AN EXPLORATION OF HOW TEACHERS' UNDERSTANDINGS OF THE NATURE OF SCIENCE INFLUENCE THEIR PEDAGOGICAL PRACTICES OF TEACHING EVOLUTION

Masters Dissertation

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Abstract

The purpose of this study is to explore how teachers' understandings of core concepts of the Nature of Science (NOS) influence their pedagogical practices in teaching Biological Evolution in the Life Sciences learning area of the high school curriculum. Evolution, an important new theme in Life Sciences, lends itself to developing deeper conceptions of NOS. The new South African curriculum presented as the National Curriculum Statement (NCS) involves a huge shift from highly prescriptive, content-based syllabus to an outcomes-based curriculum emphasising the development of skills, content and the inclusion of NOS for Natural Sciences, Life Sciences and Physical Sciences. According to the recent science education reforms, nature of science has become an area or a field of knowledge that learners have to acquire in order to have a better understanding of what science is, its processes and how it changes over time. Given the controversial nature of Evolution as a theme in Life Sciences, it is imperative that the study attempts to reveal science teachers' identities (epistemologies) and how these reflect and or influence their teaching of Evolution.

This is a qualitative study which looks at exploring how the three Grade 12 Life Sciences teachers' understandings of Nature of Science (NOS) influence their teaching of Evolution in Sisonke District. It focuses firstly on teachers' understandings of core concepts of NOS and how Life Sciences teachers link their understandings of the core concepts of NOS and their teaching of Evolution. Secondly, it looks at why do teachers teach the NOS core concepts in the manner that they do. Since this study is intended to focus on a particular theme, namely Evolution and using a conceptual framework of core concepts of NOS to understand and explore how teachers link their theory and practice, a case study method is employed. This study made use of mostly qualitative data collection and employed an interpretive analysis method. The data collected from teachers served to understand how teachers use their understandings of core concepts of the NOS in teaching a theme of Evolution and explore their epistemologies with regard to teaching and learning in the classroom.

The findings of the study suggests that although all three teachers revealed informed understanding in most of the concepts of NOS, their classroom practice was not influenced by their understanding of NOS. Another main finding revealed that teachers' epistemological beliefs about aspects of NOS and science teaching are consistent with their pedagogical practices. The last finding revealed that teachers' beliefs about science teaching and learning have impact on their curricular implementation and pedagogical practices. Teachers further revealed that community of practice of teachers played a very important role in shaping up their existing belief and in developing their pedagogical practices and strategies. Teachers support one another by sharing experiences of their diverse professional knowledge and skills in a community of practice. This professional engagement of teachers should therefore be strengthened.

DECLARATION

I, Tizana Fikeni, declare that

- The research reported in this dissertation, except where otherwise indicated, is my own original work.
- This dissertation has not been submitted for any degree or examination at any other university.
- This dissertation does not contain other person's data, graphs or other information, unless specifically acknowledged as being sourced from other persons.

Signed………………………………. Date: ………………………….

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Abbreviations and Acronyms

NOS Nature of Science

NCS National Curriculum Statement

DOE Department of Education

PCK Pedagogical Content Knowledge

CNU Christian National Education

NRC National Research Council

IKS Indigenous Knowledge Systems

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Chapter One

Introduction

1.1 Introduction

This chapter serves to outline the aim of the study, describes the rationale behind the study and provides general background to the study. The chapter further describes the problem statement which focuses on the research questions that are explored in the study. The chapter also introduces the conceptual framework and methodology which underpin the study. Finally a brief summary of the layout of the entire thesis is then given.

1.2 Aim of the study

The aim of this study is to find out how teachers' understandings of core concepts of the Nature of Science (NOS) influence their pedagogical practices in teaching Biological Evolution, in Life Sciences.

Evolution, an important new theme in Life Sciences and lends itself to developing deeper conceptions of NOS. Evolution, a concept in Life Sciences which according to the South African curriculum should be taught both as a scientific theory and as an issue in science education (Department of Education, 2003). The new South African curriculum, National Curriculum Statement (NCS) involves a huge shift from highly prescriptive, content-based syllabus to an outcomes-based curriculum emphasising the development of skills, content and inclusion of the NOS for Natural Sciences, Life Sciences and Physical Sciences. The inclusion of NOS is also emphasised in the new revised Curriculum and Assessment Policy Statement (CAPS). The Life Science CAPS document clearly states how learners should be taught in an integrated way. Furthermore, this document highlights the need for Life Sciences learners to understand that knowledge production in science is ongoing and scientific knowledge changes over time. Also it encourages teachers to inform learners of debates and arguments among scientists. This therefore means that Life Sciences need to address issues of NOS in their classroom teaching. In general terms, NOS refers to "values and beliefs inherent to the development of scientific knowledge" (Abd-El-Khalick, Bell, & Lederman, 1998, p. 418).

