people are not separate from the earth and living things; they believe that all things have come from God or a creative spirit and therefore have spiritual meaning; events happen for spiritual as well as physical reasons.

(Department of Education, 2002, p. 10-11)

The policy document asserts that both IKS and modern science should form part of the school science curriculum, and it consider the actuality that different world-views are there in the science classrooms. It is also important for teachers to note that learners travel from the home culture, over the edge into the science culture, and come back again. The survival of varied world-views of understanding and explaining natural phenomena portrays solemn disputes to the manner in which science is exercised in the classroom. Onwu and Mosimege (2004) showed up that home-grown forms of knowledge and current science may not be observed as two ideas with opposite forms of knowledge, but the science classroom situation should draw-forth the public and cultural context of IKS and the gratifying aspects of both forms of knowledge. Helping learners in understanding disagreeing world-views has become a clear suggestion of the Assessment Standards in Learning Outcome 3 for grade nine as it states:

Achievement is evident when the learner, for example, identifies sources and nature of authority in two differing explanations for an event, coming from two differing worldviews; compares ways that knowledge is held in an oral tradition and in a written, public tradition; traces the way a theory about nature has changed over centuries.

(Department of Education, 2002, p. 59)

Worldwide, however, there are differing views about diluting science with cultural knowledge or the inclusion of indigenous aspects in science courses; some suggest they are separate fields, others support their integration while some suggest some inclusion (Naidoo & Vithal, 2014).

2.8.4 Social and cultural aspects of science

A scientifically literate society of the future looks for people who will possess conversant-judgment skills and the facts about science and its aspects (Koksal & Cakiroglu, 2010). This is very important for South Africa as its recent science curriculum shifts from the programmed inductivity – foundation to developing decisive thinkers who are capable of making those conversant-judgements about Science, Technology and Society (STS) related matters in a South African cultural context (Kurup & Webb, 2009). Therefore, science education in South Africa has adopted the global goal of curriculum modifications as advocated in western countries including the promotion of scientific literacy (NRC, 1996). This is evident the Natural Sciences curriculum (Grade R-9) that states “the Natural Sciences Learning Area deals with the promotion of scientific literacy by the development and use of science process skills in a variety of settings, the development and application of scientific knowledge and understanding and appreciation of the relationships and responsibilities between science, society and the environment” (Department of Education, 2002, p.4). Through the development and use of process skills learners will “develop the ability to think objectively and use a variety of forms of reasoning, while they use process skills to investigate, reflect, analyse, synthesise and communicate” (Department of Education, 2002, p. 4). Therefore, teachers require to develop “scientific knowledge and understanding of a cultural heritage”, that will enable them to assist learners “answer questions about the nature of the physical world”, get them ready for “economic activity and self expression”, put down a foundation for more “studies in science”, and “prepare

learners for active participation in a democratic society that value human rights and promotes environment responsibility” (Department of Education, 2002, p. 4).

It has become more imperative that science curricula in school engage learners in decisive discussions on moral issues associated to the utilization of scientific and technological knowledge. The significant fraction of the RNCS is that science as a cultural commotion is manipulated by immediate socio-political circumstances and principles, and it has powers over socio-economic circumstances and ethics of individuals, in the vicinity and worldwide. The acknowledgement granted to STS matters in the RNCS is clear as one of the seven Critical Outcomes of the curriculum asserts that the learners are to be capable to “use science and technology effectively and critically showing responsibility towards the environment and the health of others” and two of the five Developmental Outcomes foresee learners role as those who can “participate as responsible citizens in the life of local, national and global communities, and be culturally and aesthetically sensitive across a range of contexts” (Department of Education, 2002, p.1).

Out of the three aims of the Natural Sciences Learning Area one goes further describing the importance of STS by conveys that:

Science and technology have made a major impact, both positive and negative, on our world. Careful selection of science content, and use of a variety of ways of teaching and learning science, should promote understanding of: science as a human activity; the history of science; the contribution of science to social justice and social development; responsibility to ourselves, society and the environment; and the consequences of decisions that involve ethical issues.

(Department of Education, 2002, p. 5)

The RNCS Department of Education policy document does not explicitly state these as NOS aspects since it does not point out the term NOS. However, these concepts are widely accepted by researcher in the study of Nature of Science both locally (for example Dekkers & Mnisi, 2003; Kurup & Webb, 2009; Linneman et al., 2003) and internationally (Lederman, 2007; Lederman & Abd-El-Khalick, 1998; McComas, 1998; Osborne, Collins, Ratcliffe, Millar & Duschl, 2003). Therefore, the South African curriculum anticipates developing learners who are scientific literate and who can understand aspects of the NOS. However, the question of pedagogy still remains: Are South African Natural Sciences teachers able to put the policy of NOS and scientific literacy into practice? Thus the main purpose of this study is to explore teachers' understanding of NOS and how their understandings of NOS are transferred into instructional planning. To be able to explore these understandings, it is important to present a lens or a conceptual framework of NOS that underpins this study.

2.9 The Conceptual Framework of NOS

The conceptual framework of NOS in the particular study is based on seven aspects or characteristics of NOS and the collection and interpretation of data is guided by these aspects. Teachers' naïve and sophisticated understandings of NOS and explicit and implicit instruction also form the conceptual framework of NOS that underpins this study.

2.9.1 The aspects of the nature of science

NOS refer to the epistemology of science or principles and beliefs inherent to the development of scientific knowledge (Lederman, 1992). It is also about how scientists develop and justify knowledge claims about the natural world (McComas et al., 1998). However, there is

disagreement about the definitions of NOS among the philosophers of science, historians of science, sociologists of science, scientists and science educators (Akarsu, 2007, 2010; Bell, Lederman & Abd-El-Khalick, 2000; Duschl, 1994; Lederman & Abd-El-Khalick, 2000). Despite this disagreement, there appears to be agreement within the science community about what aspects should be used to describe the NOS (Lederman & Lederman, 2004a). These are an understanding that scientific knowledge is “tentative, subjective, empirically based, socially embedded, and dependent on human imagination and creativity and two additional aspects involve the distinction between observation and inference and the distinction between theories and laws” (Lederman & Lederman, 2004a, p. 37).

Since there are many NOS aspects, the framework of this study are developed upon the commonly agreed key aspects of NOS (Lederman & Lederman, 2004a; Lederman, 2007; Bell, 2011). These are as follows:

2.9.1.1 Empirical nature of science

Science is a mode of knowing and explaining the natural world that hold opposing views from other ways of knowing. The scientific knowledge and scientific inquiry is empirical in nature and it uses observations to make inferences and so knowledge claims (Jones, 2010). Jones also asserts that the scientific world view is supported by the hypothesis that the natural world is understandable and this understanding depends upon careful observation of phenomena. However, it is not possible for scientists to access to most natural phenomena directly. Therefore Lederman, Abd-El-Khalick, Bell and Schwartz (2002) assert that “observations of nature are always filtered through our perceptual apparatus and/or intricate instrumentation, interpreted from within elaborate theoretical frameworks, and almost always mediated by a host of assumptions that underlie the functioning of scientific instruments” (p.499). However it is important to note that there is no distinct method of

doing science that would ensure the development of never falling science knowledge (McComas et al., 1998; Lederman, 2004; Abd-El-Khalick, Waters & Le, 2008). Even though scientists do observe, compare, measure, test, speculate, and so forth, but they do not follow one order of (practical, conceptual, or logical) activities that may unfailingly guide them to sound claims, let alone ‘certain’ knowledge (Abd-El-Khalick et al., 2008). Therefore, teachers need to encourage learners to use different methods to conduct investigations so that learners understand that science communities accept different ways of interpreting a phenomenon.

2.9.1.2 Tentative nature of science

Scientific knowledge is able to be relied on and is strong and likely to last but it is never absolute or certain (Lederman, 2004), it can be revised in the light of new evidence (McComas, 1998). Every classes of knowledge including ‘facts’, ‘theories’, ‘laws’ are observed (Rutherford & Ahlgren, 1990). Teachers have to understand that scientific claims revolutionize as latest facts are made possible through abstract and technological proceedings are accepted; “as extant evidence is reinterpreted in light of new or revised theoretical ideas; or due to changes in the cultural and social spheres or shifts in the directions of established research programs” (Abd-El-Khalick, Waters & Le, 2008, p. 838).

Therefore, scientific knowledge is categorized by its descriptive and foretelling power. However, the scientific knowledge is also open to disapproval and change; it is a tentative knowledge that possesses different levels of uncertainty as permitted by the evidence (Abd-El-Khalick et al., 2008). Researchers clarifies that scientific knowledge is uncertain and tentative in that at any time new observations and evidence may require reviews to or complete elimination of exact claims. Further it is important to clarify that both a law and a theory are tentative. Therefore the law can for

no reason attain an entirely proven status (Lederman et al., 2002). Further, “uncertainty of scientific knowledge is observed because it is inferential, subjective, creative and culturally embedded in nature” (Sarkar & Gomes, 2010, p. 4).

2.9.1.3 Observation and inference

Although the starting point for scientist to build knowledge is through observation, science has its basis on observation as well as inference (Schwartz, Lederman & Crawford, 2004). There is a difference linking observation and inference (Lederman, 2007). Observations are expressive assertions about normal observable facts easily reached through the use of senses (or expansion of senses) and about which numerous spectators can arrive at its accord with relative ease (Schwartz, et al., 2004; Lederman, 2007). On the other hand, inferences go further than the senses to the interpretations of those observations. Therefore, Lederman et al. (2002) claim that inferences are reports about observable facts or phenomena that are indirectly reachable to the senses. Inferences are elucidations reasonably derived from a blend of observation and previous knowledge and together they outline the origin of all scientific ideas. For example, Lederman (2005) explain that stars are so distant in a way that solely a comparatively tiny part of their distances can be computed using straight observation and geometry therefore for their surplus (the stars) as well as distant celestial entities, a multifaceted blend of observations and inferences need to be applied.

2.9.1.4 Subjectivity and objectivity

Lederman (2004) argues that scientist’s knowledge based on theory, on experience, training, experience itself, commitment, religious and other beliefs, political convictions, gender and racial group can form thinking that impacts on scientific investigations. These background factors affect

scientists' choices of problems to investigate (Abd-El-Khalick et al., 2008), "how to conduct their investigations, what they observe (and do not observe) and how they make sense of, or interpret their observations" (Lederman, 2007, p. 834). Melville (2011) also emphasizes that scientists, like all people, are influenced by beliefs and prior knowledge therefore saying that science is objective is not realistic and current beliefs and knowledge affect the ways in which scientists conduct their investigations and their interpretations of observations. Theories provide a framework that guides observations and allows meaningful interpretation. I think it is significant for both teachers and learners to recognize that scientific knowledge is not only objective but carry subjectivity in it.

2.9. 1.5 The role of imagination and creativity

Although scientific knowledge is empirically based and developed through the observation of nature, it nevertheless involves human imagination and creativity (Lederman & Lederman, 2004b). They further stated that science engages the innovation of explanations, and that alone involves a huge deal of creativity by scientists and therefore imagination, creativity and uncertainty/scepticism are necessary tools in the production of scientific knowledge. This means scientific knowledge acquired through experimentations, researches, observations of natural phenomena and explanations are inventions and other are of creativity by scientists. According to Abd-El-Khalick et al. (2008) the creative nature of science together with its inferential nature entails that scientific entities are meaningful hypothetical models rather than fruitful duplicates of reality.

2.9.1.6 Nature and function of theories and laws

Generally, laws are expressive statement of relations amongst observable phenomena, whereas, "theories are explanations for observable phenomena or regularities in those phenomena"

(Abd-El-Khalick et al., 2008, p. 838) that are inferred. A theory is much more complex and dynamic as it presents the inferred explanations, and it often includes a law(s) (Sarkar & Gomes, 2010). Teachers have to understand that “theories and laws are different kinds of knowledge, and one does not develop or become transformed into the other, therefore scientists do not formulate theories in the hope that one day they will acquire a status of law” (Lederman, 2007, p.833-4). Moreover, accordingly, an individual who is developing scientific literacy will increasingly understand the relationship of theory to observations – without theory man does not know what to observe” (Robinson, 1968, p. 132).

2.9.1.7 Social and cultural embeddedness of science

Science affect while being influenced by different components as well as with contexts of ethnicity in which it is practiced (Lederman & Lederman, 2004b). Therefore, it is a human enterprise embedded and practiced in society (Abd-El-Khalick et al., 2008) and scientists are the part or result of that culture or society (Lederman 2007). Scientific endeavours are activities carried out by people and therefore the scientific enterprise is subject to the personal beliefs of these people. So if science processes are practiced by people whom are the part of society then it may be obvious that their work will be definitely influenced by societal and cultural beliefs and will frequently reveal social values and varying point of views (Jones, 2010). However, scientists use methods that try to minimize some personal, cultural, or societal bias in the process of constructing scientific knowledge.

As scientific knowledge is socially negotiated (Abd-El-Khalick et al., 2008), it is unavoidable for science to reflect social values and viewpoints (McComas, 1998) and scientific work is a human activity undertaken both by individuals and by groups (Osborne et al., 2003; Sarkar & Gomes, 2010). Any new knowledge produced is generally shared and reviewed (Osborne et al.,

2003) to be acceptable to the scientific community (Sarkar & Gomes, 2010). It is also important to note that scientists may work as individuals but they contribute to the communal generation of a common, reliable body of knowledge. This tenet connect with what Linneman et al. (2003) claim as they point out that learners may learn that indigenous knowledge has a place in the science curriculum through learning how science is practices in different cultures and communities. It is therefore important for teachers to engage learners in different activities that are strategically developed to increase their understandings of NOS aspects because learners cannot acquire adequate knowledge of NOS through learning a list of its aspects (Bell, 2011).

2.9.2 The understanding of NOS: naïve versus sophisticated ideas

NOS ideas has been described as either naïve or sophisticated (Kang & Wallace, 2005; Southerland, Gess-Newsome & Johnston, 2003). A person is “harbouring naïve scientific epistemologies if he or she subscribe to such notions and beliefs as: scientific knowledge is certain and 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” (Vhurumuku, 2010, p. 100). Vhurumuku further states that harbouring sophisticated understanding of NOS means to have views and ideas as “scientific knowledge is dynamic, tentative, revisionary ... there exist multiple truths and realities which are neither fixed nor absolute; there are several appropriate methods in science; scientific observations are theory-laden and dependent on the experience and preconceptions of the observer; and the development of scientific knowledge is based on empirical investigation as well as the creativity and imagination of scientists” (p. 100).

When looking to NOS understanding Lederman, Schwartz, Abd-El-Khalick and Bell (2001) uses the term inadequate and adequate as same as naïve and sophisticated. On the other hand Tsai (2003) uses the term positivist and constructivist to differentiate the NOS understandings. It is important to note that naïve and inadequate views correspond with the positivist view and the sophisticated and/or adequate view goes with constructivists' views as described in Tsai (2003) and Kang and Wallace (2005). Teachers' NOS understanding as inadequate/naïve and adequate/sophisticated are used in this study as a frame to explore and analyse teachers' views about NOS. These understandings are also used to analyse teachers' teaching practice as the study is looking on how teachers explain scientific ideas and organize information when teaching.

2.9.3 The teaching of NOS: explicit versus implicit

Teaching does not happen by chance it requires proper planning. Also Clough (2011, p. 57) presents a notion that effective NOS instruction does not just happens by chance so teachers who genuinely want their learners to accurately understand NOS see it as a crucial goal in science education and they frequently express it as an objective in their lesson plans. Therefore this study also focuses on the distinction between explicit and implicit attention to NOS core concepts. Abell, Martini and George (2001) identified the significance of being unambiguous in the teaching of NOS than being implicit. Further, the use of explicit rather than implicit curriculum instructional approaches has been recommended for the development of learners' understandings of the NOS (Dekkers, 2006; Linneman et al., 2003; Vhurumuku, Holtman, Mikalsen & Kolsto, 2006). Vhurumuku (2010) assert that curriculum and instructional approach are considered explicit if the subject matter, teaching method and assessment of learners are intentionally aimed at developing learners' NOS conceptions. In the explicit approach, teachers should plan for NOS teaching and should intentionally draws learners' interest to aspects of NOS using conversations, channelled

reflection, and detailed questioning during “activities, investigations and historical examples” (Schwartz et al., 2004, p. 614).

On the other hand implicit approach assumes that NOS understanding is basically a result of partaking in science inquiry (Akerson & Hanuscin, 2007). It is about the lack of specific attention to NOS (Schwartz et al., 2004). It assumed that by practicing science students can develop well-versed understandings in terms of the character of scientific knowledge and scientific process (Vhurumuku, 2010). Lederman (2004, p. 315) assert that a major difficulty in implementing NOS is the expectations that learners will come to understand it by “doing science”. Khishfe and Abd-El-Khalick (2002) use the explicit-reflective approach as same as explicit strategies. In this approach the teacher draw on learners’ prior understanding and explicitly introduce them to NOS core concepts or aspects and encourage them to reflect on their prior ideas. Therefore for teachers to be able to facilitate understanding of NOS, they need to go beyond the traditional curriculum and emphasize the difficulties faced by the scientists, and how the interpretation of data is always problematic, leading to controversies among contending groups of researchers (Niaz, 2009, p. 24). Therefore planning should a thorough activity on the side of the teacher as Clough (2011) claim that:

Explicitly planning for and drawing students’ attention to NOS does not mean lecturing to them about it, rather, address it in the context of laboratory activities, videos, reading assignments, and interactive science content presentations, or try asking kinds of questions explicitly raise NOS ideas and can be used in most any lesson to get students thinking about how science and scientists’ work (p.57).

There is a range of explicit instructional techniques used to teach learners about the NOS. These explicit strategies include a combination of the explicit-reflective approach described in Khishfe and Abd-El-Khalick (2002) which is the method that is largely constructivist and allows the teacher to draw out learners’ prior understandings then explicitly introduces them to selected NOS

aspects and go further asking them to reflect on their prior ideas. They also include the historical approaches as supported by Matthews (1998) that generally ask students to read and reflect on selected historical case studies from a NOS perspective.

On a study conducted in German where implicit approach to teaching NOS aspects was used, Bell (2001) reports that it failed to change the naïve NOS understandings in pre-service teachers. In contrast Khishfe et al. (2002) reported that an explicit reflective inquiry-orientated activity improved understandings of sixth graders. Further Irez and Cakir (2006) as well as Clough and Olson (2008) in their studies conducted on teachers reported more evidence in support of explicit teaching.

As Leach (1995, p. 4) claims “if developing students’ understanding of the nature of science is to be an *explicit* purpose of science education, rather than an *implicit* consequence of it, then it is necessary to characterize the nature of the understandings that it is hoped to promote.” This Master’s study also examines teachers in terms of whether they plan to teach NOS explicitly or implicitly in their instructional planning. It examines whether teachers plan to teach and assess NOS core concepts or aspects or teach learners to practice science with the assumption that they will develop the desired or adequate understandings of NOS. Teachers’ documents were analysed in order to find out what kinds of activities they give to learners (are they explicitly or implicitly inquiry-orientated). It also examine whether teachers give the explicit-reflective activities to learners or not. The researcher developed schedule for this study using the key NOS aspects reflected in the questionnaire (Appendix G) for analysing the planning documents. Each teacher’s lesson plan was judged against NOS aspects. The categories “Explicitly Discussed (ED)” if the teacher clearly stated the NOS aspect he/she intended to address when teaching in the lesson plans was used in this study. If the teachers’ lesson plan reflected some topics/or activities that address NOS aspects but not clearly stated, it was

categorized as “Implicitly Discussed” (ID). This study also used the category “Not Discussed” (ND) if the teacher did not display the NOS aspect in the lesson plan.