According to current reforms in science education, such as the National Science Education Standards (NRC, 1996) and the National Curriculum Statement (2003), Nature of Science is now an important aspect of knowledge that is needed by learners in order to have a better understanding of science and its processes and how it changes over time (Martin-Diaz, 2006). Similarly, Martin-Diaz (2006) argues that learners' understanding of the Nature of Science helps to develop their ways of thinking that enables them to see the flaws in pseudo-science. Given the controversial nature of Evolution a theme in Life Sciences, it is imperative that the study attempts to reveal science teachers' identities (their philosophies and or epistemologies) and how these reflect and or influence their teaching of Evolution.

1.3 Background and Rationale for the study

In this section I discuss the need for the study that I have chosen and its importance for science education. As a Biology teacher in the old pre-2003 curriculum, I learnt and taught Biology from an empiricist and positivist point of view where scientific knowledge is determined empirically and is taught as being completely objective. My approach to science teaching was more of traditional teaching where science was presented as facts and theories, to be memorised and practiced. The way I taught science is proof of the argument that "at all levels science teaching and textbooks emphasise the factual recall of science content to the near total exclusion of the knowledge-generation process" (McComas, Clough, & Almazroa, 1998, p. 4). During my training as a teacher I rarely had an opportunity to learn about epistemological views of science and as a result failed to emphasise it when teaching my learners.

Now later on with the introduction of the NCS with its goals and principles particularly in Life Sciences, I was interested to know how teachers like me who never considered or even thought of NOS would incorporate such critical aspect in science, especially in the teaching of Evolution. This has implications for teacher education programmes and as a Life Sciences advisor, I was interested in finding out whether Life Sciences teachers had an understanding of the curriculum and policy knowledge required to implement the curriculum effectively. In particular, I was interested in their understanding of the nature of science which seems to be essential for the understanding and acceptance of the theory of evolution and the proper manner in which it is taught in the classroom (Holtman, 2010).

Furthermore, in my position as a subject advisor I am interested to know what teachers actually teach in their classrooms with regard to Evolution. It is therefore against this background that I became interested in knowing more about the nature of science as I have never reflected on issues of the nature of science especially in the teaching of Evolution.

The possibility that other Life Sciences teachers were also trapped in the same predicament when it came to the knowledge of the nature of science and its teaching dawned upon me.

As mentioned earlier, the curriculum change after 1994 in South Africa came with changes in the education system which also impacted on science education. For high school science, 'Life Sciences' replaced the traditional Biology learning area. One of the major changes was the inclusion of content such as Evolution that was previously deliberately omitted from the curriculum because it was not in line with the principles of Christian National Education (CNE). A portion of Grade12 prescribed content includes concepts and ideas about evolution, and it was implemented in 2008. Learning Outcome 3 in Life Sciences curriculum statement clearly defines the following aspects in the teaching of Evolution especially in Grade 12:

- History and the nature of science.
- Beliefs about creation and evolution.
- Changes of knowledge through contested nature and diverse perceptions of evolution.

(DoE, 2003, p. 40)

The new curriculum, (NCS) particularly in Life Sciences calls for the inclusion of NOS which was absent from the previous curriculum. The curriculum document for Life Sciences (National Curriculum Statement, Life Sciences (Department of Education, 2003) indicates clearly that learners should have an understanding of NOS. The nature of science include amongst others, how "scientific knowledge develops, tentativeness and subjectivity of scientific knowledge based on availability of new evidence and the need to explore and evaluate all forms of scientific knowledge" (NCS, Life Sciences, 2003, p. 10). An understanding of NOS is considered critical and most needed in science teaching as it is believed to contribute towards promoting scientific literacy (Lederman, 2000). One of the most important objectives in the science curriculum is to develop "responsible, sensitive and scientifically literate citizens who can critically debate scientific issues and participate in an informed way in democratic decision-making processes" (National Curriculum Statement, Life Sciences, DoE, 2003, p. 7).

NOS appear to be necessary in addressing several controversial issues in science education such as Evolution/creationism debate, and the relationship between science and religion etc. Teaching NOS is central to the teaching of Evolution as it allows for the opportunity to address and expose learners to many different worldviews and how they relate their understanding of science with their personal worldviews (Anderson, 2007). Therefore, to understand biological evolution, it is imperative to start with the nature of science.