2.10. Summary of the chapter

The chapter presented the reviewed literature on the NOS. It distinguished science from NOS. It drew on Lederman (2007) definition of science as “the body of knowledge, method and the way of knowing” (p. 833). On the other hand d NOS is defined “as epistemology of science, science as a way of knowing” (Lederman, 2007, p. 833), or the “value and beliefs inherent of scientific knowledge and its development” (Lederman (1992, p. 33). The NOS was discussed as a central and crucial constituent of scientific literacy (DeBoer, 2000) in the science education reform (Hanuscin, Lee & Akerson, 2011).

This study also reviewed literature on the importance of NOS; the international studies on teachers’ understanding of NOS and pedagogy; South African studies on NOS and the NOS aspects in the South African curriculum. Developing these aspects the scientific investigations, the development of scientific knowledge, nature of scientific knowledge and social and cultural aspects of science were discussed.

The aspects of NOS which involves the tentative nature of science; difference between observation and inference; objectivity and subjectivity of science; imagination and creativity; the nature and function of theories and laws; the scientific methods and the social and cultural embeddedness of science were discussed in this study as part of the conceptual framework. The conceptual framework in this study also involved the teachers’ understanding of NOS in terms of

whether they possess naïve or sophisticated ideas and whether their planning to teach NOS is done explicitly or implicitly.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter presents the theoretical framework guiding this study. It describes the theoretical perspectives underpinning the methodology, data collection techniques and data analysis to achieve the focal intention of the study. The focal intention of this study is to explore KwaZulu-Natal teachers' NOS understandings and to investigate how their understandings influence the planning of lessons to teach NOS in their classrooms.

Taking into account the purpose of this study, the following questions are addressed:-

- What do Grade 9 Natural Sciences teachers understand about the Nature of Science (NOS)?
- How do Grade 9 Natural Sciences teachers plan to teach Nature of Science (NOS)?
- How do Grade 9 Natural Sciences teachers' understandings of Nature of Science (NOS) influence their instructional planning?

3.2 Research Paradigm

In his studies of history of science Kuhn (1996) described scientists as people working within 'a paradigm' or a disciplinary milieu. When setting a knowledge claim, researchers begin their work with certain hypothesis in regard to how and what they will learn during their inquiry. These claims are called paradigms (Lincoln & Guba, 2000; Mertens, 1998); or broadly conceived research methodologies (Neuman, 2000). According to Nieuwenhuis (2010 b) a paradigm is "a set of

assumptions or belief about fundamental aspects of reality which gives rise to a particular world-view” (p. 47). Therefore through paradigms, researchers address “fundamental assumptions about nature of reality (ontology), the relationship between the knower and known (epistemology)” (Nieuwenhuis, 2010 b, p.47- 48), what values go into it (axiology), how we write about it (rhetoric), and the processes for studying it (methodology) (Creswell, 1994). It is important to clarify that there is a close relationship between epistemology and methodology, however, epistemology relates to the “ways of researching and enquiring into the nature of reality and the nature of things” (Cohen, Manion & Morrison 2011, p. 3) while methodology refers to the what are suitable techniques of researching multifaceted and numerous realities (Cohen, Manion & Morrison 2011; Henning, Van Rensburg & Smit, 2005).

In their portrayal of sociological paradigms which they locate in four separate quadrants Burrell and Morgan (1979) presented research paradigms that includes critical theory, structuralist theory, interpretivism and positivism. They presented their thought diagrammatically as follows:

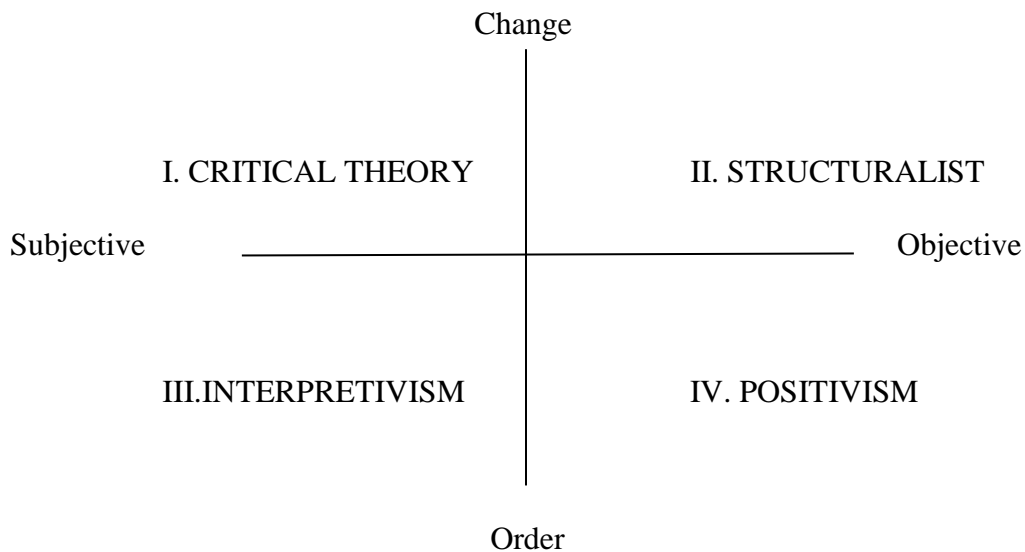


Figure 3.1 Research paradigms (Burrell & Morgan, 1979, p. 61)

Burrell and Morgan's (1979) representations of paradigms is founded on four familiar contestations or disputes in sociology which includes: a) the perception of realism that tries to determine whether a persons' realism is grown up by means of communal structure or whether reality is a creation of one's mentality; b) its focal point is how a person commences to comprehend a new idea, conception or custom and questions if is there a necessity for one's experiences to realize those ideas; c) it deals with what guides individuals to make decisions their free will or their environment; and d) question facades on how comprehension is best achieved. The Cartesian axes of the paradigmatic model of social theories (see Figure 3.1) addresses the manner in which one analyses these four debates. The critical issue examines communal theories that give emphasis to constancy (Order) to theories that give emphasis to fundamental change (Change), they then take the direction of distinctiveness (Subjective) or organizational (Objective) theories (Burrell & Morgan, 1979).

Another model formulated by Chua (1986) supported by Orlikowski and Baroudi (1991) suggested three categories based on the underlying research epistemology: positivist, interpretive and critical. In 1994 Guba and Lincoln extended this Chua's model in suggesting four underlying paradigm for research that is, positivism, post-positivism, critical theory and constructivism. This study uses the interpretive paradigm (from Chua's model) because its central endeavour in the context is to understand the biased human's world experiences and Guba and Lincoln's paradigm of post-positivism because of the data collection tool used also has the essence of post-positivism in it. Therefore, in this study the discussion of interpretivism and post-positivism will be done in greater detail as disconnected and different paradigms.

3.2.1 Post-positivism

The term, “post-positivism,” refers to the thoughts past positivism, opposing the fixed conception of the absolute truth of knowledge (Phillips & Burbules, 2000) and be aware of the fact that we cannot be optimistic about our claims of knowledge when learning the conduct and deeds of humans (Creswell, 2003). Post-positivists accept the notion that facts and observations are theory-laden and value-laden (Popper, 1980), that the accumulation of facts and theories can involve making mistakes and that different theories may support specific observations. Guba and Lincoln (1994) describe post-positivism and critical theory as two research traditions that occupy the space between positivism and constructivism. Post-positivism is a useful paradigm for researchers who wish to integrate positivism into interpretivist concerns around subjectivity and meaning and those who are interested in exploring the pragmatic issues emerging from a combination of qualitative and quantitative methods. Post-positivist approaches take for granted that reality is numerous, biased and constructed in the mind of a person. It also claims that reality is not an unchanging entity and it is to a certain level acknowledged that reality is a formation of the persons engaged in the research endeavour (Nieuwenhuis, 2010 b).

3.2.2 Interpretivism

The central endeavour in the context of the “interpretive paradigm is to *understand* the subjective world of human experience” (Cohen et al., 2007, p. 21). Interpretivism has its roots in hermeneutics, “the study of the theory and practice of interpretation” (Nieuwenhuis, 2010 b p. 58). As in constructivism, naturalistic and micro-ethnography theories, a main characteristic in the interpretivist belief gives attention particularly to the societal production of knowledge (Lather,

1991). According to Mouton (2001) the focal point of interpretivist framework and interpretivist-based research is on implications and efforts to comprehend the background and entirety of each circumstance using different qualitative methods. Denzin and Lincoln (2003) see respondents in an interpretive approach as lively agents who are free and capable of creating their social reality.

This paradigm tries to find explanations about the participant's actions from their individual point of view, as opposed to presenting them as external imposition to the conditions in which they are located (Cohen, Manion & Morrison, 2011). Therefore the focus of interpretivism is epistemologically on the comparative nature of knowledge and recognizes that knowledge is constructed, interpreted and understood from a societal and also individual perspective (Kurup, 2010). Cohen et al., (2011, p. 116) adds that the "interpretive paradigm rests, as part, on a subjectivist, interactionist, socially constructed ontology and an epistemology that recognized multiple realities, agentic behaviours and the importance of understanding a situation through the eyes of the participants." Further the interpretive researcher should understand how reality goes on at one time and in one place and compare it with what goes on in different times and places. Nieuwenhuis (2010 b) state the most critique levelled against the interpretivist research paradigm as the one that is directed at the subjectivity and the failure of the approach to generalise its findings beyond the situation studied as often encountered in small case studies. Furthermore, he presents a lucid understanding of the interpretivism approach, valuable to the paradigm selected for this study, using the following representation (see Figure 3.2):

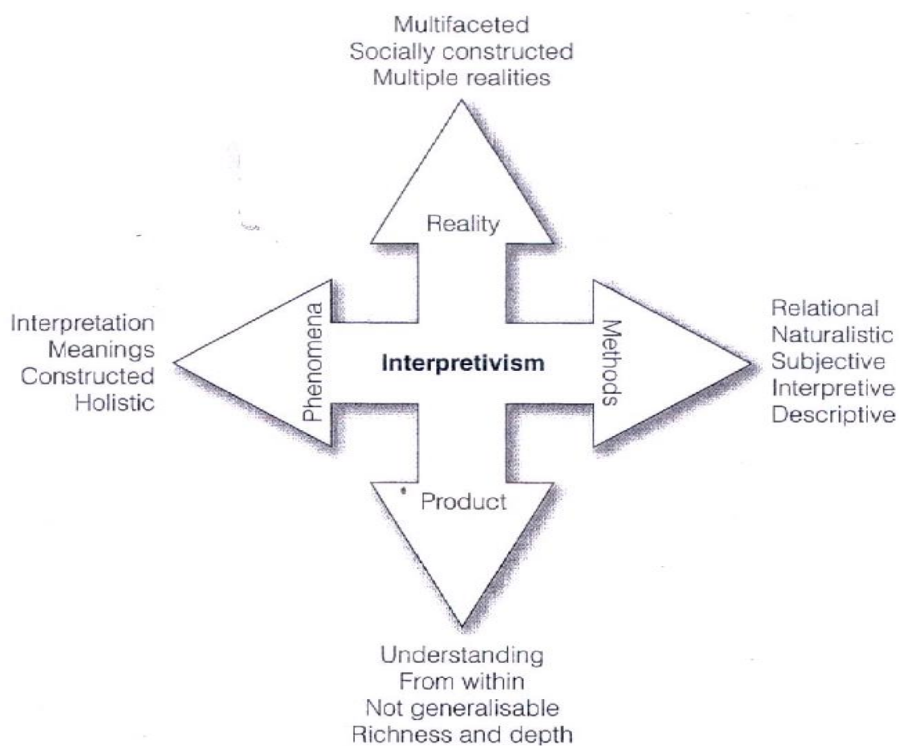


Figure 3.2 Representation of interpretivism [adapted from Nieuwenhuis, 2010, p. 61]

3.3 Research Design

Cohen, Manion and Morrison (2011) state that research design is ruled by the conception of ‘fitness for purpose’, “the purpose of the research determine the methodology and design of the research” (p. 115). This study uses the qualitative approach thus the interpretive paradigm is appropriate. Therefore qualitative data to be collected in this study must involve “thick descriptions” (Cohen et al., 2011, p. 538). They add that while qualitative data often focuses on lesser numbers of people compared to quantitative data, the data have a tendency to be in depth and rich. Qualitative data as described by Patton (2002) are “detailed descriptions of situations, events, people, observed behaviours, direct quotations from people about their experiences, attitudes, beliefs, and thoughts ...” (p. 22). Qualitative research is typically descriptive or evaluative (Rossman & Rallis, 2003), therefore unlike in the quantitative approach, the qualitative approach to data is presented in the form of words

rather than numbers. Qualitative studies do not lend themselves to generalisations because they take place in naturalistic settings and are situated in the particular background in which the phenomenon is being studied (Rossman & Rallis, 2003).

When stressing the main goal of the qualitative researcher, Creswell (2008) state that is to explore and understand a central phenomenon which is the concept or process explored in a qualitative research study, for example, Nature of Science in this study. On the other hand Denzin and Lincoln (2005) view the qualitative researcher as the one who usually approaches reality from the constructivist position that permits for multiples of meanings of individual experiences. Since the qualitative researcher collects words and images about the central phenomenon, he/ she serves as an instrument of data collection and asks the participants broad, open-ended questions that may drive them on sharing their views and experiences with the phenomenon (Ivankova, Creswell, & Clark, 2010).

The most important qualitative designs comprises of case study, phenomenology, grounded theory, ethnography and narrative research (Creswell, 2007). A case study is “an empirical inquiry that investigates a contemporary phenomenon within its real life context using multiple sources of evidence” (Yin, 1984, p.23). Yin’s definition accords with Bromley (1990, p. 302) as he describe a case study research as a “systematic inquiry into an event or a set of related events which aims to describe and explain the phenomenon of interest.” On the other hand, Creswell (1994) defines a case study as a single instance of a bounded system but in opposition. Yin (2009, p. 18) argues that the border- line between the phenomenon and its context is unclear because a case study is a study of a case in a context and it is important to set a case within its context. This study uses the interpretive paradigm because its central endeavour in the context is to understand subjective world of human experience. Further Denzin and Lincoln (2000) describe the case study as one type of an interpretive

research suitable for understanding qualitative inquiry within a context. Therefore, drawing from Babbie and Mouton (2001), in this study the researcher, investigate the behaviour of the respondents in their usual background and try to make meaning of their behaviour in relation to their beliefs, history and context. Case studies recognize and accept that there are several factors in a single case therefore grasping the implications of these factors or variables regularly involves more than one tool for data collection and many sources of evidence (Cohen et al., 2011).

This research is a case study. The key strength of its method is the utilisation of numerous ‘sources and techniques in the data collection process’ (Nieuwenhuis, 2010a, p. 76). Thus the data collection process in this study involves a limited survey through open-ended questionnaires, interviewing of teachers for their NOS understandings and analysing their instructional planning documents, of which, all are analysed inductively to address the research question posed. It is important to note that in these methods of data collection, the participants are actively involved and the researcher attempts to figure out how participants make sense of their experiences (Merriam, 2009). In a qualitative case study, a researcher is required to spend much time with the participants in their natural setting in order to be able to interact in person with all diverse facets and dynamics of the case, evaluating and re-examining actions and illustrate what has taken place (Stake, 2005).

The types of case studies are numerous. Merriam (1988) categorises case studies in three diverse kinds namely, ‘interpretive’, ‘descriptive’ and ‘evaluative’. Interpretive case study is intended at developing conceptual categories inductively in order to examine initial assumptions whereas descriptive case study present narrative accounts and evaluative case study is judging and explaining. Yin (1984) classified case studies into ‘exploratory’, ‘descriptive’ and ‘evaluative’ and his classifications accords with Merriam. As indicated earlier, there is little research on how teachers’ understandings of NOS influence their instructional planning in South Africa. Since this study is

aimed at exploring and developing better understanding of the participants' knowledge of NOS, an interpretive case study is a good fit.

3.4 The selection of Participants

A sample size in qualitative research is debatable. It is not precise how much the sample size should be (Patton, 2002). Cohen et al. (2011, p. 144) argues that “there is no clear-cut answer, for the correct sample size depends on the purpose of the study, the nature of the population under scrutiny, the level of accuracy required, the anticipated response rate, the number of variables that are included in the research, and whether the research is quantitative or qualitative”. There are two major classes to which sampling methods belong, namely probability methods and non-probability methods (Maree & Pietersen, 2010; Cohen et al., 2011). According to Maree et al. (2010, p. 172) “probability methods are based on the principles of randomness and probability theory” while non-probability is purposive and selective as it “derived from the researcher targeting a specific group, in the full awareness that it does not represent a broader population but itself” (Cohen et al., 2011, p. 155). The latter is frequently used in a small scale study. This is a small scale study consisting of six Grade Nine (9) Natural Sciences teachers' of UMsunduzi Circuit in UMgungundlovu District followed over a period of one year. Data was collected from August 2012 over a period of 8 months due to the constraints relating to the availability of teachers who were participants.

As this study embarks on purposive sampling, this was a sample of convenience (also known as opportunity sampling). Because of geographic accessibility, it was easy to travel to the schools and transportation costs were minimized. Cohen et al. (2011) argue that convenient sampling involved selecting the closest persons to serve as informants and continuing that practice until the necessary

sample size has been attained or those who happen to be obtainable and easily reached at the time of collection of data. A description of the background of each participant is given in section 4.2. In this ‘NOS teaching preparation’ case study, each teacher’s classroom planning was analysed together with their learners’ planned activities, and the description of the analysis from lessons prepared and interpretations were presented as a case. The participants in this study are not the representatives of all Grade 9 Natural Sciences teachers in UMsunduzi circuit therefore the results obtained from the study may not be generalized thus it is argued that “the parameters of generalizability in this type of sampling is negligible” (Cohen et al., 2011, p. 156).

3.5 Data collection methods

As mentioned previously that this study is a case study, case studies are diverse in the type of data that are used (Cohen et al., 2011). Observation and participant observation are usually exceptional in the case studies but they are by no means the only sources of data (Cohen et al., 2011). Qualitative data in this study is collected through the use of the open-ended questionnaire, semi-structured interviews and documentary analyses.

Table 3.1 Data Collection Plan

Questions	Data collection plan	Justification
Why is the data being collected?	To explore Natural Science teachers understanding of NOS and how that knowledge influence their instructional planning.	Natural Sciences teachers seem to possess limited understanding of NOS and their NOS understandings and knowledge does not always translate into practice.
What is the research design?	Participants will complete questionnaires, be interviewed individually and their instructional planning document will be analysed.	The documents will reveal the teachers' intentions and their planning to teach NOS.
Who will be the sources of data?	Six Grade 9 Natural Sciences teachers	It will represent a sample of Grade 9 Natural Sciences teachers in UMsunduzi circuit.
Where will the data be collected?	At schools where Natural Sciences teachers teach.	The schools are the sites where NOS is taught and teachers will be in their naturalistic teaching and learning environment which lead to validity of this case study research.
How often will data be collected?	One long interview to be conducted for each teacher which will be approximately 45 minutes. A documentary analysis for a selected lesson that focuses NOS knowledge for each teacher will be conducted.	The interview will probe the level of NOS understanding. Documents will give insight into how teachers plan to integrate NOS in their lessons.
How will the data be collected?	Questionnaires to be collected from teachers. Interviews to be conducted using an interview schedule. Documentary analysis to be conducted.	To probe Natural Sciences teachers' understanding of NOS. To probe the variety of instructional strategies planned to be used for NOS teaching and learning. Also to probe a relationship between teachers' NOS understanding and their instructional planning.

3.5.1 Methods used to collect data

This study collected data from the participants in three different ways over the period of 8 months aiming to understand the connection between participants' NOS understanding of NOS and how they translate it into their planning documents. These include: (1) a VNOS-C questionnaire, (2) the VNOS-C questionnaire in a follow-up interview protocol was used as a semi-structured schedule, (3) participants work schedules and lesson plans.