As highlighted by McComas et al., (1998), NOS is a very important aspect in guiding teachers on how to precisely describe science to learners. For example, Darwin's theory of Evolution requires learners to know and have an understanding of the different constructs of the theory and how these constructs relate to one another. Furthermore, learners must have an understanding of what evidence is used to support and or question the theory and why the theory of Evolution is widely accepted by the scientific community.

In my experience, the previous South African curriculum mainly focused on learning of the product of science, rather than the process (Dekkers & Mnisi, 2003). Science was taught as a body of knowledge with little questioning, few arguments and little critical thinking. Very little was done with regards to the process of science and its relationship to its discoverers, for example, history of the DNA (Watson-Crick) and history of Genetics (Gregor Mendel). From talking to teachers informally at workshops, they regarded these aspects as just history and therefore not that relevant to learning of Biology concepts. In addition, they perceived the teaching of these aspects as an unnecessary waste of teaching time since they did not feature in the examinations. Contrary to this, the new curriculum's outcomes emphasise the teaching of both science as a product and science as a process. The emphasis of science as a process is largely evident in the inclusion of NOS.

The aim of teaching NOS is to give an opportunity to learners to question, argue and think about the nature of science, about what evidence can and cannot be used to support its propositions. For example, Bell (2008) argues that NOS assist learners in developing accurate views of what science is, how it differs from other disciplines as well as strengths and limitations of scientific knowledge. McComas, Clough, and Almazroa (1998, p. 4) acknowledge the importance of teachers understanding of NOS as they argue that the "explanation for general public's poor understanding of how science develops is due to the science teaching and science textbooks which emphasises the factual recall of science content", ignoring science as a process" (McComas et al., 1998, p. 4).

The new curriculum for science is aimed to prepare learners to be critical thinkers and scientifically literate. It then rests with the science teachers "as agents of change" to ensure that such curriculum goals are fulfilled (McComas et al., 1998). One way of ensuring that a goal of producing learners who are scientific literate is achieved, is addressing the issues of NOS, in science classrooms.

Unfortunately research done both nationally (Dekkers & Mnisi, 2003; Linneman, Lynch, Kurup, Webb, & Bantwini, 2003) and internationally (Koulaidis & Ogborn 1995; Lederman, 1998; Abd-El-Khalick & BouJaoude, 1997; Khishfe & Lederman, 2006), showed that teachers and learners have a limited understanding of NOS. This inadequate understanding of NOS may have a negative impact on what and how teachers teach science and as a result what learners learn. In the study done by Cavallo and McCall (2008), results indicated that if learners acknowledged the tentative nature, and saw science as changing all the time, then it would be more accepting of the Theory Evolution. On the other hand, learners who viewed science as fixed did not accept the Evolutionary Theory. The controversy and non-acceptance of the Theory of Evolution amongst learners and teachers could be based on their limited understanding of NOS (Holtman, 2010). The critical question therefore is whether teachers are able to portray their understandings of NOS into meaningful classroom practice and appropriate classroom pedagogy when teaching Evolution in Life Sciences.

Teachers, therefore need to realise that classroom teaching and learning is influenced not only by scientific views taught in class but also by cultural, political, personal, religious, and epistemological views that their learners hold (Woods & Scharmann, 2001). Hence Holtman believed that "teachers need to be challenged to adapt their teaching styles and to approach their teaching differently" (Holtman, 2010, p. 105). She further suggested that in order to develop critical thinking skills among learners, in addition to the understanding of the content knowledge, teachers need to adopt a Pedagogical Content Knowledge (PCK) strategy for teaching concepts like Evolution. As argued by Shulman (1986), teachers need a specific type of knowledge that will enable them to translate their pedagogical knowledge to their content knowledge. In other words, although teachers may have an understanding of the core concepts of NOS and evolution, they still need to develop strategies to incorporate their understanding into meaningful classroom instruction. For example, instead of transmitting content knowledge in a passive manner, the emphasis in teaching must be on creating opportunities and various activities which enable learners to develop critical thinking and be involved actively in the learning process (Stears, 2012).