3.5.1.1 VNOS- C questionnaire

The instrument used to draw up a survey teacher understanding aspects of NOS was the Views of Nature of Science questionnaire (VNOS). The Views of Nature of Science Questionnaire has numerous editions and all editions use open-ended questions. The regularly used versions are the VNOS-B (7 items) and the VNOS-C (10 items). In these two versions each question is dealing with a different aspect of science and both questionnaires give participants the freedom to express their understandings of the seven target aspects of NOS in their own words. This study used the VNOS-C (see Appendix D) to explore teachers' understanding of the aspects of NOS. The VNOS-C was developed by Abd- El-Khalick (1998) through modifying and expanding the VNOS-B questionnaire by adopting item 3, modifying items 1, 2, 5 and 7 and adding five new items (Lederman et al., 2002). This questionnaire's content was validated by a panel of five experts whom were university professors of which three were science educators, a historian of science and a scientist (Lederman et al., 2002).

The VNOS-C questions were adapted from Abd-El-Khalick (1998), Lederman et al. (2001) and Lederman et al. (2002), each question focuses on different science aspects. The questionnaire

items asked participants to give good reason for their responses and to sustain them with appropriate case in points or examples. Through rationalization the researcher was aiming at assessing the intensity of the respondents' understandings in regard to NOS aspects. Each VNOS-C item was written on its own page for respondents to have sufficient space to note down their responses. The participants were persuaded to put in writing as much as they can in response to any one item, ensure that they attend to every sub-sections of an item, and give examples where asked to. To encourage them (respondents) to write freely they were informed that no response will be taken as correct or to any item but the target focus on obtaining their understandings based on NOS aspects. Due to time constraints and since the respondents were practicing teachers they completed the open-ended questionnaires at home and it was collected in a week's time. This was done although according to Abd-El-Khalick (1998) administering the questionnaires in an uncontrolled setting increase concerns in terms of validity of participants' responses.

The questionnaire contained ten items the study used the seven key or targeted aspects of the scientific views as a coding scheme adopted from Abd-El-Khalick and Lederman's (2000) study: Scientific knowledge is: "(a) tentative (subject to change); (b) empirically-based (based on and/or derived from observations of the natural world); (c) subjective (theory-laden); (d) partially based on human inference, imagination, and creativity; and (e) socially and culturally embedded. Two additional important aspects are the distinction between observation and inference, and the functions of, and relationship between scientific theories and laws" (p. 1063). These key aspects of NOS were linked with each question in the VNOS-C questionnaire (see Appendix D). This was based on the work done by Abd-El-Khalick (1998), Lederman et al. (2001) as well as Lederman et al. (2002). Responses to questionnaire items were used to describe more than one target aspect of NOS.

The researcher in this study decided to use the VNOS-C because it has been used internationally and in the South African context (e.g. Dekkers & Mnisi, 2003; Naidoo & Govender, 2010), it has been validated and the language used is clear and unambiguous, especially for English second-language speaking teachers. The questionnaire also permitted the participants to “write a free account in their own terms, to explain and qualify their responses and avoid the limitations of pre-set categories of response” (Cohen et al., 2011, p. 382). The administration of the VNOS-C questionnaire was followed by the respondents’ individual interview.

3.5.1.2 VNOS-C questionnaire used in follow-up Interview Protocol

In this study the VNOS-C questionnaire was used in interviewing all six (100%) of the participants using the recommended semi-structured interview follow-up protocol (see Appendix E). The instrument was adapted from the work done by Lederman et al. (2002). Numerous studies used both the questionnaire and semi-structured interview follow-up protocol to further establish the validity of the VNOS-C (for example: Abd-El-Khalick, 2001; Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick & Lederman, 2000; Akerson et al., 2007; Hanuscin et al., 2006; Lederman et al., 2001; Schwartz et al., 2004). In this study the researcher compared interview responses to written responses to the VNOS-C questionnaire for reliability or consistency. Where there was inconsistency between the questionnaire and interview data the researcher gave priority on interview data, similar to Lederman et al. (2002). Interviews were carried out in controlled locations in vacant school classrooms and lasted between 30- 45 minutes. With the permission of the participants’ responses to the interview, questions were audio-taped, noted and transcribed. Further, three participants (50%) were also interviewed by the researcher with the aim of gaining in-depth understanding of how these teachers plan to *integrate* the tentative nature of scientific knowledge and the role of creativity and imagination when preparing for classroom practice. These teachers selection for further interviews

was based on their schools' location, reputation and the resources they have in their schools to support teaching and learning.

Through the use of the semi-structured interview schedule, the researcher tried to gain the in-depth data from the participants and to find out what lies behind teachers' action (Creswell, 2003). Because the interviews were semi-structured, the researcher was able to ask questions that probed how teachers integrated NOS in their teaching plans. As “an interview is a two-way conversation in which the interviewer asks the participant questions to collect data and to learn about the ideas, beliefs, views, opinions and behaviours of the participant” (Nieuwenhuis, 2010a, p, 87), it helped me as a researcher to understand the experiences of the participants, their background knowledge and social reality of their daily school lives (Nieuwenhuis, 2010a). The interview transcripts for all participants were analysed with the aim to validate participants' responses to the VNOS-C questionnaire.

3.5.1.3. Documentary analysis

Having adequate NOS understanding as well ability to transfer that understanding into practice is very important. Therefore teachers have to possess Pedagogical Content Knowledge (PCK) for teaching NOS that involves content knowledge related NOS and having knowledge of instructional strategies, examples, and activities to reflect NOS in class (Hanuscin, Lee & Akerson, 2011). In that sense, work schedules and lesson plans of Natural Sciences teachers might serve as suitable tool to examine their NOS understanding and how it relate to their instructional planning and practice. It was anticipated that teachers' lesson plans and its analysis regarding NOS can provide an understanding of how they integrate instructional activities and assessment strategies of NOS as well as integration of NOS into science content.

Documentary analysis as used in this study focused on written communications that may shed light on teachers' NOS understanding and how their understandings affect their teaching in the classroom. The study focused on the primary sources as it scrutinized the teachers' work schedule, lesson plans, activities planned for learners by a teacher and the assessment tasks planned for learners. For document analysis the researcher collected the copies of the documents to be analysed. The researcher focused on whether teaching NOS is planned explicitly as described in Bell (2001), Khishfe et al. (2002), Lederman (2006) and Matthews (1998) in the documentary analysis process.

The schedule (Appendix G) for analysing the planning documents was developed for this study using the key NOS aspects reflected in the questionnaire by a researcher. Each teacher's lesson plan was judged against NOS aspects. The categories "Explicitly Discussed (ED)" if the teacher clearly stated the NOS aspect he/she intended to address when teaching in the lesson plans was used in this study. If the teachers' lesson plan reflected some topics/or activities that address NOS aspects but not clearly stated, it was categorized as "Implicitly Discussed" (ID). This study also used the category "Not Discussed" (ND) if the teacher did not display the NOS aspect in the lesson plan.

Each teacher's documents were scrutinized for one lesson focus knowledge. Most of lessons took about a week therefore the researcher analysed all the activities planned for the specific topic to see if there was anything relating to the nature of science that was presented either implicitly or explicitly. Notes were taken while the analysis was taking place. A narrative description of the information that emerged in the documents served as a source of data.

3.5.2 Process of data analysis

Although this study is deductive in nature, it employs the inductive process for analysing its data since in this study the researcher worked from the raw data collected. Inductive process is the process of organising the data into categories and identifying patterns among the categories (Thomas, 2006). Data from the VNOS-C questionnaire, semi-structured interview schedule and documentary analysis were used to answer the three research questions posed. In chapter two of this study the core aspects of NOS were outlined as part of the conceptual framework underpinning teachers' understanding of the core aspects of NOS, these aspects were used to gain profound insight into the six Natural Sciences teachers. The seven NOS aspects were used as standard categories or themes in the study. Since this was a small scale case study as mentioned previously, both questionnaire and interview responses were analysed together to answer the first research question.

After reading the questionnaire and interview data for several times, the emergent categories were developed by the researcher from both questionnaire and interview data. The emergent categories were discussed with my two supervisors to ensure their validity. The term 'naïve' was used in this study for understandings that were not correct and not in line with aspects of NOS whereas the term 'inadequate' referred to aspects of NOS that was partially correct but an incomplete understanding as required by teachers who are teaching Physical Science at secondary level and 'adequate' was linked with the understanding of NOS that matched the NOS aspects descriptions as in literature. Further the term 'mixed' was related to the dichotomous understanding, where some aspects within the category were understood and some confused. These emergent categories were presented in tables together with enumerations of responses from questionnaire and interviews and justifying responses. Since this is a qualitative study enumerations were used only to assist the researcher in clarifying words used in the report such a few or many.

To answer the second research question three participants out of six were interviewed on how they plan to teach or integrate the tentative nature of scientific knowledge and the role of imagination and creativity in their teaching. These were selected because were the better representatives of wider school population as they comprises of a White male teacher from a girls' multiracial school, an Indian female teacher from a multiracial school and an African female teacher from an African school. Their narrative responses were given and then the data was summarised in a table.

The planning documents for each teacher were also used to identify and explore how teachers intend to integrate NOS aspects into their instructional planning tools. These tools are the work schedules and the lesson plans. The researcher used the NOS core aspects to develop a checklist to analyse both the work schedule and lesson plan documents copies for each teacher. To be able to identify the NOS aspects in these documents, they were read and analysed, descriptive accounts were presented and then the syntheses was done to present NOS aspects identified. This analysis helped me to answer the research question three.

Further the analysis of questionnaire and interview data together documentary data were used to develop an insight into how teachers' understandings of NOS influence their instructional planning. The data analysis in this study is therefore divided into three major themes. Figure 3.3 below present these major themes:

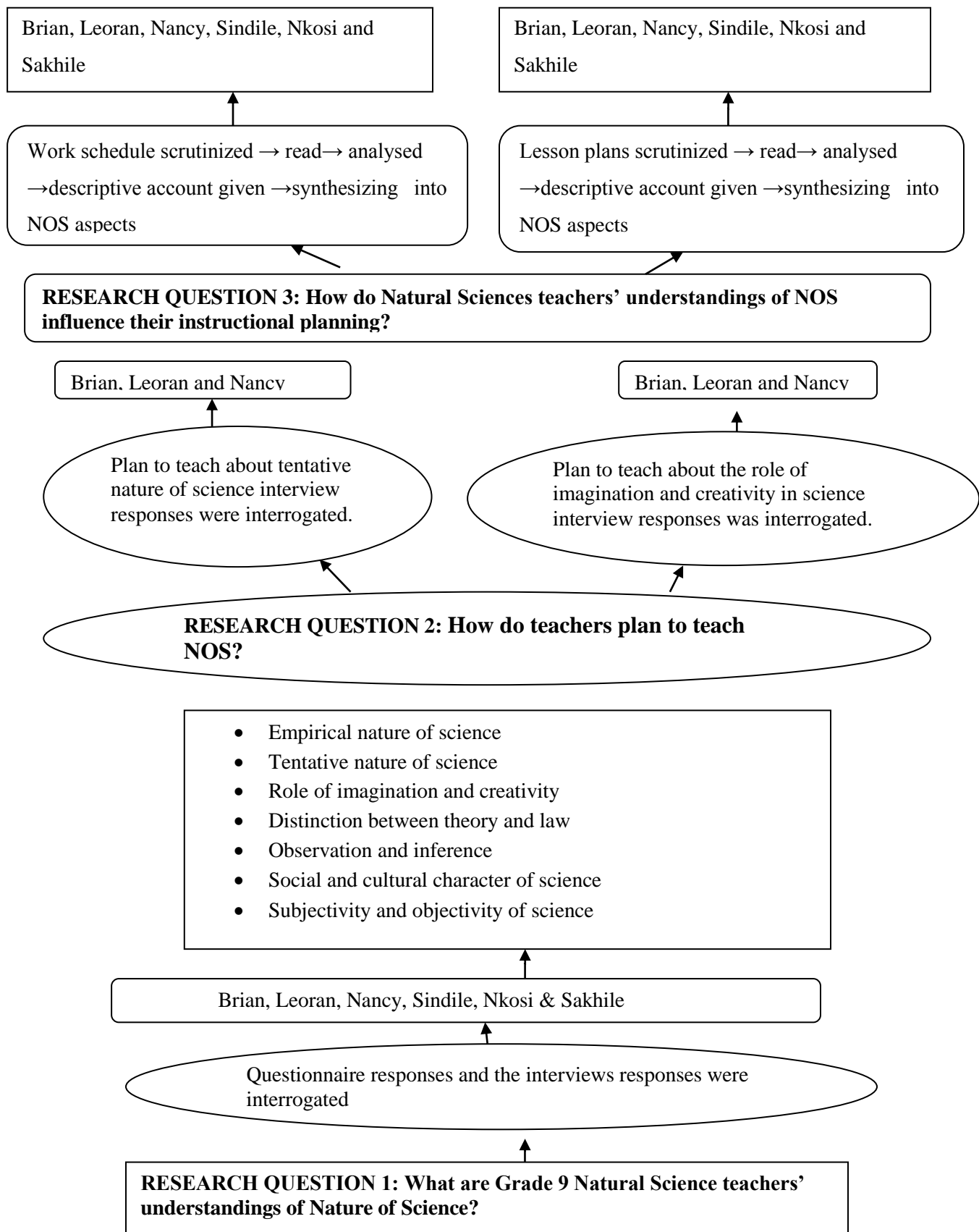


Figure 3.3 An overview of data analysis

3.6 Design limitations

There are certain limitations that were experienced during the research, such as: time constraints on the side of participants; unavailability of teachers due to their school programmes and/or teacher absenteeism due to various illnesses. This meant more visits to the school to ensure adequate collection of data for the study. Since this is a small-scale case study, the results may not be generalized and may not be simply open to cross-checking hence they may be selective, biased, personal and subjective (Nisbet & Watt, 1984).

3.7 Trustworthiness

This research used three types of data collection methods. The data collection instruments used in this study was fit for the purpose to ensure that the data collected is trustworthy (Cohen et al, 2007). For ensuring that the most precise accounts of teachers' authenticities are articulated, questionnaires, interviews and documentary analysis were triangulation of data collection methods employed in this study. The open-ended questionnaire and semi-structured interviews were the appropriate instruments as they were used to probe for in-depth data of teacher understandings. Both the VNOS-C questionnaire and the VNOS-C follow-up interview schedules were adapted from well-known NOS researchers were previously validated instruments. Furthermore, audio-taped interviews ensured accuracy and reliability as they eliminated unconscious selection of data that might have resulted in written data. The researcher ensured that the interviewee read the interview transcripts for validity before data was finally processed. Further document analysis was also appropriate as the researcher had the opportunity to understand how the participant prepared themselves for teaching. The documentary analysis schedule was designed by the researcher basing it on the targeted NOS aspects and was discussed with the supervisor. However, a single lesson plan was scrutinized per

participating teacher. This has brought about the shortcoming that scrutiny completed about how teachers' NOS understandings relate to their classroom planning were, to some extent, dependent on the science topic taught on the week it was planned for. As a result the researcher cannot be definitely sure that the participants were integrating NOS or not in their entire teaching.

Reliability and validity are means of communicating and demonstrating rigour of research and trustworthiness (Cohen et al, 2007). Maree (2007) defines trustworthiness as the technique wherein the researcher is able to prove to the audience that the outcomes are worth paying attention to and that the study is of high quality. Triangulation in this study is employed to validate or sustain a particular standpoint of a certain social observable fact (Jang, McDougall, Pollon, Herbert & Russell, 2008). Triangulation is defined as “the use of two or more methods of data collection in the study of some aspect of human behaviour” (Cohen et al., 2011, p. 195). It permits for larger validity through evidence as well (Doyle, Brady & Byrne, 2009). Therefore, in this study triangulation is used to compensate the individual data limitations as this study focuses on meanings and attempts to understand the context and totality of each situation. Creswell (2003) states triangulation may neutralize the weakness in singular approach while building on their strengths. In this study triangular techniques helped to overcome the problem of method-boundedness (Gorald & Taylor, 2004).

3.8 Ethical issues

This study was conducted for a Masters degree from a university and the researcher obtained the ethical clearance from the University of KwaZulu-Natal (see Appendix A). Further, the study was conducted in schools and the researcher also obtained permission from the KwaZulu-Natal Department of Education to conduct research in the schools. Permission to conduct the study at the schools was requested and granted by the principals of the schools where the respondents work (see

Appendix B). The principals of schools for all six participants were requested to sign the request letters to conduct a study in their schools.

Griffiths (1998) suggests transparency and honesty as necessary measures of ensuring that a researcher observes ethics. Therefore in this study the participants were given an information sheet (Appendix C), to read about the study and be familiar with the researcher's aims of the study. This document explained what the research was all about, how it will be conducted and what the data will be used for. It also assured the respondents that decline to participate that there will not be any negative penalty imposed on them or the school and that they were liberated to pull out from participation at any time. To guarantee confidentiality, anonymity and non-traceability, respondents were assured that their identities were to be concealed by pseudonyms. Pseudonyms were used for both schools and participants when writing this study report. The respondents were free not to write their names on questionnaires if they do not feel like doing so. The participants were informed that they have a right to pull out at any time and to ensure non-maleficence (Creswell, 2003); the researcher ensured that the research process did not harm the participants, emotionally, financially or otherwise.

3.9 Chapter Summary

This study's research design is influenced by interpretivist perspective. The research is based on teachers' NOS understandings and how much influence do their understandings have on their instructional planning. This is a qualitative research. Because of its qualitative nature, though conducted on a small scale, this study will eagerly add more light to what has already been explored.

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

CHAPTER FOUR

DATA ANALYSIS

4.1 Introduction

This study set out to investigate the following research questions:

- What do Grade 9 Natural Sciences teachers understand about the Nature of Science (NOS)?
- How do Grade 9 Natural Sciences teachers plan to teach Nature of Science (NOS)?
- How do Grade 9 Natural Sciences teachers' understandings of Nature of Science (NOS) influence their instructional planning?

This chapter will focus on the description of the participants teaching and school background, the analysis of the research instruments used in this study, this include the VNOS-C questionnaire, the VNOS-C interview schedule and the teachers' planning documents which involved their work schedule and their lesson plans.

4.2 Brief descriptions of Study Participants Teaching and School Background

The six teachers in my study were described as Brian, Leoran, Nancy, Sindile, Nkosi and Sakhile (all pseudonyms). I outline the teachers' teaching experience; subject taught; qualifications and their school context below.

Brian is a white male teacher in his late 30s with nine years of teaching experience. He obtained his Teachers' Diploma in 2003 and also the B.Sc. Agriculture Engineering part-time. He is a

teacher at Springvalle High School (pseudonym), teaching Natural Sciences in Grade 9 and Physical Sciences and Mathematics in Grade 10-12. The school is a girl's only school with an enrolment of about 1250 learners. It is situated in an upper class suburb and learners pay school fees of R16 000 per annum. The large percentage of the school population is White learners then Africans and a small percentage of Indians and Coloureds. The school enjoys a privilege of possessing adequate resources that are needed for teaching and learning.

Leoran is the young Indian female teacher in her late twenties. She started teaching in 2007 after completing her Bachelor of Education with the University of KwaZulu-Natal [UKZN]. Since she majored in Biology, she teaches Life Sciences from Grade 10-12 and Natural Sciences in Grade 9. She is busy towards studying toward her BEd Honours Degree with UKZN. She teaches in a high class suburb area in school called Roadside High School (pseudonym) which a multi-racial school (former Model C). The school is \pm 5 kilometres away from the city. It caters for learners from different parts of UMgungundlovu. The tuition fee is R 1 150 per month for 10 months which amounts to R11 500 per annum. The population of the school is made of 50% of Africans, 45% of Indians and Coloureds and 5 % of White learners. The school also has boarding facilities.