Vygotsky (1996) acknowledges learning as a social process in which learners construct meaning from their learning experience, what they already know. This they can only do themselves, the teacher can only provide learning experiences where learners make sense of and link new information with what they already know. Designing and creating lessons that help learners link the new information with the already existing information in an accurate and appropriate manner is not an easy task. This requires a shift towards reflective teaching where teachers constantly review, reconstruct and critically analyse their own pedagogical practices as well as their understanding of the NOS and the theory of Evolution. Life Sciences teachers' knowledge of NOS and their content knowledge of Evolution are likely to influence and have impact on how they teach learners about Evolution and its process (Abrie, 2010).

Teaching a concept like Evolution with adequate depth requires not only the understanding of scientific literacy including the nature of science, it may also challenge deeply held belief systems of religious and cultural nature. Science classrooms and more specifically, science teachers play a very critical role in bridging the gap between scientists' understanding of Evolution and learners' resistance to it (Nehm & Schoenfeld, 2007). In order to bridge this gap and develop learners' understanding of Evolution, Gess-Newsome and Lederman (1999), argue that science teachers should have a good knowledge and understanding of the content knowledge on Evolution as well as the nature of science. Furthermore, teachers, in their teaching of Evolution should address: learners' misconceptions, religious and cultural beliefs about Evolution; conceptual change strategies and model pedagogical content knowledge.

Evolution is key and central in the discipline of Life Sciences (Rutledge & Mitchell, 2002) and although it is well-supported in the scientific community, it is highly controversial within the general public and as such has stirred up major debates with respect to teaching and learning in science classrooms (Stears, 2012). The controversy around teaching the Theory of Evolution is, teachers' lack of exposure to Evolution (Holtman, 2010), specifically in the South African context limited subject knowledge of the theory amongst teachers (Stears, 2012) and religious conflicts all seem to pose a huge challenge to science teachers and their classroom practices.

1.4 Research Questions

Since Evolution is a new theme in the Life Sciences learning area in South Africa, not much is known about science teachers' knowledge and understanding of the theory of Evolution and NOS and how these influence their pedagogical practices in the context of teaching Evolution. In addition, since Evolution is a new theme, it is imperative to understand how Life Sciences teachers teach and what informs their chosen pedagogical strategies and this can be answered by looking closely into teachers beliefs. As indicated earlier, teaching a concept like Evolution, with adequate depth requires not only the understanding of scientific literacy including the nature of science, it may also challenge deeply held belief systems of a religious and cultural nature. It is therefore imperative that the study attempts to reveal science teachers' identities (their philosophies and or epistemologies) and how these reflect and or influence their teaching of Evolution. In respect of the background outlined above, this study therefore serves to explore the following four research questions:

- What are Life Sciences teachers' understandings of NOS in teaching Evolution?
- How do Life Sciences teachers' understandings of the core concepts of NOS influence their pedagogical practices in teaching Evolution?
- What epistemological framework informs Life Sciences teachers' pedagogical strategies in addressing core concepts of NOS in teaching Evolution?
- Why do Life Sciences teachers' exhibit such pedagogical strategies in addressing core concepts of NOS in teaching Evolution?

1.5 Research Design and Methodology

This is a qualitative case study which looks at exploring how Life Sciences teachers' understandings of NOS influence their teaching of Evolution. It focuses firstly on teachers' understandings of core concepts of NOS and how Life Sciences teachers link their understandings of the core concepts of NOS and their teaching of Evolution. Secondly, it looks at why Life Sciences teachers teach the NOS core concepts in the manner that they do. Since this study is intended to focus on a particular theme, namely Evolution and using a conceptual framework of core concepts of NOS to understand and explore how teachers link their theory and practice, a case study method is employed. Patton (1987, p. 19) points out that, case studies are useful specifically when one aims to "understand some particular problem or situation in great-depth, and where one can identify cases rich in information". In addition, Merriam (1988, p. 12) defines a case study research as "deep, holistic descriptions of and analysis of a particular instance which involves a contextualised interpretation of events".

This study will make use of mostly qualitative data collection method and it will employ an interpretive analysis method to analyse the data, as qualitative research aims to understand, describe and explain social phenomena as they occur in their natural settings. Furthermore, qualitative research also aims to understand and describe human behaviour from an insiders' perspective (Babbie & Mouton, 2001). The data collected from Life Sciences teachers will inform on their understanding of the core concepts of NOS, and furthermore explain how this understanding influence their teaching of the theme of Evolution. Qualitative methods enable one to gain rich and detailed data as required by this study (Cohen, Manion, & Morrison, 2007).