Nancy is between 45 and 50 and has been a teacher for twenty- two years. She has the Secondary Teachers Diploma (STD), majored in Biology; Further Diploma in Education (FDE) and B. Ed Honours majored in Mathematics and Science Education [FET Phase]. She is a teacher at Phaphama High School (pseudonym), teaching Natural Sciences in Grade 9 and Physical Sciences in Grade 11 and 12. The school has the good reputation for its good matriculation results and it closer to two tertiary institutions. It has a large number of African learners of which some are boarders and the rest, day scholars. The school fee is about R1000 and boarders pay extra for boarding facilities. The school has proper building and plenty of resources essential for teaching and learning.

Sindile is at her late 40s with teaching experience of 27 years. She started teaching as an unqualified teacher in 1987. She did Bachelor of Arts (B.A) degree, STD and an Honours Degree, all obtained part-time, from the University of South Africa. She teaches Natural Sciences in Grade 9 and also Life Sciences in Grade 11 and 12. Her school, Siyayidudula High School is situated at the edge of a lower class township with informal settlements at the other side. Therefore most of their learners come from informal settlement where the rate of crime, unemployment and poverty is high. The school do have classrooms however due to historical circumstances the classrooms are overcrowded. The school is a fee paying school and even learners from the informal settlement have to pay the school fee of R400. The school has limited resources and the administration block has only a photocopying machine.

Nkosi is at his late forties with the experience of eight years of teaching. He obtained a B.Sc. degree on Physics and Chemistry in Zambia in 1995. He is original from Zambia with the permanent South African citizenship. He is studying for a Post-Graduate Certificate in Education (PGCE) part-time at UNISA. He teaches Grade 8-9 Natural Sciences and Grade 10-12 Physical Sciences at Siyanqoba High School (pseudonym). He teaches in a large school of about 1064 learners with the population of 100% of African learners. The school is situated in the high class township with a low rate of unemployment, crime and poverty. The school is a few kilometres away from a large shopping mall. The school has good buildings, electricity, the security system, water and sanitation system, and better resources' needed for proper teaching and learning.

Sakhile is at his late forties with the twenty-three years of teaching experience. He is a qualified teacher with the Secondary Teachers Diploma (STD), Higher Diploma in Education and

Bachelor of Education (Honours Degree). He is teaching Natural Sciences in Grade 8 and 9 at Dondotha High School (pseudonym). The school is situated in the lower class township with high rate of unemployment, crime and poverty. Learners pay R 450 school fees per annum. There is security at the school. The school has an enrolment of about 1500 African learners only. The school has textbooks and a photocopying machine as its essential resources. It has the science laboratory with some chemicals and basic equipment but I noted that the laboratory is used mostly as a science teachers' staff-room.

4.3 Brief Description of data analysis process

The VNOS-C questionnaire and VNOS-C follow-up interview schedule responses were both qualitatively analysed. The assertions held by the participating teachers were developed inductively. The planning documents were then analysed and commented on and discussion notes were developed. It is important to state that in this chapter the results will presented and discussed according to the order of the research questions. The chapter is therefore divided into three major parts based on these three research questions. The first question is based on the teacher's understanding of NOS therefore questionnaire responses and the interviews responses were interrogated together to answer this question. The second question is based on how do teachers plan to teach NOS as reflected in their Work Schedule and Lesson plans, in this, instructional planning documents were analysed. To get data about how the teachers' NOS understandings (if any) impact on their lesson planning for teaching (research question 3), their documents and some interviews' responses were analysed. The interpretive paradigm was the base of this study thus used the inductive approach to analyse data from both questionnaire responses and the interview transcripts. I decided to work inductively because I was interested in reading and developing an understanding of each teacher's understanding of NOS. Inductive analysis refers to methods that mainly use detailed

readings of raw data to obtain concepts, themes, or a model through interpretations made from the raw data by researcher (Thomas, 2006).

4.4 Teacher' understandings of the Nature of Science

This study focuses on the teachers' understandings of NOS and these understandings are based on seven aspects of the NOS discussed earlier (in Chapter 2). Therefore the seven aspects of NOS were drawn out and used as the lens to analyse the data. Although the questionnaires comprised of ten open-ended questions or items for participants to respond to, the researcher reduced the questionnaire items from ten to seven key elements by combining items that refers to a broad aspect of NOS (see Table 4.1). Also the questions from the VNOS-C questionnaire follow-up interview protocol were grouped together to suit the seven targeted NOS aspects (see Table 4.2). These seven key components of NOS were used as standard categories or themes in this study.

The questionnaire together with the semi-structured interviews was used in this study to explore teachers' understanding of the core aspects of NOS.

Table 4.1 Key NOS aspects and questionnaire items

Key NOS aspect	Corresponding questionnaire item(s)
Empirical nature of science	1, 2 and 3
Tentative nature of scientific theories	6
Role of imagination and creativity	8
Observation and inference	4 and 7
Distinction between scientific theories and laws	5
Social and cultural character of science	10
Subjectivity and objectivity of science	9

All teachers' responses per question in their order of corresponding to NOS aspects (see Table 4.1 and 4.2) were separately typed on a Word Document and read for a number of times and gradually emergent categories were developed. Looking at the developed sub-categories per question, I then decided to work across all responses on the same question from both the questionnaires and the interview schedule with the aim of reducing them by identifying emergent categories. To develop the emergent categories, I decided to group the sub-categories with more or less meaning and enumeration was made. Enumeration does not necessarily mean that the study will present the quantitative data but were helpful in clarifying words such as 'majority', 'many', 'some', 'almost all' and so on, in my report writing. The emergent categories were utilized to develop assertions which provide a clear statement of the findings on what are teachers' understandings of targeted aspects of NOS. NOS targeted aspects form the standard categories for this study and emergent categories were developed for each question corresponding to the relevant NOS aspect.

Table 4.2 Key NOS aspects and follow-up interview protocol items

Key NOS aspect	Corresponding interview item(s)
Empirical nature of science	1, 2, 7 and 8
Tentative nature of scientific theories	3 and 6
Role of imagination and creativity	4 and 7
Observation and inference	5
Distinction between scientific theories and laws	6
Social and cultural character of science	9
Subjectivity and objectivity of science	9

The NOS aspects, that is, empirical nature of scientific knowledge; tentative nature of science; the distinction between observation and inference; distinction between scientific theories and laws; the role of imagination and creativity; objectivity and subjectivity of scientific knowledge; and the social and cultural embeddedness of science were scrutinized in this study. Since there are many aspects of NOS, I decided to choose these NOS aspects because the science community agreed that these aspects should be used to describe the NOS (Bell, 2011; Lederman and Lederman, 2004a; Lederman, 2007). Further to evaluate teachers' understanding of NOS, the NOS aspect descriptions adapted from Schwartz, Lederman, and Crawford (2004) were used and are discussed as follows. Teachers' understandings that seem to be in line with these NOS aspect descriptions were accepted as adequate.

Table 4.3 NOS aspects and descriptions that serve as a basis for evaluation of questionnaire and interview responses

NOS Aspects	Descriptions
Tentativeness	Scientific knowledge is subject to change with new observations and with the reinterpretations of existing observations. All other aspects of NOS provide rationale for the tentativeness of scientific knowledge.
Empirical nature	Scientific knowledge is based on and/or derived from observations of the natural world.
Subjectivity	Science is influenced and driven by the presently accepted scientific theories and laws. The development of questions, investigations, and interpretations of data are filtered through the lens of current theory. This is an unavoidable subjectivity that allows science to progress and remain consistent, yet also contributes to change in science when previous evidence is examined from the perspective of new knowledge. Personal subjectivity is also unavoidable. Personal values, agendas, and prior experiences dictate what and how scientists conduct their work.
Creativity	Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world.
Social and cultural embeddedness	Science is a human endeavour and is influenced by the society and culture in which it is practiced. The values of the culture determine what and how science is conducted, interpreted, accepted, and utilized.
Observation and inference	Science is based on both observation and inference. Observations are gathered through human senses or extensions of those senses. Inferences are interpretations of those observations. Perspectives of current science and the scientist guide both observations and inferences. Multiple perspectives contribute to valid multiple interpretations of observations.
Laws and theories	Theories and laws are different kinds of scientific knowledge. Laws describe relationships, observed or perceived, of phenomena in nature. Theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena. Hypotheses in science may lead to either theories or laws with the accumulation of substantial supporting evidence and acceptance in the scientific community. Theories and laws do not progress into one and another, in the hierarchical sense, for they are distinctly and functionally different types of knowledge.

Adapted from Schwartz, Lederman, and Crawford (2004, p. 613)

4.4.1 Assertion 1: Teachers possess a variety of understandings of the seven identified aspects of NOS

Each of the seven aspect of NOS identified is categorised as naïve, mixed, inadequate or adequate and discussed in detail with extracts from the questionnaires and verbatim student interviews.

4.4.1.1 Empirical nature of science

Science is a means of knowing and elucidation of the natural world that embrace contrasting views from other modes of knowing. The scientific knowledge and scientific inquiry is empirical in nature and it employs observations to make inferences and knowledge claims (Jones, 2010). For assessing teachers' understandings concerning science as a discipline and its function in elucidation of the natural world, the impact of empirical verification in developing scientific understanding and the understanding of the scientific method, numerous questions were posed both in the questionnaire and interview. Table 4.4.1.1 presents emergent categories of teachers' responses:

Table 4.4.1.1 Categories related to teachers' responses related to empirical nature of science

Label	Emergent categories related to this aspect	Number of questionnaire responses	Number of interview responses	Justifying response
A	Science is about observing and understanding the natural world. [adequate]	4	5	Science is about utilization of process skills like observation, experimenting and so on in order to develop understanding about the natural world.
B	Science differs from other disciplines of enquiry because it is based on facts that have been proven to be true. [inadequate]	3	4	Science is based on proven facts other disciplines are based on people's understandings, their faith, belief and culture which are totally unquestionable.
C	Science is based on experiments. [inadequate]	4	5	Science involves much research and experimentally based ideas.
D	Scientific method is a prescribed step-by-step way or procedure of conducting investigations to provide proof. [inadequate]		3	Like the method we use when we are doing experiments. I can explain it as a one way method that we are obliged to use to get proof.
E	There is no uniform or prescribed way of doing scientific method. [adequate]		3	Scientific method for me a method is a technique that follows a certain order that is well-planned and well-known to get a solution. I do not believe in a scientific method because in science there is no order to be followed... Scientists are well experienced and creative people, I do not think they can enjoy their work doing the same procedure every day.
F	Experiments are the only way of developing scientific knowledge because in science we need evidence so they provide proof. [inadequate]	6	4	Without an experiment you cannot see science. Experiments have to be performed... scientific method is a procedural idea. There is a procedure to be followed in everything.

Teachers possess a variety of conceptions of NOS in the empirical category. This includes inadequate and adequate understanding of the empirical nature of science. The emergent categories that were developed on this tenet were six of which two were adequate and four inadequate. Out of 6

respondents, 4 in their questionnaire responses and 5 from the interview response explained that science is about observing and understanding the natural world and is based on experiments. For example, Sakhile said on the ‘science is about observing and understanding the natural world’ category “*Science is about utilization of process skills like observation, experimenting and so on in order to develop understanding about the natural world*”. Further Leoran said on “experiments are important in science for providing proof” category “*experiments are important because in science we need proof that is why we conduct experiment with learners we need to see the evidence.*” Even though the teachers recognised the importance of experiments in science, they also possess inadequate understanding that experiments are the only source of evidence in developing scientific knowledge. For example Brian responded “*without an experiment you cannot see science, experiments have to be performed... scientific method is a procedural idea. There is a procedure to be followed in everything*”. Lastly teachers possess a dichotomy of understanding based on meaning of the scientific method. Two out of six responses possessed adequate understanding that “there is no uniform or prescribed way of doing scientific method” whereas the other four possessed inadequate understanding that “scientific method is a prescribed step-by-step way or procedure of conducting investigations to provide proof”. To confirm this Nancy responded “*the scientific method is the step-by step way of investigation. I think that scientist use certain methods when they are doing their investigation. So they observe, they collect data, they discuss it, they end up having their conclusions. I believe that for obtaining true results they have to accurately follow the steps*”.

4.4.1.2 Tentative nature of scientific theory

Although scientific knowledge is resilient, it is “subject to change with new observations and with the reinterpretations of existing observations and all other aspects of NOS provide rationale for the tentativeness of scientific knowledge” (Schwartz, Lederman & Crawford, 2004, p. 613). Meaning

not only the new information and discoveries can show the way to the change of scientific knowledge. To get the teachers understanding of this tenet they were asked questions that provoked their understandings about the tentative nature of theories and laws. The following table presents emergent categories of teachers' responses:

Table 4.4.1.2 Categories related to teachers' responses related to tentative nature of science

Label	Emergent categories related to this aspect	Number of questionnaire responses	Number of interview responses	Justifying responses
A	Theories change because of new evidence, new information, new data or new discoveries made. [adequate]	6	6	Theory does change. Our environment changes, so does the scientific theory. New advanced technology is introduced nowadays. Our scientists do experiments continually using these advanced technology instruments in order to understand and to gain knowledge and information about our changing environment. New discoveries are made all the time. Scientific theories change with the new discoveries.
B	Sometimes the theory does not change but the top up is made. [adequate]	2	3	Theories can also be updated if the new information has been discovered. The original theory remains as it was before but the better one replaces it. Sometime the theory can be extended by adding the new idea on the existing one.
C	Laws cannot be changed. [naïve]		4	Law cannot change because for a scientific idea to be accepted as law it has to undergo extensive experimentation and be proven.
D	Scientific laws change over time. [adequate]		2	I think they [laws] should change because they are based on articles discovered over time. Because time is ever changing so science is ever changing. Scientists are developing more information, so if they develop more information and learn more about scientific laws then laws should change.

Teachers' idea of the tentative character of science was mostly adequate. Out of four emergent categories developed in regard to this tenet, only one reflected the naïve idea. All of the participants in both questionnaire and interview responses revealed that teachers understand the change of theories although they possessed different ideas as to why theories change. Teachers viewed the change of theories as a result of new evidence; new information; new data and/ or new discoveries made. There was also a thinking that theories change because of change in time; environment; people and/ or the world and also think that when there is proof that proves the theory wrong or contradicts, it will definitely change. Few responses two in the questionnaire and three in the interview responses showed that sometimes theories do not change but a top-up is made. Brian said on 'Theories change because of new evidence, new information, new data or new discoveries made' category "*when new evidence and new data is found then scientists then compare the old idea with the new, because of the new ideas that has come up the older idea is replaced. There is a shift.*"

During the interviews when teachers were asked if scientific laws do change, the majority of teachers' responses (four out six) revealed that they think laws cannot change because they are proven experimentally; they are constant with no exceptions and are based on facts. The minority, that is, two out of six possessed the adequate idea that laws do change because times are changing and so as the physical world and science is a human activity therefore humans also change. Nancy on the category 'laws cannot be changed because they are proven experimentally' said "*I do not think laws ever change because a law is a law. Laws are proven experimentally and cannot be changed. They are usually based on facts.*"

4.4.1.3 Role of imagination and creativity

Scientific knowledge is constructed from "human imaginations and logical reasoning and this creation is based on observations and inferences of the natural world" (Schwartz et al., 2004, p. 613).

The participants were questioned if scientists make use of their creativity and imagination during their investigation and when do creativity and imagination fit in their investigation.

Table 4.4.1.3 Categories related to teachers' responses related to the role of imagination and creativity

Label	Emergent categories related to this aspect	Number of questionnaire responses	Number of interview responses	Justifying responses
A	There is no creativity involved in science only facts. [naïve]	1	1	I do not think scientists use their creativity and imaginations what so ever. I think scientists base their knowledge on researched facts. Although scientific method should not be in the linear form, I do not think the scientists will add something that is not scientific in their research
B	Imagination and creativity are needed for scientific knowledge development. [adequate]	5	5	When scientists are investigating, they use more than one method. They cannot investigate without setting an investigative question. Designing a researchable question calls for creativity, and hypothesizing calls for creativity and imagination. Then scientific knowledge is based on scientist creative thinking.
C	Ones approach determines suitable time for being creative it might be in research question design, hypothesis; data collection, analysis or interpretation. [Mixed]	4	4	Creativity fit in only after you have been able to observe and theorize. You have been able to be theoretical come out with what you want. Then now you have to be creative because if you have to produce the same results the idea will remain more like a theory but they to be more creative.
D	Scientists are creative throughout the entire scientific investigation. [adequate]	2	2	Creativity and imagination are used throughout the entire scientific process...Scientists use creativity to determine which smaller questions are likely to yield results, imagine possible answers to their questions, and devise ways to test those answers... Scientists explanations are well informed and not mere guesses but cannot escape the fact that they are ultimately product of imagination.

Table 4.4.1.3 reflects that in questionnaire and interview responses, the understandings of the role of creativity and imagination in science vary from naïve, adequate and mixed. The majority of participants [5 out of 6] recognised the importance of creativity and imagination in science. However, even though they understood that creativity has a role in science, the majority of teachers [4 out of 6] also possessed the mixed understandings as to when scientists are being creative in their scientific investigations. These teachers viewed creativity as only suitable at one stage of the scientific investigation. For example, Brian responded: *“Creativity fit in only after you have been able to observe and theorize. You have been able to be theoretical come out with what you want. Then now you have to be creative because if you have to produce the same results the idea will remain more like a theory but they to be more creative”*. Contrary to this idea two participants were adequate as they understood that creativity and imagination in science are not limited to a specific stage of scientific investigation. Sindile possessed the different idea that was naïve in regard to this tenet as she responded: *“I do not think scientists use their creativity and imaginations what so ever. I think scientists base their knowledge on researched facts. Although scientific method should not be in the linear form, I do not think the scientists will add something that is not scientific in their research”*.

4.4.1.4 Observation and inferences

Both observation and inference are the basis of science. “Observations are drawn together through human senses or extensions of those senses whereas inferences are elucidations of those observations. Perceptions of current science and the scientists guide both observations and inferences and multiple perspectives contribute to legitimate multiple interpretations of observations” (Schwartz et al., 2004, p. 613). To determine the teachers' understanding of the distinction between observation and inferences, they were asked to respond to questions based on how certain are scientists about the certain aspect on scientific knowledge.

Table 4.4.1.4 Categories related to teachers' responses to the distinction between observation and inferences

Label	Emergent categories related to this aspect	Number of questionnaire responses	Number of interview responses	Justifying response
A	Scientists use instrument to observe the phenomena. [adequate]	4	5	No one had ever seen an atom with his or her eyes. Books also state that they are very tiny and can be seen through a microscope. I think that scientist observed using different apparatus and developed models to present what they observed. Their uses of the models indicate some sort of inferring from the side of the scientist.
B	Scientists use models to illustrate observed phenomena. [adequate]	4	4	... Scientists used models to determine what an atom look like. The way the structure of the atom was devised was through a long series of experiments. Each one was designed to look at a specific aspect of the atom. At one time the atom was thought to be a solid ball of positive charge with electrons embedded in it. In the current model the number of electrons in the atom is determined by gamma and x-ray spectroscopy. Many additional experiments were performed to confirm the model as finally developed and so far the results obtained are as one would expect from the model.
C	Scientists are certain about the structure of an atom. [naïve]	6		Scientists are certain about the structure of an atom because they say it is a basic unit of matter that consists of a dense central nucleus surrounded by a cloud of negatively charged electrons
D	Scientists are certain about the definition of species. [naïve]	6		Species as defined is true and the idea of "crossing" is what we look at when looking at characterization of organisms... Species refer organisms with the same features or characters and therefore crossing breeding or interbreeding which leads to the interaction of different organisms from different species interacting with each other. This is also experimental and through research work and co-operating together.

The teachers' understandings of observation and inferences were both adequate and naïve.

Two categories that were adequate reflected that the majority of the teachers understood that scientist may use extensions of human senses to observe the phenomena. They mentioned that scientists used

the microscope to observe the structure of the atom. They also reveal that scientists infer in order to interpret their observations that is they use of models to illustrate the structure of an atom. For example, Nancy in her response covered both ‘scientists have seen an atom through a microscope not by naked eyes’ and ‘scientists use models to illustrate the structure of an atom’ categories as she responded, *“I do not think so because when you read books it seems like the scientists themselves are not sure how an atom look like. Firstly the atom is not tangible and invisible and according to books it can be seen through the use of the microscope.”*

Although the majority of the teachers possessed adequate understanding of role of observation and inferences in science, all of these teachers were naïve as they believe that science is certain. On the category ‘Scientists are certain about the species because they observed them and come up with the definition’ .Sindileresponded *“They are certain because the offspring produced look the same as parents, their behaviour, nutrition, and so forth. They also use same habitat.”*

4.4.1.5 Distinction between theory and law

Theories and laws are dissimilar types of scientific knowledge. “Laws describe relationships, observed or perceived, of phenomena in nature whereas theories are deduced descriptions for natural phenomena and mechanisms for connections among natural phenomena. Hypotheses in science might lead to either theories or laws through the building up of significant sustaining verification and reception in the scientific society. Theories and laws do not steps forward into one and another, in the hierarchical sense, for they are divergently and practically diverse forms of knowledge (Schwartz et al., 2004, p. 613). .

Table 4.4.1.5 Categories related to teachers' responses related to the distinction between theory and law

Label	Emergent categories related to this aspect	Number of questionnaire responses	Number of interview responses	Justifying responses
A	Theories are tentative whereas laws are not therefore laws have important value compared to theories. [mixed]	2	4	Laws are important than theories but a theory need to be proven for a long period of time looking at it from different angles or areas. When it does not change then it can be taken as law.
B	Theories give birth to laws. Theories are important compared to law. [naïve]	1	4	A theory is more important than a law because a theory is a foundation of a law. A law comes after theory.
C	Laws and theories are distinct. [adequate]	5		A scientific theory is a justifiable explanation of some aspect of the natural world, based on the body of facts that have been confirmed again and again through observation and experiment... A scientific law is a statement based on repeated experimental observation that describes some aspects of the world. Scientific laws always apply under the same conditions, and imply that there is a connecting relationship involving its elements. Laws differ from scientific theories in that they do not speculate explanation of phenomena but are representations of the results of repeated observation.

The six teachers' views fall into three categories regarding this NOS aspect. The participants' responses were placed into one of three categories: adequate, mixed, or naïve. A common misconception among participants in their interview probes was a perceived hierarchal relationship between laws and theories even though they had possess adequate ideas of the tentative character of

science. On the category 'Theories give birth to laws', Nkosi responded "*laws are important than theories but a theory need to be proven for a long period of time looking at it from different angles or areas. When it does not change then it can be taken as law.*" Further Nancy, for example, revealed a rather naïve understanding of this aspect as she responded "*Scientific theory can change based on the new discovery. Scientific law is proven experimentally and cannot change. It is usually based on facts.*"

However five out of six participants had an adequate understanding of this aspect in their questionnaire responses. Sakhile response distinguished between the theory and law as follows: "*A scientific theory is a justifiable explanation of some aspect of the natural world, based on the body of facts that have been confirmed again and again through observation and experiment... A scientific law is a statement based on repeated experimental observation that describes some aspects of the world. Scientific laws always apply under the same conditions, and imply that there is a connecting relationship involving its elements. Laws differ from scientific theories in that they do not speculate explanation of phenomena but are representations of the results of repeated observation.*"

4.4.1.6 Social and cultural character of science.

Science is a human venture that is manipulated by the community and way of life in which it is practiced. The cultural beliefs institute the way science is "conducted, interpreted, accepted, and utilized" (Schwartz et al., 2004, p. 613).

Table 4.4.1.6 Categories related to teachers' responses related to the social and cultural character of science

Label	Emergent categories related to this aspect	No. questionnaire responses	No. of interview responses	Justifying response
A	Science is universal [adequate]	4		Science is universal. From my definition of science, I made mention of the fact that, science is the study of nature and the entities / elements involved there in. Meaning that, science focuses on every aspect of human endeavours and how to overcome such with a scientific knowledge approach.
B	Background; societal and cultural values influence scientists' work. [adequate]	3	6	Scientists are human beings who were born and grown in societies like everybody, with beliefs, myths and culture. This may also include the religion one practices. Even their training might be affected by a certain backgrounds that alone might contribute to the way they view things and the way they choose to do things in their investigations and what not to do.

All of the participants believed in contemporary and adequate understandings that science is element of social and cultural traditions. Brian, Leoran, Nancy, Nkosi, Sindile and Sakhile were of the opinion that scientific knowledge is not free from social or cultural milieu. Although some members in the science education community take the pose that the reliability of scientific claims are culture dependent, they are not universal, the responses addressing scientific knowledge claims as universal were considered adequate because the responses addressed the role of society in doing science. On the category 'scientists are society members with societal and cultural values that have impact on their work', Sakhile claimed "*we as human beings we have knowledge that we acquire from different sources in life and as we grow we develop experiences so scientists are not supernatural but ordinary human beings as we are, what happen to us happen to them too. Their pre-*

knowledge, experiences, training, beliefs mostly acquired from societal and cultural sphere influence their methods and the way they infer with data thus lead them in developing different conclusion.”

4.4.1.7 Subjectivity and objectivity of science

Lederman (2004) argues that scientist’s knowledge based on theory, on experience, training, experience itself, commitment, religious and other beliefs, political convictions, gender and racial group can form thinking that impacts on scientific investigations. These background factors affect scientists’ choices of problems to investigate (Abd-El-Khalick et al., 2008), “how to conduct their investigations, what they observe (and do not observe) and how they put together logic of, or understand their observations” (Lederman, 2007, p. 834). These are obligatory prejudice that permits science advancement and remain reliable, as well contribute to science transformations where earlier verification is scrutinized in the perception of latest information (Schwartz et al., 2004).

Table 4.4.1.7 Categories related to teachers' responses related to the subjectivity and objectivity of science

Label	Emergent categories related to this aspect	Number of questionnaire responses	Number of interview responses	Justifying responses
A	Distinction theories are not a proven to be true. [adequate]	2		Now the conclusions presented by their extinction may both not be true because now I think they were made out of people beliefs which involve their background and cultural upbringing. The interpretation of data here was affected scientists social backgrounds.
B	Imagination; and creativity; beliefs; background; upbringing, religion and culture contribute on subjectivity of science. [adequate]	4	3	First of all no one lived in the dinosaurs' time, the only thing we have is the fossils. I think their structures are created by man using the fossils at hand. They observe and infer using their imaginations and creativity...I think they were made out of people beliefs which involve their background and cultural upbringing.
C	Science is both objective and subjective. [adequate]		4	Science is objective but we cannot deny that it can have an element of subjectivity in the sense that because of backgrounds scientists can choose the problems they want to investigate and how. They can even choose what to observe and what not to and how they interpret what they have seen based on their beliefs and religion. So basically it is not science that is subjective but scientists or people involved in science.

The teachers' responses were most adequate. Four teachers think that science is both objective and subjective and involves some people's background. Four teachers' responses from the questionnaire and three from the interview possessed the adequate understanding that imagination; and creativity; beliefs; background; upbringing, religion and culture contribute on subjectivity of science. On the category 'science is both objective and subjective', Leoran responded "*Science is*

both objective and subjective it will be both because it is based on facts from what people have researched.”

4.4.1.8 Discussion and summary of teachers’ aspect of NOS understandings

Even though the teachers possessed the different understanding of NOS that comprises of naïve, inadequate, mixed and adequate understanding, the emergent categories developed in this study reveals that the teachers’ understanding of NOS was more adequate than naïve or inadequate or mixed. Table 4.3.1.8 present a summary of teachers’ NOS understandings.

Table: 4.4.1.8 Summary of naïve, inadequate, mixed and adequate understanding of NOS

NOS Aspect	Number of Adequate understanding	Number of Naïve understanding	Number of Mixed understanding	Number of Inadequate Understanding
Empirical nature of science	2	NIL	NIL	4
Tentative nature of scientific theory	3	1	NIL	NIL
Role of imagination and creativity	2	1	1	NIL
Observation and inferences	2	2	NIL	NIL
Distinctions between theory and laws	1	1	1	NIL
Social and cultural character of science	2	NIL	NIL	NIL
Subjectivity and objectivity of science	3	NIL	NIL	NIL

Table 4.4.1.8 reveal that from emergent categories developed, participants in this study possessed extreme inadequate understandings than adequate on the empirical nature of science whereas in relation to tentative nature of science participants possessed more contemporary and adequate understandings than naïve. With regard to observation and inferences the adequate understandings seem to be equal to the naïve understanding. Surprisingly, the adequate understandings were possessed by all participants in both social and cultural character of science and the subjectivity and objectivity of science. This might be because of media as people these days are more exposed to information technology and are watching more of television shows therefore in this way science is communicated to them.

4.4.2 Assertion 2: Teachers are not explicitly planning for NOS teaching in the their classroom practice

This assertion is attending to the second research question of the study, namely, “How do teachers plan to teach Nature of Science (NOS)?” The aim of the second research question is to get the deeper understanding of how do teachers plan to teach the NOS in their planning for their classroom practice.

To get an understanding of how teachers plan for NOS in their classroom teaching, three out of six (50%) of the participants in the study were asked during the interviews how do they plan for teaching the tentativeness of science to the learners in their classroom as well as how they integrate imagination and creativity during Natural Sciences teaching. These teachers were purposively selected because of the situation of their schools. These were selected because were the better representatives of wider school population as they comprises of a White male teacher from a girls’ multiracial school, an Indian female teacher from a multiracial school and an African female

teacher from an African school. Further, these teachers were coming from well resourced schools and as a researcher I thought that they had opportunity to use the resources they have to plan for explicit teaching of NOS.

To get evidence of how teachers plan to teach the tentative nature of science and imaginative and creativity aspect of science in their classroom practice, Brian, Nancy and Leoran were asked during their interviews how do they teach learners that theories change as part of tentative nature of scientific knowledge . In their response none of them was certain that she/ he would plan this for their teaching. They all claimed that it would depend on the topic and one teacher said if learners asked questions pertaining to theories and laws, they would then tell them. The following is what they had to say:

Brian:

“...not most of the times, it depends on the topic that is the condition. If the topic requires you to teach about theories and laws, sometimes then you have to tell them that theories and laws change depending on the theories or the law you are teaching about because some do not change, so it depends.”

Nancy:

“I have never prepared this as a lesson. Sometimes it happens we discuss it in class because maybe there was a question or I see the need maybe like when maybe I see learners in class confused.”

Leoran:

“Honestly in most cases we teach what is on the book if the book does not state it you do not tackle that aspect only on rare occasions where you find learners asking questions that lead to a discussion of theories being change because of new evidence.”

On their response on how do they give learners the chance to use their imagination and creativity during their Natural Sciences lesson,

Leoran responded:

“It depends on the focus knowledge we are dealing with. Honestly we do a little of that because of time we have and the content we have to cover. In most cases we follow what is in the books when we do experiments with the aim of showing the learners that what is said in books is true.”

Nancy said:

“You know what I do in class is to teach the content knowledge and I try to explain everything to learners so that they understand. There is no time to waste because we have a lot of content to cover and our Grade 9 learners have to be prepared for the CTAs at the end of the year. That do not mean that our learners are restricted, they use their imaginations and creativity when given projects and investigations to do. You will be surprise to see how creative they are if they do their investigation and designs for the science expos.”

Brian responded:

“Yes I give a chance to learners to use their creativity and imaginations and their opinions are shared with other students. Some ask questions about things, some come out with ideas which we discuss to see if it is tangible because all I will say is most of the things that are to be discovered now have been discovered all the things we do are like the top up, just to make things shaper, to be straight.”

To explain more what he meant he gave the following example

“... a car was discovered so many years ago ... but many cars have been produced after that , which if you look you’ll see that it’s a same procedure the one thing that has been done maybe the engine has a higher horse power and so forth and forth. They created higher function, higher than you think, so it about the ability to think and go an extra mile. That is how the law has been amended and you must extend what you know.”

Table 4.4.2 Summary of how Natural Sciences teachers plan to teach NOS

	Brian	Nancy	Leoran
Tentative nature of science	Plan but depends on the topic.	Does not plan but incidentally integrate.	Incidental, the focus is on textbook.
Imagination and creativity	Provides opportunities	None	Incidental
Plans to teach NOS	Partially explicit	No	Incidental
Teaching approach	Telling and discussions	Teacher-based	Discussion occasionally
Reasons for not planning to teach NOS	None	Time constrains Content to be covered Examination	Time constrains Content to be covered

Table 4.4.2 above shows that out of three teachers interviewed only one teacher (Brian) plan to integrate the targeted NOS aspect in his teaching. On the other hand Nancy and Leoran did not plan to teach these aspects it only happens incidentally. Brian’s responses reveal that when teaching about the aspects of NOS, he uses two approaches, that is telling and discussion approach. Nancy’s approach seems to be teacher-based as she mentioned that she *explain everything until*

learners understand. Leoran's focus is on the textbook and she occasionally uses the discussion approach.

Responses from all three teachers show that none of them intend to assess these NOS aspects as part of the content of Natural Sciences. It is not clear whether these teachers are familiar with planning for the achievement of NOS aspects or not. What is clear is that the interview responses show that learners are not getting enough opportunities to see and practise science outside the classroom, or incorporating their ideas during class lessons nor do they use argumentation to build knowledge and be involved in inquiry type of lessons with the aim of developing their NOS understandings. What seems to happen in their classroom is a matter of coincidence and not pre-planning and explicit inclusion of NOS aspects. However Nancy's and Leoran's responses revealed time constraints, the quantity of content to be covered and external examination as hindrances towards their planning to integrate NOS aspects in their teaching. The external examination brought about external limitations and teachers are to perform the administration role.

4.4.3 Assertion 3: Teachers' conceptions of NOS do not necessary influence their instructional planning

The assertion is attending to the third research question of the study that scrutinizes the authority of NOS in classroom practice. The aim of the third research question is to get the deeper understanding of how do teacher integrate the NOS in their instructional planning. To develop further understanding of how teachers plan to integrate for the teaching of NOS in their classrooms, the analysis of essential documents in teaching and learning were scrutinized. These documents were the work schedule and lesson plans.

4.4.3.1 Analysis of the teachers' work schedules

Four teachers (Sindile, Nkosi, Sakhile and Nancy) in this study were using the work schedule which was provided by KZN Provincial Department of Education (DoE) for the year 2012/2013. Provincial Document is derived from the policy document where Natural Sciences content is being demarcated according to grades. It is then distributed over four terms of the year. Since data for this study was collected in the third term the focus was on the content knowledge dealt with during the term. According to the work schedule, the particle model of matter in chemical reaction, models of molecules of common compounds, chemical reactions of acids with metals, metal oxides and carbonates are dealt with in term three. Brian was using the work schedule for Grade 9, 2011. This work schedule only clarified the strands and the topics to be covered however learning activities were not stipulated. It is important to note that the core knowledge stipulated by DoE was similar to Brian's. Leoran was using the work schedule designed in her school which her Head of Department (HOD) claimed it is based on the topics that are mostly covered in the Common Task Assessments (CTAs). These are the assessment tasks set by the Department of Education that need to be completed by the learners. Table 4.4.3.1 presents the summary of NOS aspects emanating from the Work Schedules.

Table 4.4.3.1 Summary of NOS aspect emanating from the Third Term Natural Sciences Work Schedules

	NOS Aspect	Justification
DoE	<ul style="list-style-type: none"> • creativity • empirical nature of science 	<ul style="list-style-type: none"> • Learners to build models. • Conducting investigation / experiments
Brian	<ul style="list-style-type: none"> • Creativity 	<ul style="list-style-type: none"> • Representing reactions of elements and compounds using models, pictures, words and balanced chemical reactions
Leoran	<ul style="list-style-type: none"> • None 	<ul style="list-style-type: none"> • None

Upon scrutiny, the teachers' work schedules did not explicitly state the NOS aspects that need to be integrated during teaching, however the learners' planned activities by the Department of Education suggested teaching and learning strategies that were stipulated explicitly for each topic. For instance, building the models of different molecules, conducting investigations and experiments, observing and identifying acids and bases using household products and litmus paper, classifying elements and compounds, recording and identifying products of reactions using models or other representations of the reactions are encouraged. The use of models and the conduction of investigation and experiments are in line with the aspect of nature of science although not explicitly stated. Further, models and symbolic representations of chemical change and chemical reactions was one aspect to be covered in Brian's work schedule. The use of models requires creativity with is one aspect of nature of science. Leoran's work schedule showed no link to nature of science either implicitly or explicitly.

Since 70% work should be covered as outlined in the NCS Natural Sciences Learning Area Statement, teachers still have opportunities to enhance the curriculum through the 30% work that is not stipulated in the work schedule. To see if teachers had planned any curriculum enhancements specifically that integrate the aspects of NOS, their lesson plans were analysed in depth.

4.4.3.2 The analysis of the teachers' lesson plans

As mentioned above the lesson plan is one of the most important tools in classroom practice as it contains the complete and coherent series of teaching, learning and assessment activities. The main aim of analysing the teachers' lesson plans was to identify any planned actions or activities that would point to the intervention of NOS aspects discussed in the questionnaire and interviews. Therefore each teacher's lesson plan was scrutinized to see if it reflects any NOS understanding and how the teacher aimed to integrate the NOS aspects in classroom practice. One lesson plan per teacher that highlighted activities to be taking place for a week or two depending on the teacher was scrutinized. As it was stated in Chapter three, each teacher's lesson plan was to be judged against the NOS aspects. The researcher used the categories "Explicitly Discussed (ED)" if the teacher clearly stated the NOS aspect he/she intended to address when teaching in the lesson plans. If the teachers' lesson plan reflected some topics/or activities that address NOS aspects but not clearly stated, it was categorized as "Implicitly Discussed" (ID). This study also used the category "Not Discussed" (ND) if the teacher did not display the NOS aspect in the lesson plan.

Teacher 1 (Brian)

The lesson plan that Brian's planned to teach his learners focused on the following topics: Elements, mixtures and compounds; formulae; equations and reactions. The duration of his lesson was two (2) weeks. He planned the learning activities and stated that in five (5) lessons the topics will be tackled. The Learning Outcomes 1-3 were stated, together with their Assessment Standards. His teaching approach was based on the activities his learners will engage in (for detailed lesson plan see Appendix H).

Analysing planned activities of Brian, it was noted that learners were to make models of molecules; however there was no evidence to indicate whether he planned to explain to his learners why models are used in science. He also planned for learners to investigate some reactions. It was evident that the teacher planned to fit into place the learners in scientific research to build up scientific acquaintance. However, there was no evidence of whether he planned to engage them in fruitful arguments in consideration of all investigation features that were might possible lead to the development of an understanding of how science is done.

Table 4.4.3.2 The NOS aspects that were or were not integrated in Brian’s lesson plan

NOS Aspect	Explicitly Discussed	Implicitly Discussed	Not Discussed
Empirical nature of science			✓
Tentative nature of scientific theory			✓
Role of imagination and creativity			✓
Observation and inferences		✓	
Distinctions between theory and laws			✓
Social and cultural character of science			✓
Subjectivity and objectivity of science			✓

The table shows that only the NOS aspect “observation and inferences” were implicitly discussed.