Purposive sampling as a sampling strategy was used to select Grade 12 Life Sciences teachers in East Griqualand (also known as Kokstad). East Griqualand as a location for the study has been chosen due to its close proximity from my area of residence and work and also its demographic representativity. Questionnaires, classroom observations and interviews were conducted to determine how teachers' understanding of NOS translates into their classroom practice. An in-depth qualitative study was done on the three Grade 12 Life Sciences teachers. Grade 12 level was selected because the topic of Evolution is extensively covered thus the researcher will be able to get thick data. It was of interest to explore how these teachers address and deal with core concepts of NOS and religion as specified in the Grade 12 content framework of Evolution.

1.6 Conclusion

Chapter 1 clarifies the aim and focus of this study. It briefly describes the conceptual framework and research design that is going to be used and it also defines the rationale of the study in a South African context. Chapter 2 of the study comprises in-depth overviews of relevant literature on the nature of science and core concepts of NOS that serve as a basis of foundation from which the data collected in this study may be analysed. In Chapter 3, research methodology is discussed wherein use of a case study is justified. Also the research design and methods to answer the research questions posed in Section 1.3 are discussed. Finally the chapter identifies the ethics involved in conducting such a study. Chapter 4 presents a descriptive analysis of the data. Finally, Chapter 5 is a concluding chapter that provides the main synthesis of the findings of my research in relation to the four research questions posed that guided this study and presents conclusions, implications, recommendations and limitations of the study.

Chapter 2

2.1 Introduction

The following literature review addresses several aspects and issues of the concept of 'Nature of Science' from various perspectives and discusses how these perspectives influence how teachers teach science topics such as Evolution in their classrooms. This chapter discusses various arguments on the value of incorporating NOS in the teaching of science concepts with specific reference to Evolution as well as challenges posed by its implementation. The chapter acknowledges the concept of Evolution as one of the most controversial theme in science education, hence the discussions and explanations of Evolution as a scientific theory, definitions of science and religion and then the controversy and challenges around teaching evolution in science classrooms.

The chapter further acknowledges the role of Life Sciences teachers as "critical determiners" (Rutledge & Mitchell, 2002, p. 2) of quality classroom teaching and active agents of any change within teaching and learning in the classroom (Gess-Newsome & Lederman, 1999). Since teachers are considered implementers and active change agents, this chapter emphasises the need for the knowledge of nature of science by science teachers so as to enhance an understanding of science as a discipline amongst learners (Gess-Newsome & Lederman, 1999). Most research done on secondary science teachers' understanding of NOS suggests that the aspects of NOS are not adequately understood by teachers (Abd-El-Khalick & BouJaoude 1997; Koulaidis & Ogborn 1995; Lederman, 1992; Dekkers & Mnisi 2003; Hoh, 2013). The lack of adequate understanding of nature of science by most science teachers is of major concern particularly when teaching about theories such as Biological Evolution that necessitates adequate understanding and teaching about NOS (Bybee, 2001).

2.2 The Theory of Evolution

The theory of Evolution is closely associated with Charles Darwin and his book called, *On the Origin of Species* (1859). In this book, Darwin formulated a theory with two claims. The first claim became known as the theory of universal common descent. In this theory, he claimed that every creature on Earth is ultimately descended from a single common ancestor somewhere in the distant past. In other words this theory portrays a picture of history of life on Earth. The second main claim, Darwin proposed a mechanism that he thought could cause existing living organisms to change and also cause new living forms to arise. He called this mechanism natural selection. In this mechanism, Darwin observed that individuals within the group are not exactly the same but they vary in their traits. Occasionally these variations between individuals play a huge role in determining which members of the group survive and which do not. Over-time, Darwin argued that this process can cause permanent changes in species and can eventually cause new living forms to arise. The ideas of universal common descent together with that of natural selection form the core of Darwin's theory of Evolution. This book gives explanation of how life reached its current state and that biologically it is driven by natural selection.

2.2.1 Evidence for the theory of Evolution

Evolution has various important components: Natural Selection, Macro-evolution, and Micro-evolution. Microevolution refers to varieties within a given type. Change happens within a group, but the descendant is clearly of the same type as the ancestor. Macro-evolution refers to major evolutionary changes over time, the origin of new types of organisms from previously existing, but different, ancestral types. While Micro-Evolution is observed and well documented, Macro-Evolution is not and thus highly disputable. The main pillars at the centre of the theory of Evolution are; first, evidence that natural selection can produce evolutionary change and, second, evidence from the fossil records that evolution has occurred. Furthermore, information from various areas of biology, including embryology, anatomy, molecular biology and biogeography can be regarded merely as an outcome of Evolution. Evidence presented by these various sources largely, but tentatively supports the Darwinian theory of Evolution.