Teacher 2 (Leoran)

Leoran’s planned lesson topic was Atomic Structure and the Periodic Table. She stipulated the core knowledge she wanted for her learners to grasp as: the basic structure of the atom, how the atoms of one element are different from those of the other and elements are arranged in the periodic table. For detailed lesson planned by Leoran see (Appendix I). One of the learning activities that Leoran planned for was based on the scientist ideas around about the structure of atoms, the models used to present the structure and why did scientists use models. Although the lesson plan did not clarify how this will be done, implying the teaching approach was not clearly stated, the teacher intended to integrate some NOS aspects in her teaching. The evidence around that is based on the use of the word “ideas” and “models”. It seems that the teacher possess adequate understanding of the use of models in science and that in science there is no single idea or truth and the discoveries done

by scientists changed or were added on as new discoveries came up. It was also evident that the teacher wanted her learners to understand the reasons why scientist used models to present the structure of the atom. In this case the teacher's planning showed that some NOS aspects such as observation and inferences were to be addressed.

In her lesson plan the teacher stated the assessment task she planned for her learners. Three of the planned assessment tasks carried the aspects of NOS around them. Task 1: "Use the table about the history of discovery of atoms to trace the way a theory about the structure of atom has changed over the period of time". In this task learners had to identify the changes in the theory of the structure of the atom. In other words learners had to understand the tentative nature of science. In Task 2 learners had to use pins to make models of atoms. In this activity learners had to use their creativity and imagination and also inferences were to be required. Another assessment tasks the teacher planned for the learners was a group discussion whereby she planned for the learners to discuss in groups why there are gaps in the periodic table. This was not explicitly stated however through this discussion the researcher assumed that the teacher wanted her learners to understand that science is tentative therefore they should expect that in their following grades they might be able to uncover some gaps filled in the periodic table because of new discoveries.

Table 4.4.3.3 The NOS aspects that were or were not integrated in Leoran's lesson plan

NOS Aspect	Explicitly Discussed	Implicitly Discussed	Not Discussed
Empirical nature of science		✓	
Tentative nature of scientific theory		✓	
Role of imagination and creativity	✓		
Observation and inferences	✓		
Distinctions between theory and laws			✓
Social and cultural character of science			✓
Subjectivity and objectivity of science			✓

The table shows that only the NOS aspect “empirical nature of science and tentative nature of scientific theory” were implicitly discussed whereas the “role of imagination and creativity and observation and inference were explicitly discussed.

Teacher 3 (Nancy)

Nancy planned to teach about reactions that go better with heating. The core knowledge he planned to focus on was reactions of metals and non-metals with oxygen, rusting and decomposition of compounds. She planned to cover all three Learning Outcomes. The planned lesson does not clarify what aspects of NOS are to be covered. However a little of inferences was planned to be integrated as learners were going to draw molecule models. The one activity planned for assessment was to link the modern science with indigenous knowledge. In this activity they were to answer questions about how people obtained iron in the olden days (see Appendix J for detailed lesson plan).

Table 4.4.3.4 The NOS aspects that were or were not integrated in Nancy’s lesson plan

NOS Aspect	Explicitly Discussed	Implicitly Discussed	Not Discussed
Empirical nature of science		✓	
Tentative nature of scientific theory			✓
Role of imagination and creativity			✓
Observation and inferences			✓
Distinctions between theory and laws			✓
Social and cultural character of science			✓
Subjectivity and objectivity of science			✓

The table above shows that only the NOS aspect “Empirical nature of science” was implicitly discussed.

Teacher 4 (Sindile)

Sindile planned to teach reaction of oxygen with metals and non-metals. To achieve this she planned to lead a discussion about elements using a Periodic table; demonstrate a simple test to show how metals/ non-metals reacts with oxygen and how to write the equation. The planned learners’ activities involved grouping elements into metals and non-metals, recording observations, conduct simple investigation, write word equations, use symbols and balance equations and understand ways of preventing rusting and corrosion and its impact on the economy. Her lesson plan did not reflect any integration of the NOS (for detailed lesson plan see Appendix K).

Table 4.4.3.5 The NOS aspects that were or were not integrated in Sindile's lesson plan

NOS Aspect	Explicitly Discussed	Implicitly Discussed	Not Discussed
Empirical nature of science			✓
Tentative nature of scientific theory			✓
Role of imagination and creativity			✓
Observation and inferences			✓
Distinctions between theory and laws			✓
Social and cultural character of science			✓
Subjectivity and objectivity of science			✓

The table shows that none of the NOS aspects were discussed.

Teacher 5 (Nkosi)

The focus knowledge planned by Nkosi was Atoms and molecules. To develop learners' understanding of the concepts he planned for the learners to investigate the dots that make up a photo; teach them about molecule, elements and compound. He also planned to teach and make them understand why models are used in science. Lastly he planned to use models to teach learners about chemical reactions. In his lesson plan what also transpired were the assessment activities he planned for the learners. Among these assessment activities there were activities where learners were to make models. Learners were to make models of elements and compounds; role play models to demonstrate their understanding of chemical reaction and to make a bean model of the magnesium and oxygen reaction (for detailed lesson plan see Appendix L).

In analysing Nkosi’s lessons, lesson plan show that he planned to teach learners so that they understand why in science or scientists use models and he used models to make them understand chemical reactions. Learners were to demonstrate their understanding through making their own models and do models through role playing. In such teaching situations, the learners will be able to understand that scientists use their creativity and imaginations in science and they also infer what they have observed. Through this teaching the learners were to be able to understand two aspects of NOS although the teacher did not state explicitly that he will be tackling these aspects.

Table 4.4.3.6 The NOS aspects that were or were not integrated in Nkosi’s lesson plan

NOS Aspect	Explicitly Discussed	Implicitly Discussed	Not Discussed
Empirical nature of science		✓	
Tentative nature of scientific theory		✓	
Role of imagination and creativity			✓
Observation and inferences			✓
Distinctions between theory and laws			✓
Social and cultural character of science			✓
Subjectivity and objectivity of science			✓

The table shows that only the NOS aspect “empirical nature of science and the tentative nature of scientific theory” were implicitly discussed.

Teacher 6 (Sakhile)

The focus of Sakhile's lesson was on the atomic structure, the nucleus of the atom, the periodic table and reactions of metals and non-metals with oxygen. In his plan he clearly stated the learners' role or activities and the teachers' activities. For his role he planned to discuss with learners the history of discovery of atoms; explain why scientists used models to present the structure of an atom and why Bohr model of an atom is used; discuss with learners the nucleus of an atom; discuss with learners the differences between the old and modern periodic table and used the simple test to demonstrate how metals and non-metals react with oxygen. Learners were to compare the scientists' atomic models; make their own models; apply knowledge about the nucleus of the atom; use the periodic table to classify elements in terms of gases, metals and non-metals; identify elements, mixtures and compounds; record what they have observed from the teacher's demonstration; in groups design own investigation on metals and non-metals reaction with oxygen, observe, record their findings and report back (for detailed lesson plan see Appendix M).

An analysis of Sakhile's lesson plans also did not explicitly state the aspects of NOS that he intended for learners to understand. However, through discussing the history of discovery of atoms and the comparing the old and modern periodic table, learners will be able to understand that science is tentative as they would understand that new discoveries were made by different scientists which changed or add on what was discovered before. They were also to understand that scientists discuss, provide evidence, and are critical of their discoveries and decide as a unique group, through peer-reviewed publications, what to accept and what to be rejected. Through understanding why models are used to present the structure of the atom, learners were to understand that scientists sometimes also use inferences to come to a decision.

Table 4.4.3.7 The NOS aspects that were or were not integrated in Sakhile’s lesson plan

NOS Aspect	Explicitly Discussed	Implicitly Discussed	Not Discussed
Empirical nature of science			✓
Tentative nature of scientific theory	✓		
Role of imagination and creativity		✓	
Observation and inferences	✓		
Distinctions between theory and laws			✓
Social and cultural character of science		✓	
Subjectivity and objectivity of science		✓	

The table shows that the NOS aspect “Tentative nature of science and observation and inferences” were explicitly discussed and the NOS aspect “Role of imagination, Social and cultural character of science and Subjectivity and objectivity of science” were implicitly discussed.

Based on the presented samples of teachers’ planned lessons, the researcher argue that even though some of these teachers included some activities either for their learners or for themselves as an intention to address NOS aspect, they do not explicitly teach about NOS. They planned to conduct lessons where there was no clear indication of integrating NOS aspects in the introduction, aim and conclusion of the lessons. Their lessons can be generally described as following the implicit method of teaching NOS as explained in Khishfe et al. (2002) and Lederman (2006) as there was no intentional attempt 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. Table 4.4 is a summary of intended NOS aspects of all six teachers’ lesson plans

Table 4.4 A summary of intended NOS aspects of all six teachers' lesson plans

NOS ASPECTS	Brian	Leoran	Nancy	Sindile	Nkosi	Sakhile
Empirical nature of science	ND	<i>ID</i>	<i>ID</i>	ND	<i>ID</i>	ND
Tentativeness of science	ND	<i>ID</i>	ND	ND	<i>ID</i>	ED
Imagination and creativity	ND	ED	ND	ND	ND	<i>ID</i>
Observation and inference	<i>ID</i>	ED	ND	ND	<i>ID</i>	ED
Distinction between scientific theories and laws	ND	ND	ND	ND	ND	ND
Social and cultural character of science	ND	ND	ND	ND	ND	<i>ID</i>
Subjectivity and objectivity of science	ND	ND	ND	ND	ND	<i>ID</i>

ED= Explicitly Discussed

ID= Implicitly Discussed

ND= Not Discussed

Even though the results of this study (see Table 4.4) revealed more adequate understanding of NOS aspects, the teachers' NOS understandings were barely transferred into their anticipated classroom practice especially in their planning to teach as revealed in Table 4.4. These results will be conversed in detail in chapter 5 to follow.

4.4 Conclusion

This chapter served to provide insight into the six teachers' understanding of NOS and how their understandings transfer to their instructional planning. This chapter presented the findings of the

study. It began with the brief description of the study participants and a brief description of the data analysis process. It described how ten question items from the questionnaire and the interview schedule were condensed to fit into seven targeted NOS aspects. In this chapter I made three assertions in an attempt to answer the three research questions. The first assertion referred to a variety of understandings teachers possessed in regard to identified aspects of NOS. The second one looked at how teachers are planning for NOS teaching in their classroom practice. The third one looked at how teachers' conceptions of NOS influenced their instructional planning.

Chapter 5 which follows highlights the main results and discussion of the findings of my research in relation to the three research questions posed. It also alludes to the limitations and implication of my research study. It will also present the recommendations for future research in the field.

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1 Introduction

In the previous chapter, the presentation and analysis of data were presented. This chapter is aimed at bringing together the main findings of this research. The broader purpose of this study is to explore teachers' understanding of the Nature of Science (NOS) and how they integrate their understanding in their lesson planning to teach Natural Sciences. The study focuses on the following research questions:

- What do Grade 9 Natural Sciences teachers understand about the Nature of Science (NOS)?
- How do Grade 9 Natural Sciences teachers plan to teach Nature of Science (NOS)?
- How do Grade 9 Natural Sciences teachers' understandings of Nature of Science (NOS) influence their instructional planning?

In this chapter a number of foremost discoveries that materialized from the data were identified. One is that teachers never do explicit planning for teaching the key ideas of the NOS at all time in their classroom as their teaching is largely teacher-centred and based on content knowledge focusing on tests and examination. This was interesting because the new South African Natural Sciences curriculum focuses on both content and the processes of science instead of just only on examination of content. It is imperative that in the discussion the findings are justified, sustained and if required opposed through connecting main findings with the findings in the literature review. This chapter wrap ups by recording limits of the study and the recommendations for additional research.

5.2 Focussing on the Research Questions

The major results that serve to respond to each of the three research question were extorted from the analysis of data in the previous chapter (chapter 4). The answers to the research question were steered by the conceptual framework of the core ideas accessible in Chapter 2 and in table 4.1. To answer the first research question, this study examined and inferred the VNOS-C questionnaire (Appendix D) and the VNOS follow-up semi-structured interview schedule (Appendix E). This is followed by question two and three and these were answered through analysing the data sourced from the semi-structured interview and documentary analysis of work schedules and lesson plans respectively.

5. 2.1 Focusing on teachers' understanding of the core aspects of NOS (Research Question 1)

Although research has revealed that in many parts of the world both primary and secondary teachers possessed inadequate understandings of the NOS (Abd-El-Khalick et al., 2000;Lederman, 1992; Abd-El-Khalick et al., 2002; Dekkers & Mnisi, 2003; Linneman, Lynch, Karup, Webb & Bantwini, 2003) there are recent studies that provide different results in revealing that teachers possess adequate understanding of NOS. The majority of participants in this study have an informed understanding of the seven aspects of NOS examined. Some participants' responses were classified as informed on each of the target aspects, others uninformed and only a minority of responses were mixed.

5.2.1.1 Empirical nature of science

Even though the emergent categories in based on the empirical nature of science reflect two adequate categories and four inadequate categories, the largest proportion of the participants were adequate in believing that science describe the complex behaviour of the natural world as they claim that it is a study of natural and physical world which is different to disciplines of inquiry due to the fact that it has been proven to be true. For example, out of 6 participants, 5 claimed that “*science is the study of the natural world*”. To elucidate on this issue, Sakhile’s response was: “*science is about utilization of process skills like observation, experimenting and so on in order to develop understanding about the natural world*”. Lederman (2007) defines sciences as the “body of knowledge, a method and way of knowing” (p.833). Participants views in this regard is adequate because they see the aim of using science as that of getting to understand or of knowing the world and they also see the way of knowing is through the use of process skills.

However science is believed, by the participants in this study, to be a collection of correct incontrovertible facts, an idea that is narrow and naïve. The participants in this study also correctly believe that science is developed through research and experiments that involved observations and that makes science differ from other disciplines of inquiry. By articulating the view that only experiments and investigations are what detach science from other disciplines, some teachers in this study showed that they hold very limited understandings about what science is. This is evident as on both interviews and on the questionnaire, the accounts of phrases “*experiments in science provides proof*”; science is “*proven to be true*” and is based on “*facts*” accumulated through “*step-by-step*” investigations appeared frequently (12 times) in the participants’ response. Scientific knowledge does not constantly depend on what is observable for it to be accepted. Creativity and imagination do play significant and unexpected roles in creating scientific knowledge. Further it was not surprising

finding such views from teachers in this study because they are in line with studies conducted earlier on NOS (Lederman, 1992).

Moreover half of the participants in this study possessed a wrong idea as they view scientific methods as step-by-step or a linear way of conducting investigations with the aim of validating truth or theory; to demonstrate facts and/or testing to provide proof. The teachers based undue importance of experiments in developing scientific knowledge and as being conducted in a systematic (following a certain order) way. For example, Nancy in her response viewed the scientific method as “*the step-by-step way of investigation. I believe that for obtaining true results they have to accurately follow the steps.*” whereas Nkosi viewed it as “*the systematic way of conducting the investigation whereby you do it in order to find the solution to a problem.*” In this Leoran saw an obligation towards proof as she responded “*I can explain it as a one way method that we are obliged to use to get proof*”. These kind of views contradict one of the aspects of NOS because the use of the word “obliged” by Leoran means that scientists cannot involve their creativity and imagination skills in science and it seems as if she does not understand that there is no single method of doing science (Abd-El-Khalick et al., 2008; Lederman, 2004 & McComas et al., 1998).

Further the importance that 5 out of 6 respondents place on experiments as the only thing to provide proof and evidence is naïve as confirmed in this study. Dekkers and Mnisi (2003) also revealed that the teachers believe that science is dependent only on experiments and that experiment provide proof rather than supporting scientific claims. Moreover, these results also concur with results of the recent study conducted in South Africa by Kurup (2010) that revealed that participating teachers understood that the construction of scientific knowledge is a logical, gradually process which stipulates a well-made devotion to inductive techniques and that, except for the period of the first stages of an investigation planning, scientists make no use of imagination and creativity but only

depend on experiments to authenticate what they claim. The majority of participants in this study were apparently not conscious of the NOS view that scientific knowledge is also the result of inference, human imagination and creativity (Abd-El-Khalick et al., 2002). That teachers would possess such naïve understandings about the NOS is not astonishing as teachers around the world have been reported to subscribe to such understandings (see, Abd-El-Khalick et al., 2000; Lederman, 1992; McComas, 1998).

5.2.1.2 *Tentative nature of science*

There is a dichotomy of understanding that teachers hold in regard to the tentative character of science. One understanding is infallible as they based the change of theories in time. This understanding is adequate. However, another understanding which was demonstrated by most of the teachers was fallible as they think that since laws are ‘fact’ based and ‘experimentally proven’ they cannot go wrong and therefore cannot be changed. Although Dekkers and Mnisi (2003) revealed that South African teachers in their study possessed shallow ideas of the tentative character of science, it seemed not the same with the teachers in this study in regard to the tentative nature of theory. Every participant in the study, that is, six out of six recognised the tentativeness of the theories although they possess different understanding as to why theories are tentative. All responses found in the questionnaire and in the interview responses reveal that teachers understand the change of theories as a result of “*new evidence; new information; new data and/ or new discoveries*” made. These teachers had the notions that new evidence always result in a theory being changed instead of saying new evidence either confirms or falsify a theory. However there were five responses in both sources that reveal that theories change because of “*change in time; environment; people and/ or the world*” and also thinking that when “*there is proof that proves the theory wrong or contradicts it will definitely change*”. These responses appeared four times. There were also three occurrences in the responses

that showed that sometimes in spite of discoveries made, theories “*may not change but a top-up*” is made or an extension of it is made. In her response Sindile responded “*the theories will change at any time because this world is changing and scientist are not resting but conducting investigations to understand the reasons behind the change.*” The evidence confirms that teachers in this study possess adequate understanding of the tentative nature of the theories. The studies around the world (see Abd-El-Khalick et al., 1998; Bell et al., 2000) reveal that teachers possess adequate understandings of the tentative nature of theory.

Although the teachers showed awareness that scientific theories change, some of their responses were also naïve and some of their responses to questions about laws were vague. The understanding of the tentativeness of the laws seem to be totally naïve as most of teachers’ responses, that is, four out of six, revealed that they think laws cannot change because they are proven experimentally, they are constant with no exceptions and are based on facts. However two out of six acknowledged that time, physical world changes and that because science is a human activity it may leads to the change of laws. For example, Nkosi responded “*it is impossible to change the scientific laws because are description of behaviour based on numerous experimental result. Laws are constant with no known exceptions therefore changing them will make them not being law*” The conclusions of Dekkers and Mnisi (2003) and Schwartz and Lederman (2002) advocate that teachers accept as true that laws in science cannot be flawed if they are experimentally proven. On the other hand, Leoran’s response contradicts what Nkosi said as she responded “*I think they [laws] should change because are based on articles discovered over time. Because time is ever changing so science is ever changing. Scientists are developing more information, so if they develop more information and learn more about scientific laws then laws should change.*” Rutherford and Ahlgren (1990) claim that all kinds of knowledge including “facts”, “theories”, “laws”, are tentative because science is a process of producing knowledge and it depends on carefully made observations and development of

theories for making sense on what has been observed. Further Abd-El- Khalick, Waters and Le (2008) emphasized that scientific knowledge is also open to disapproval and change; it is a tentative knowledge that possesses different levels of uncertainty as permitted by the evidence.

5.2.1.3 Role of imagination and creativity

The six teachers' views fall into two major categories regarding this aspect although there were four emergent categories presented in chapter. The two other emergent categories are closely related to one major category while the other is standing on its own. Out of six participants' responses in the questionnaire five responses (Brian, Leoran, Nancy, Nkosi and Sakhile) believed that science knowledge is not fixed by nature only but are also creations of the human mind implying that in science there is imagination and creativity involved. However their interview data reveals different thoughts as to when scientists become or involve creativity in their scientific investigation. Sakhile and Nkosi were two participants who held a notion that scientists are creative throughout their scientific investigation. With respect to the creative element of science these teachers' responses were consistent to the empirical nature of science. In his response, for example, Sakhile said *“designing the investigation alone is a creative activity. Thinking of a research question needs someone who is creative. Scientists are human beings and human beings are creative and can be imaginative so it possible to adopt the aspect of creativity and imagination in their investigation.”* This means that science is not rigid and is not a linear process that is ascribing to a certain way of doing things. The literature reveals that creative NOS, attached with its inferential nature, involves that scientific bodies are “functional theoretical models rather than fruitful copies of reality” (Abd-El- Khalick et al., 2008, p.838). In spite of this, Brian is of the view that a scientist should observe and theorize then start to be creative. Two participants specified one aspect each where scientists can only

be creative. Leoran said “only during the interpretation of data” whereas Nancy said “only during the hypothesis can they be creative”.

One participant, Sindile believed to the naïve idea that in science there is no imagination and she was unable to name occasions where imagination and creativity can probable used as she responded, “*I think scientists base their knowledge on researched facts, not creativity. Although scientific method should not be in the linear form, I do not think the scientists will add something that is not scientific in their research.*” However it is important to note that although she do not see the need for creativity in science, she still subscribe to the notion that scientific investigation should be in a linear form. Although, Lederman (2004) acknowledges that there is no distinct method of doing science that would ensure the development of science knowledge, another naïve claim was presented by half of the participants as they subscribe to the idea that an observation comes before a theory. However another half subscribed to the idea that science is a enterprise practised by humans that is not rigid but depends on one’s approach which involves creativity.

Some participants’ responses give the impressions that say the opposite to their responses to the empirical nature of science. For instance 50% (3 out of 6) of all teachers in this study believed in a fixed linear scientific method, on the other hand 83% (5 out of 6 teachers) subscribe to the creativity aspect of scientists. The same conflicting views regarding these NOS aspect were noted at the beginning of the course in a study conducted by Akerson and Hanuscin (2007).

5.2.1.4 Observation and inferences

The participants presented dichotomous ideas on this aspect of NOS. Firstly they subscribed to the idea that the use of technology (microscope) to observe and models to illustrate the structure of the atom scientists are inferential in this regard. On the other hand they subscribe to the idea that scientific knowledge is also certain. The first is adequate as Lederman et al. (2002) assert that inferences are accounts regarding phenomenon that are accessible but not directly to the senses. Even though they subscribe to the idea that scientist never observe atoms using their sense of sight, they hold a naïve view that scientists are firm on the subject of the structure of the atom, meaning they are absolutely sure about the structure yet they use models to present the structure of the atom. These ideas are naïve.

5.2.1.5 Distinction between theory and law

Surprisingly five participants [83%] in this study expressed a clear understanding of the distinction between scientific law and theory and their understandings concurs the categories presented in Schwartz, Lederman, and Crawford (2004). However there was a waver in describing the value and status of theory and law. The interview responses in regard to this aspect of NOS revealed that 67% (4 out of 6) of the participants subscribed to the belief that theories may change over time and laws are unchanging therefore the latter have important value in science compared to the former. For example in this regard Nancy responded “*scientific theory can change based on the new discovery. Scientific law is proven experimentally and cannot change. It is usually based on facts...the law.*” Because of the tentative nature of theory, the other 33% of participants believe that laws are important because they do not change. The same percentages subscribed to the notion that theories are more important than laws because theories are the foundation for the laws, they are tested

continuously and they become mature and give birth to law. For example Brian gave this response “*Theory gives birth to a law. Without theory we can’t have a law. It’s like when you observe something you have to be theoretical to see what is in that information and then you can bring it out as a law. When a law comes out now everyone will follow and as the time comes out the law can be amended when certain new ideas are discovered*”.

Two participants [Brian and Sakhile] believe that hierarchy relationship develops from the hypothesis that leads to the theory and then a theory results into a law. This evidence is drawn from Sakhile’s response as he said “*Theories are used as a foundation to gain further scientific knowledge. Theories are created by scientists from hypothesis that have been confirmed through the scientific method, then they gather evidence to test their accuracy*”. These results shows that the teachers in this study even though they understand that theories and laws are diverse categories of knowledge, they failed to understand that “one does not develop or become transformed into the other, therefore scientists do not formulate theories in the hope that one day they will acquire a status of law” (Lederman, 2007, p.833-4). These results concur with the results founded by Koksai and Cakiroglu (2010) as they revealed their participants had immature understandings about connections between law and theory and the majority of their participants subscribed to the notion that there is a hierarchy among hypothesis, theory and law. Also in a South African study conducted by Kurup and Webb (2009), both groups of participants believed that theories graduate into law. Therefore the understandings reflected by this study’s participants are not surprising.

5.2.1.6 Social and cultural character of science

There are views that science influence and is influenced by different components and frameworks of culture where it is exercised (Lederman & Lederman, 2004b), it is a human enterprise

embedded and practiced in society (Abd-El-Khalick et al., 2008) therefore it is unavoidable for science to reflect social values and viewpoints (McComas, 1998) and scientific work is a human activity undertaken both by individuals and by the group (Osborne et al., 2003; Sarkar et al., 2010). Moreover, scientists are the product of the certain culture (Lederman 2007). All of the teachers in this study subscribed to existing and adequate idea that science is element of social and cultural traditions. Brian, Leoran, Nancy, Nkosi, Sindile and Sakhile were of the belief that scientific knowledge is not free from social or culture and Leoran and Sindile had no responses in their questionnaires. In this regard Sakhile responded:

We as human beings have knowledge that we acquire from different sources in life and as we grow we develop experiences so scientists are not supernatural but ordinary human beings as we are, what happen to us happen to them too. Their pre-knowledge, experiences, training, beliefs mostly acquired from societal and cultural sphere influence their methods and the way they infer from data lead them in developing different conclusions. [Interview response]

These results are contrary to Dekkers et al. (2003) and Linneman et al. (2003) findings but concur with Akerson et al. (2000), Webb et al. (2005) and Naidoo et al. (2010) studies.

5.2.1.7 Subjectivity and objectivity of science

According to Schwartz et al. (2004) this category means that both observation and inference lay the basis for science. Observations are collected by using person's senses. Inferences give explanation for the observations. Observations and inferences are directed by the viewpoints of the modern science as well as scientists. Various points of view add to well-founded many explanations of observations. Further Lederman (2004) argues that scientist's knowledge based on theory, on

experience, training, experience itself, commitment, religious and other beliefs, political convictions, gender and racial group can form thinking that impacts on scientific investigations. These background factors affect scientists' choice of problems to investigate (Abd-El-Khalick et al., 2008) the way of conducting their investigations, "what they observe (and do not observe) and how they make sense of, or interpret their observations" (Lederman, 2007, p.834).

All of the teachers in this study subscribed to contemporary and adequate views that science is both subjective and objective. Regarding this notion, Leoran for example responded:

First of all no one lived in the dinosaurs' time, the only thing we have is the fossils. I think their structures are created by man using the fossils at hand. They observe and infer using their imaginations and creativity...I think they were made out of people beliefs which involve their background and cultural upbringing. [Interview response]

The understanding possessed by Leoran reflects that science is also subjective and depends on the nature of the evidence uncovered. The teachers' views also concur with the results that found by Kurup 2010 in his dissertation as he revealed that more than a half of his participants thought that social, cultural and personal subjective concerns influence the scientists.

5.2.2 Focus on how teachers plan to teach certain NOS aspects (Research Question 2)

Although only half of the participants in this study were interviewed to answer the second question, it would appear that teachers had no intentions to plan to teach NOS aspects in their classrooms. These teachers were selected because they were better representatives of wider school population in the KwaZulu-Natal province as they comprises of a White male teacher from a girls' multiracial school, an Indian female teacher from a multiracial school and an African female teacher

from an African school. Brian, Nancy and Leoran were not certain during their interviews whether they did integrate the tentative nature of science and role of imagination and creativity aspects in their teaching. The teachers' responses portrayed that they do not do proper planning for teaching nor assessing aspects of NOS.

5.2.2.1 Discussion

There is little evidence showing that learners 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. What seems to happen in their classroom is a matter of coincidence. The method that Brian viewed learners as recipients of knowledge as he admitted in his response saying "...sometimes then you have to tell them that theories and laws change." This response concurs with the results in Naidoo and Govender (2010) study as they revealed that the participants had adequate NOS understanding and taught the most important ideas of NOS but in a conventional teaching-lecturing approach. On the other hand Nancy and Leoran mentioned the list of hindrances that made them not to integrate aspects of NOS in their teaching as this involved time constraints, content to be covered and frequent tests and examinations were presented as the main problem of the lack of NOS inclusion in teaching. To highlight this point, Nancy and Leoran responded:

Nancy:

"You know what I do in class is to teach the content knowledge and I try to explain everything to learners so that they understand. There is no time to waste because we have a lot of content to cover and our Grade 9 learners have to be prepared for the CTAs tests and examinations at the end of the year".[interview]

Leoran:

“It depends on the focus knowledge we are dealing with. Honestly we do a little of Nature of Science because of time we have and the content we have to cover. In most cases we follow what is in the books when we do experiments with the aim of showing the learners that what is said in books is true”. [Interview responses]

On top of the constraints experienced, these teachers mentioned they also clarified that they embarked on the cook-book experiments to show the learners proof. Seemingly these teachers believed that only experiments provide proof to support scientific claims (Dekkers et al., 2003). Further, these teachers’ complaints about the variables that hindered them to integrate NOS aspects in their teaching are not something new. Wang (2001) and Lederman and Zeidler (1987) also found complaints from their participants based on constrains that hinder them to implement NOS in their teaching. These constrains involved demands to finish the syllabus (Abd-El -Khalick, Bell & Lederman, 1998); teaching experience (Lederman, 1995); unsure of their NOS understandings, shortage of resources at schools and the teacher’s lack of understandings regarding how to assess learners’ NOS understandings (Abd-El-Khalick et al., 1998).

5.2.3 Focus on how teachers’ NOS understanding influence their instructional planning as reflected in their Work Schedule and Lesson Plan (Research Question 3)

Teachers plan to teach NOS as reflected in their Work Schedule and Lesson plans was used as the basis to respond to research question three. Evidence from summaries of Tables 4.3.1.8 and 4.3.2 indicate that the teachers in this study possessed adequate understandings in most NOS aspects but their understandings seem not to translate into their planning to teach as evident in Table 4.3.3.1 and 4.4. These teachers are nowhere nearer to conduct lessons where there is clear indication of

integrating NOS aspects in the introduction, aim, activities and/or closure of the lessons. It appeared that these teachers are not familiar with planning for the achievement of NOS aspects therefore they do not do proper planning for teaching nor assessing aspects of NOS. Bell et al. (2000) study also revealed that in their study there was no evidence of NOS in the teachers' intentions and made no effort to assess learners' NOS understandings.

5.2.3.1 Discussion

As mentioned previously in chapter four and evidenced in Tables 4.3.3.1, the teachers' work schedules did not specifying how NOS is to be integrated in their teaching. Further out of six participants in this study only two [Leoran and Sakhile] teachers' lesson plans reflected an attempt to plan to teach only two aspects of NOS explicitly. It was surprising that while all participants in this study possess a complete, clear and adequate understanding of social and cultural character of science and also adequately understood the subjectivity and objectivity nature of science, only a single teacher attempted to integrate these all aspects in his planning explicitly. The results for research question two concurs with Lederman (1999) as his study revealed that even though participants possessed better understanding of NOS, their classroom practice was not affected because their lesson plans records shown that teachers made no effort to transferring their knowledge of NOS to learners and the learners themselves never learn anything on NOS because teachers were by no means explicitly aim to teach it. As similar to Linneman et al. (2003) study, the larger amount of the participants in this research never consider NOS as a goal in their classroom practice and they never consistently incorporate NOS into instruction in an explicit manner (Bell et al., 2000). Therefore possessing and understanding of NOS does not mean that the teacher can automatically translate their understanding into teachers' classroom practice (Akerson et al., 2000; Bell et al., 2000; Kurup et al., 2009; Lederman, 1999; Webb et al., 2005).

5.3 Conclusions emanating from the Study

The cross-examining of the qualitative data collected from interviews disclosed a clear change in teachers' NOS understandings from their questionnaire responses (Annexure D). This study has revealed that teachers have a mixture of naïve, adequate, inadequate and mixed understandings about NOS. However, based on Table 4.3.1.8 in the previous chapter, the finding of this study suggests that participants possessed adequate understandings in most of the aspects of NOS compared to naïve, mixed and inadequate understandings.

The interrogation of the interview responses based on how do teachers plan to teach about NOS aspect, suggests that most of the teachers do not explicitly plan to teach NOS aspects as it only happens incidentally. Teachers revealed that they are mostly depended on the textbooks and even their experiments are done to prove what is stated in the textbook. Further, it emanated from the document analysis that the participating teachers were unable to perceive NOS aspects stipulated in the work schedules. The findings further suggests that even though the teachers possessed adequate understanding of NOS aspect, most of the teachers did not plan to teach NOS explicitly but some of their teaching approaches can be described as implicit. It is most likely that their NOS ideas will not even emanate in their teaching practices. Further only 33 % (2 out of 6) of the participating teachers were able to plan for teaching explicitly at least two aspects of NOS.

Even though it has been stated above that the participating teachers possessed more adequate understandings of NOS, this study may also conclude that no major links between the teachers' understanding of NOS and their planning for teaching was noted. This simply means that the teachers failed to translate their NOS understandings into their classroom practice. If teachers do not integrate

NOS aspects in their lesson planning then learners bear the consequence of possibly being not fully scientifically literate citizens.

Weighing all the results presented, I conclude that the participants in this study, although have had little formal exposure to the NOS construct and its aspects, displayed a somewhat adequate NOS understandings. However, their lesson plans reveal that these teachers still carry positivistic views of the science indicating a temptation to teach only the knowledge aspects of science. They also lay emphasis on vocabulary instead of developing NOS concepts. Their planning of lessons thus may have negative impact on learners' understanding the process of science as it may lower the importance on inquiry-oriented and problem solving teaching methods in the classroom and affect the way learners develop informed conceptions of NOS.

5.4 Implications and Recommendations

There is a wide-spread consensus that effective and knowledgeable teachers create favourable conditions of learners' learning (Hanuscin, Lee & Akerson, 2011). Therefore teachers must not only understand subject matter and pedagogy but be able to transform such understandings within their teaching practice (their PCK) so that learners can conceptualize new ideas (Shulman 1986). Many studies (Abd-El-Khalick et al., 2000; DeBoer, 2000; Khishfe et al., 2006; Laugksch, 2000) revealed that the major science education's ambition throughout the world is developing learners' understanding of NOS. Therefore teachers need to develop adequate understanding of NOS and use science processes to develop teaching techniques (Linneman et al., 2003). With these understandings teachers would be able to assist learners they teach better understand the subjective, tentative and social underpinnings involved in the production of scientific knowledge (Brown, Luft, Roehrig & Kern, 2006) and become scientifically literate and diligent citizens. However, if teachers fail to

integrate NOS in their instructional planning and practice that would mean learners will be less effective in competing with other learners throughout the world. Therefore the teaching of NOS using different science methods exploited in an effective manner is imperative for learners to become scientifically literate and understand huge dimension of science ideas our society deals with (Lederman et al., 1998; Clough & Olson, 2004; Rudolph, 2007; Herman et al., 2013).

NOS are viewed as a central and essential element of scientific literacy (DeBoer, 2000) in the science education reform (Hanuscin et al., 2011). Where there is a reform there is a change. It was mentioned in Chapter 1 that teachers are agents of change in curriculum implementation therefore they have to surmount the problems that are brought about by the new curriculum. It is essential that teachers acquire adequate NOS understanding if we are to achieve the goal of the intended South African science curriculum of promoting scientific literacy (Kurup & Webb, 2009) and create a scientifically literate society (Webb et al., 2005).

This study showed that the participating teachers are not aware of the compelling reasons to teach NOS and seemingly the chances they will implement it will diminished. Teachers need assistance to understand the deep compelling reasons to teach NOS and many opportunities must be provided for them to develop accurate notions of NOS and how to effectively implement it in science classroom. Therefore the Department of Education, specifically the subject advisors, should provide more support for teachers in terms of NOS classroom practice as part of curriculum reform development and training, so that they can know how to teach about NOS. It is important that Natural Sciences teachers are supported and professionally enhanced by the relevant, appropriately qualified subject advisors. It is recommended that when subject advisors design Work schedules for teachers, they must explicitly state NOS aspects to be taught as the study showed teachers have difficulties in perceiving and including relevant NOS aspects in their work schedules. These recommendations

concur with Kurup and Webb (2009) as it was evident in their study that the two groups of teachers in their study required further support to be able to develop skills in teaching NOS aspects so that the requirements of the new curriculum are met.

It is also recommended that the subject advisors adopt what Clough (2006) says as he addresses how teacher educators can model effective NOS instruction through explicit and reflective practices and scaffolds by offering NOS courses that offer an elective reformation NOS science activities. In these courses teachers may learn the philosophical underpinnings of the NOS and apply these concepts to develop lessons and modify cookbook activities so they accurately, explicitly, and reflectively portray NOS in a manner that scaffolds along the “decontextualized to highly contextualized continuum” (p. 487). Through these courses teachers would develop the understanding of “the role of, and interplay among, explicit, implicit, decontextualized, moderately contextualized and highly contextualized NOS instruction; attend to both continua in lesson planning and sequencing of lessons; and map their own NOS implementation practices” (Clough, 2006, p. 487).

Apart from the support that is provided by the subject advisors, teachers should also be able to learn from one another therefore it can be recommended that Natural Sciences teachers form a school science subject committee and also hold cluster meetings with neighbouring schools. In these meetings novice teachers will get assistance from the veteran teachers on how to integrate inquiry and problem solving aspects in the teaching environment. On the other hand as the concept of NOS is a fairly new concept in the South African curriculum, the novice teachers who have been exposed to NOS concepts and how to integrate it into classroom practice may assist the veteran teachers with the concept. This will also assist them to develop and become knowledgeable in the content and the pedagogical aspects, including NOS and pedagogical content knowledge aspects in teaching Natural

Sciences learning area. If teachers can be more knowledgeable about NOS and have their NOS understanding made to be more adequate, science teaching would greatly benefit.

As it has been stated previously that the participants in this study have had little formal exposure to NOS construct and its aspects, therefore it is recommendable that Natural Sciences teachers enrol with Tertiary Institutions in programmes to upgrade and develop their content knowledge and PCK including NOS aspects.

Lastly, it is recommended that schools prioritize on buying textbooks and resources that explicitly include NOS activities. This may assist in making science learning more meaningful for learners as teachers would be knowledgeable as to when to integrate NOS in their classroom practice.

5.5 Limitations of the study

The study was based on a reasonably small sample therefore it is recommended that more studies with bigger samples be conducted to ascertain the understandings teachers harbour and how their understandings translate to their instructional planning. Using a larger sample size in terms of additional teachers would increase the ability to infer characteristics from the sample to the larger population of Grade 9 Natural Science teachers as a whole.

The use of semi-structured interviews was strength in this study because the participants were asked the same questions but their responses guided deeper probing. In this regard using a small sample has both strengths and weaknesses. Because of the small sample size, the data collected was manageable-that was strength, on the other hand, a weakness because the results cannot be generalized to all Natural Science teachers in South Africa.

Convenience sampling made the basis for the selection of teachers for this study rather than on statistical considerations. Further a single lesson plan was scrutinized per participating teacher. This has brought about the shortcoming that scrutiny completed about how teachers' NOS understandings relate to their classroom planning were, to some extent, reliant on the science topic taught on the week it was planned for.

In this study there were many instances where more probing could have been done to get more insight into the teachers' responses but teachers' time was a premium. Further classroom observations were limited mainly due to time constraints.

It is reasonable to suggest that much more research evidence needs to be accumulated, eliciting teachers' translations of NOS aspects in classroom practice, before we can confidently state that these teachers failed to integrate NOS concept into classroom teaching. The present study has revealed some capacity for upcoming research. Since the outcomes are restricted to the six teachers that were the participants the conclusions cannot be generalized.

5.6 Suggestions for further research

This study explored the questions, "What do Grade 9 Natural Science teachers understand about the Nature of Science and how do they translate their understandings into instructional planning?" The following are suggestions for further research concerning the teachers' NOS understandings as well as ways of integrating it in teaching practice:

- the importance and necessity for teacher explicit NOS training workshops and how these can narrow a gap between policy and practice;
- the need for NOS teaching packages and resources;

- the evaluation of science textbooks in each Grade for NOS activities;
- employ measures to determine constraints that hinders teachers to integrate NOS that are more objective and outside of participants' discernments.

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APPENDIX A: ETHICAL CLEARANCE CERTIFICATE



5 September 2012

Mrs Barbara Duduzile Zulu 206524478
School of Science, Mathematics and Technology

Dear Mrs Zulu

Protocol reference number: HSS/0833/012H

Project title: Natural Science teachers' understanding of the Nature of Science: A case study of six teachers in Umsunduzi circuit in KwaZulu-Natal.

Provisional approval- Expedited

This letter serves to notify you that your application in connection with the above has been approved, subject to necessary gatekeeper permissions being provided.

This approval is granted provisionally and the final approval for this project will be given once the above condition has been met. In case you have further queries/correspondence, please quote the above reference number.

Kindly submit your response to the Chair: Prof. S Collings Research Office as soon as possible

Yours faithfully

.....
Professor Steven Collings (Chair)

/px

cc Supervisor Dr J Coleman
cc Dr N Govender
cc Academic leader Dr D Davids
cc School Admin. Mrs S Naicker

Professor S Collings (Chair)
Humanities & Social Sc Research Ethics Committee
Westville Campus, Govan Mbeki Building

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Founding Campuses: ■ Edgewood ■ Howard College ■ Medical School ■ Pietermaritzburg ■ Westville

INSPIRING GREATNESS



APPENDIX B: LETTER TO THE PRINCIPAL

Hlelingomuso Primary School
P.O. Box 1377
Pietermaritzburg
3201
20 June 2012

Dear Sir / Madam

Research Project:

Natural Science teachers' understandings of the Nature of Science: A case study of six teachers in UMsunduzi circuit in KwaZulu Natal.

I *Barbara Duduzile Zulu* student number *206524478* a student at the *University of KwaZulu-Natal*, hereby request the permission to conduct a research in your school. My research is a *case study of Natural Sciences teachers' understanding of the nature of science and how their understandings influence their classroom practice.*

I will use the data collected to compile a research report to be submitted at the above-mentioned institution towards a fulfilment of requirements for my Masters Degree in Science Education.

For this study in need a Grade 9 teacher from your school who is teaching Natural Sciences in the current year. My data collection procedures entail filling a questionnaire, conducting individual interviews as well as documentary analysis for lessons that took place. I will use the audio-tape to record the interviews and will take notes manually during the conversation.

I give assurance that I will not use your school's real name in my transcripts and research report but I will use pseudonyms to ensure that your school remain anonymous and data that I collected will only be viewed by me and my supervisor. When my research report is complete I will shred the data.

Principal' signature

APPENDIX C

SCHOOL STAMP & DATE

SUBJECT INFORMATION SHEET

I *Barbara Duduzile Zulu* student number *206524478* a student at the *University of KwaZulu- Natal*, invite _____ to be the participant in my research project.

My research is a case study of Natural Science teachers’ understandings of the nature of science and how their understandings influence their classroom instructional practices.

I will use data collected to compile a research report to be submitted at the above-mentioned institution towards a partial fulfilment of requirements for Masters Degree in science education. For my study I need grade 9 teachers who have attended the training on RNCS and are teaching grade 9 in the current year.

My data collection procedure will entail filling a questionnaire, conducting individual interviews as well as documentary analysis for lessons that took place. I will use an audio-tape to record the interviews and will take notes manually during the conversation.

For each data collection procedure I will need approximately 45 minutes of your time. I will further request a few minutes of your time after school on the day of document analysis to make a short interview about the learner activities done.

Participation in the 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.

I give assurance that I will not use your real name in my transcripts and research report but I will use pseudonyms to ensure that you remain anonymous and the data that I collected will only be viewed by me and my supervisor. When my research report is complete I will shred the data.

Participant’s signature _____ Date _____

APPENDIX D: VNOS-C Questionnaire

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. What is an experiment?

3. Does the development of scientific knowledge require experiments?

- If yes, explain why. Give an example to defend your position.
- If no, explain why. Give an example to defend your position.

4. Science textbooks often represent the atom as a central nucleus composed of protons

(positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. After, scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?

- If you believe that scientific theories do not change, explain why. Defend your answer with examples.
- If you believe that scientific theories do change:

(a) Explain why theories change?

(b) Explain why we bother to learn scientific theories? Defend your answer with examples.

- If yes, then at which stages of the investigations you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
- If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

9. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

10. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

- If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.
- If you believe that science is universal, explain why. Defend your answer with examples.

From:

[Abd-El- Khalick, F. (1998). The influence of history of science courses on students’ conceptions of nature of science. Unpublished doctoral dissertation. Oregon State University, Corvallis.

Lederman, N. G., Schwartz, R. S., Abd-El-Khalick, F., & Bell, R. L. (2001). Pre-service teachers’ understanding and teaching of nature of science: An intervention study. *Canadian Journal of Science, Mathematics, and Technology Education, 1*, 135-160.]

APPENDIX E: VNOS- C Questionnaire: Follow-up Interview Protocol

The follow-up interview protocol used in conjunction with the VNOS-C open-ended survey questionnaire included the following questions that will be used by the interviewer as a guide. (Related questions have been grouped together.):

1. What in your opinion is science?

2. How does science differ from other ways of knowing, such as philosophy or religion?

3. Why do theories change? (Or is new evidence/ data the only reason theories ever change?)

4. What do you think comes first in scientific investigation, theories or observation?
 - a) Why?
 - b) Where did you learn these ideas?

5. Have scientists ever seen an atom?
 - a) If so, how do they observe atoms?
 - b) If not, how do they know what atoms are like?
 - c) Where did you learn these ideas?

6. Do scientific laws ever change?
 - a) How would you rank scientific theories and laws in regard to importance?
 - b) Can you give any example of laws that have changed?
 - c) Where did you learn these ideas?

7. What is the scientific method?

Follow-up Interview Protocol continued

- a) Do all scientists use the scientific method when conducting investigations?
 - b) Where does creativity fit in?
 - c) Where did you learn these ideas?
8. How necessary are experiments in the development of scientific knowledge?
- a) Is any scientific knowledge developed without experiments?
 - b) Where did you learn these ideas?
9. (Regarding responses of participants referring to instances when the participants believe a scientist's background influences the scientists' conclusion.) What do mean by different backgrounds?
- a) How do these different backgrounds affect scientists' conclusions when they are looking at the same data?
 - b) Is science simply a matter of interpretation? Is one person's view as good as the next?
 - c) Is science subjective?
 - d) Where did you learn these ideas?

From:

[Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. (2002). Views of nature of science questionnaire: Towards valid and meaningful assessment of learner's conceptions of nature of science. *Journal of Research in Science Teaching*, 39(6), 497-521.]

APPENDIX F: Schedule for analysing each teacher's lesson plans.

NOS Aspect	Explicitly Discussed	Implicitly Discussed	Not Discussed
Empirical nature of science			
Tentative nature of scientific theory			
Role of imagination and creativity			
Observation and inferences			
Distinctions between theory and laws			
Social and cultural character of science			
Subjectivity and objectivity of science			

APPENDIX G: Schedule for analysing all teachers' lesson plans.

NOS ASPECTS	Brian	Leoran	Nancy	Sindile	Nkosi	Sakhile
Empirical nature of science						
Tentativeness of science						
Imagination and creativity						
Observation and inference						
Distinction between scientific theories and laws						
Social and cultural character of science						
Subjectivity and objectivity of science						

ED= Explicitly Discussed

ID= Implicitly Discussed

ND= Not Discussed

APPENDIX H: A sample of Brian's scrutinized Lesson Plan

LESSON PLAN		
Learning Area: Natural Sciences Duration : 10H30		Grade : 9 Weeks : 4-6 weeks
<u>Learning Outcomes</u> LO 1 Scientific investigations	<u>Assessment Standards</u> Conducts investigations and collect data Evaluate data and communicate findings	<u>Integration</u> Languages LO 3 &5
LO 2 Constructing Scientific Knowledge	Recalls meaningful information Categorises information Interprets information Applies knowledge	Life Orientation LO 1 Mathematics LO 1, 2 & 5
LO 3 Science, Society and the Environment	Understand science as human endeavour	
Core Knowledge/ Focus Knowledge CHEMISTRY <ul style="list-style-type: none"> • Elements, Mixtures, Compounds • Formulae • Equations • Reactions 		
Learning activities		Teaching approach
Lesson 1: Atoms, Compounds, Elements and compounds		<ol style="list-style-type: none"> 1. Identify elements, mixtures and compounds 2. Match definitions 3. Apply knowledge about substances 4. Make links between health and elements 5. Learn about types of molecules
Lesson 2: The Periodic Table		<ol style="list-style-type: none"> 1. What is a periodic table 2. Categorize the elements according to group number or period number 3. Use the periodic table to list elements from 1-20 with their atomic number, atomic symbol and atomic mass
Lesson 3: Chemical formulae and chemical equations		<ol style="list-style-type: none"> 1. Analyse chemical formulae 2. Make models of molecules 3. Practice balancing chemical equations
Lesson 4: Energy transfer in chemical reactions		<ol style="list-style-type: none"> 1. Investigate exothermic and endothermic reactions 2. Plans an exothermic reaction
Lesson 5 : Assessment		Informal Assessment Formal Assessment= rubric & memo
Resources		Learner's book and teachers' guide Science Today Access to internet or library Beaker, thermometer, copper sulphate, zinc powder, glass rod, spatulas
Expanded opportunities		Learners will design their periodic tables Work in group to provide additional examples

APPENDIX I: A sample of Leoran's scrutinized Lesson Plan

LESSON PLAN	
LEARNING AREA: Natural Sciences Lesson : Atomic Structure and Periodic Table Duration : 4 weeks	
Grade: 9 Week : 1-4	
Learning Outcomes LO 2 LO 3	Assessment Standards Recall meaningful information Categorise information Interpret information Interpret knowledge Understands science as a human endeavour
Linking with previous lesson: The particle nature of matter	Linking with next lesson: Chemical bonding
Core knowledge: The basic structure of atoms How the atoms of one element are different from those of the other How elements are arranged in a Periodic Table The groups in the Periodic Table	
Learning Activities and Assessment: <ul style="list-style-type: none"> • Scientists ideas about the structure of atoms • Models used to illustrate atoms and why do scientists use models to illustrate atoms • Theories about the arrangement of electrons around the nucleus • How does the development of the Periodic Table came about • Develop learners understanding of how groups of the Periodic Table behave and what affects their behaviour. 	
Assessment Activities <ul style="list-style-type: none"> • Making models of atom • Relating atomic models to the periodic table • Write elements in each group and explain how elements in each group behave • Identify elements that are useful in human life 	
Formal Assessment Group activity: <ul style="list-style-type: none"> • Discuss why there are gaps in the periodic table • Use the table about the history of discovery of atoms to trace the way a theory about the structure of atom has changed over a period of time 	
Resources: Cardboards (10cm × 10cm) Pins, library, internet, periodic table, resource books	Reflection:

APPENDIX J: A sample of Nancy's Lesson Plan

A LESSON PLAN	
LEARNING AREA: <u>Natural Sciences</u> GRADE: <u>Nine</u> LESSON: Reactions that go better with heating Duration/ Dates:	
<u>Learning Outcomes:</u> LO: Scientific investigation LO: Constructing Science knowledge LO: Science, Society and Environment	<u>Assessment Standards :</u> AS 1, 2,3,4 AS 3, 4 AS 1
<u>Linking with previous lesson:</u> Understanding of atoms and molecules	<u>Linking with next lesson:</u> Acids and bases
<u>Core knowledge:</u> <ul style="list-style-type: none"> • Reactions of metals and non-metals with oxygen • Rusting • Decomposition of molecules 	
<u>Learning Activity:</u> <ol style="list-style-type: none"> 1. How element can react to produce a compound 2. Reactions with oxygen that occur at ordinary temperature 3. Decomposition of compound by heating them 4. Decomposition of compound by them with element 	<u>Assessment:</u> <ul style="list-style-type: none"> • Observe details of the reaction and record details of product. • Answer questions on the worksheet • Answer question from the extract on page 81[learners book] • Oral answers • Molecule model writing and drawing [LB pg 82- 85] • Teacher-led discussion • written task = answer questions based on how people get iron in the olden days
<u>Forms of assessment:</u> <ul style="list-style-type: none"> • Practical work (GROUPS) • Independent practical work (Project) • Class discussion • Open-book test (Formal Assessment) 	<u>Resources:</u> <ul style="list-style-type: none"> • Science for all Grade 9 Learners' book and Teacher's Guide • Bean model kits • Copper carbonate, magnesium ribbon, candle, sulphur powder, steel wool, gas-jars, heat potassium, zinc granules.
<u>Expanded opportunities :</u> Investigate how rusting occur.	<u>Teacher reflection:</u>

APPENDIX K: A sample of Sindile's Lesson Plan

A LESSON PLAN	
Learning Area: Natural Sciences Grade: Nine	
Lesson: Reaction of oxygen with metals and non-metals	
Start Date: 20 August 2012 Date to complete: 31/08/2012	
<p><u>Learning Outcomes:</u> LO1 Scientific Investigation</p> <p>LO2 Constructing scientific knowledge</p> <p>LO3 Science, society and the environment</p>	<p><u>Assessment Standards :</u> AS 1; 2 and 3</p> <p>AS: 1 and 2</p> <p>AS: 2</p>
<p><u>Linking with previous lesson:</u> Different phases of mater (solids. liquids, gases)</p>	<p><u>Linking with next lesson:</u> Models of chemical reactions</p>
<p><u>Core knowledge:</u> Reactions of metals and non-metals with oxygen</p>	
<p>Learning Activities and assessment</p> <ul style="list-style-type: none"> • List elements from the Periodic table • Categorize the elements into metals and non-metals • Record what they have observed from the teacher's demonstration- give a name of the metal and the changes occurred • Learners conduct their own simple test to observe the reactions of metals and non-metals with air or oxygen • Test for acidity and alkalinity • Write equations in words • Use symbols to write equations • Balance equations 	<p>Teacher Activity :</p> <ul style="list-style-type: none"> • Teacher lead the learners into discussion about elements using a Periodic table • Demonstrate a simple test to show how metals and non-metals reacts with oxygen • Group learners in groups of 6 for investigation • Teach learners how to write equations • Explain the use of indicators for testing acidity and alkalinity of solutions • Discuss the impact of rusting
<p><u>Forms of assessment:</u></p> <ul style="list-style-type: none"> • Informal assessment activities (Groups activities) • Formal assessment task (TEST) 	<p><u>Resources:</u></p> <ul style="list-style-type: none"> • Steel wool, charcoal, tins, water, indicators, cooking oil, magnesium ribbons, iron and aluminium
<p><u>Expanded opportunities :</u> Completion of worksheet on reactions of metals and non-metal with oxygen Investigate ways of preventing rusting and corrosion and its impact on our economy.</p>	<p><u>Teacher reflection:</u></p>

APPENDIX L: A sample of Nkosi's Lesson Plan

LESSON PLAN	
LEARNING AREA: <u>NATURAL SCIENCES</u> GRADE: <u>9</u>	
LESSON: Atoms and Molecules DURATION/ DATES __2 weeks	
<u>Learning Outcomes:</u> LO 2: Constructing Science Knowledge	<u>Assessment Standards :</u> AS 1= Recall meaningful information AS 2= Categorises information AS3 = Interpret information AS 4= Applies knowledge
<u>Linking with previous lesson:</u> The moving particles theory of matter	<u>Linking with next lesson:</u> Reaction that go better with heating
<u>Core knowledge:</u> ATOMS AND MOLECULES	
<u>Learning Activity:</u> 1. Dots that make up the photo 2. Molecules, elements and compounds 3. Understanding why scientists use models 4. Models of chemical reactions	<u>Assessment:</u> <ul style="list-style-type: none"> • Pair work and group discussion • Recall names and symbols of elements • Make models of elements and compounds • Match the formula to the picture • Make their own tables differences between elements and compounds • Learners role play models to demonstrate their understanding of chemical reactions • Make a bean model of the magnesium and oxygen reaction
<u>Forms of assessment:</u> <ul style="list-style-type: none"> • Peer Assessment • Informal Assessment • Formal Assessment [TEST] 	<u>Resources:</u> <ul style="list-style-type: none"> • Science for All (Learners' book and Teacher's Guide) • Photographs from newspapers, hand lenses, molecule kits (make own using beans)
<u>Expanded opportunities :</u> Extra work will be provided for the learners with difficulties	<u>Teacher reflection:</u>

APPENDIX M: A sample of Sakhile's Lesson Plan

A LESSON PLAN	
LEARNING AREA: Natural Sciences GRADE: Nine	
DURATION: Three Weeks Start Date: 13 August 2012 Date to complete: 31/08/2012	
<p><u>Learning Outcomes:</u> LO1 Scientific Investigation</p> <p>LO2 Constructing scientific knowledge</p> <p>LO3 Science, society and the environment</p>	<p><u>Assessment Standards :</u> AS: Plans investigation</p> <ul style="list-style-type: none"> • conduct investigations and collect data • evaluate data and communicate findings <p>AS: Recalls meaningful information</p> <ul style="list-style-type: none"> • categorizes information • interprets information • applies knowledge <p>AS: Understand science as a human endeavour</p>
<p><u>Linking with previous lesson:</u> Different phases of mater (solids. liquids, gases)</p>	<p><u>Linking with next lesson:</u> Models of chemical reactions</p>
<p><u>Core knowledge:</u></p> <p>1. The atomic structure 2. The nucleus of the atom 3. The periodic table 4. Reactions of metals and non-metals with oxygen</p>	
<p><u>Learning Activities and assessment</u></p> <ol style="list-style-type: none"> 1. Compare scientist's atomic models 2. Make their own models 3. Apply knowledge about the nucleus of the atom 4. Using the periodic table to classify elements in terms of gases, metals or non-metals 5. Identify elements, mixtures and compounds 6. Record what they observed from teacher's demonstration 7. Work in groups of five [5] to design their own investigations about the reactions of metals and non-metal with oxygen using things they brought from home 8. Record their findings and report back. 	<p><u>Teacher Activity :</u></p> <ol style="list-style-type: none"> 1. Discuss with learners the history of discovery of atoms 2. Explain why scientists used models to present the structure of the atom 3. Discuss with learners the nucleus of the atom 4. Discuss with learners the modern periodic table 5. Use a simple test to demonstrate how metals and non-metals reacts with oxygen
<p><u>Forms of assessment:</u></p> <ul style="list-style-type: none"> • Informal assessment activities (Groups activities) • Formal assessment task (Assignment) 	<p><u>Resources:</u></p> <ul style="list-style-type: none"> • Library and internet • Periodic table • Different metals and non-metals • Grade 9 NS Learners' book and Teacher's guide
<p><u>Expanded opportunities :</u> Investigate corrosion and rusting as the reactions that occur in our everyday life.</p>	<p><u>Teacher reflection:</u></p>