In light of this Darwinian Theory, some scientists disputed some of the mechanisms he proposed for natural selection. In the twentieth century, however, most biologists had accepted the basic premise that species gradually change, even though the mechanism for biological inheritance was still not clearly understood. Scientific studies eventually were able to interpret data through an evolutionary viewpoint and link these core concepts into the modern Theory of Evolution.

Presently, amongst the scientific community, due to the history and supporting evidence, the debate is no longer about whether evolution occurs but the details of the mechanisms by which it takes place (McBride, Gillman, & Wright, 2009). However, in the general public there is still much controversy around the Theory of Evolution. On one hand, there are people who altogether reject the concept of evolution, not on scientific grounds but on the basis of what they take to be religion, its unacceptable implications, like, the implication that human beings and other species have common ancestors and are therefore related. On the other hand, there are people who reject the concept of evolution because they claim that it contradicts with their religious beliefs.

2.2.2 Controversy around the evidence of Evolution

The controversial issues linked with the theory of Evolution in general and its evidence still exists in general public. For example, with regard to fossil records, Darwin's critics claimed, there are no fossil intermediates, referring to the many gaps in the fossil record. However, most fossil intermediates in vertebrate evolution have been found since Darwin's day. In addition, Darwin's critics who perceived science as an inductive process in which the collecting of facts was the only basis for constructing a theory attacked him for violating scientific methodology. They argued that Evolution is just a hypothesis that is not adequately demonstrated since there were no concrete facts to show the existence of random variation.

Similarly, creationists define science in terms of observable facts. They argue that because no one was present when life first appeared, the theory of evolution is no more than a religion.

Another huge controversy was brought by Darwin second book 'T*he Descent of Man'* which extended the theory of Evolution to include human evolution. Although some people were able to accept that other organisms evolve, they found it hard to believe that humans have also evolved. This was because no fossil humans had been found, although Darwin did suggest that Africa would be the most likely place to find such fossils and indeed he was correct.

Given the perceptions and understandings that general public have about science and religion, I find it very relevant to explore the relationship between science and religion especially in the teaching of the theory of Evolution (Anderson, 2007).

2.3 Defining Science and Religion

2.3.1 What is Science?

Science is generally defined as a 'body of knowledge' and a methodology. Van Driel, Beijaard and Verloop (2001, p. 138) argue that "science is usually presented as a rigid body of facts, theories, and rules to be memorised and practiced, rather than a way of knowing about natural phenomena". Hence, in the philosophy of science, philosophers such as Karl Popper, Thomas Kuhn and Imre Lakatos devoted their time in researching about what science is or the criteria for the demarcation of science. For example, Thomas Kuhn grounded science in a framework of assumptions and background of beliefs which he called a 'paradigm'. Kuhn (1962) believed that science does not progress in a linear form by accumulation of new knowledge, but undergoes periodic revolutions which he called "paradigm shifts" in which the nature of scientific inquiry within a particular field is abruptly transformed. On the other hand, Lakatos (1977) had a different view from that of Kuhn.

He argued that in science a 'theory' is a succession of slightly different theories and experimental techniques developed over time that all share a "common hard core", a collective he referred to as the "research programme". Lovely and Kondrick (2008) defined science as knowledge that attempts to explain natural phenomena through an inductive process in which observations and experiments are used to develop and test hypothesis.

The emphasis on evidence is what distinguishes science from other human endeavours such as philosophy and religion. Various literatures about science suggest that science is to be based on observations and experimentations, this way facts established constitute a solid, objective and reliable foundation of scientific knowledge (Chalmers, 1999). The above scholars imply that science depends largely on facts established by observation and experimentation (a view of empiricists and positivists).

Over the years scientists have built up a body of knowledge to try and explain things that have been observed in nature. Before being accepted into the 'body of knowledge' called 'science' scientists demand that these hypotheses must be supported by a wealth of scientific evidence (Chalmers, 1999). Every now and then, scientists might challenge what is contained in this knowledge base. If scientific evidence shows that what has been accepted for a long time has to be amended, and other scientists agree, then the hypothesis is changed. This way, the scientific knowledge become changed and grows over time. This shows the tentative or the changing nature of scientific knowledge over time.

2.3.2 What is Religion?

The answer to this question is very complex and complicated as there are many religions and as such most scholars in the literature identify general characteristics of most religions rather than an attempt to define religion and the nature of religion. Reiss (2009) describes religions as ‘encompassing elements’ such as worship, preaching, prayer, yoga, meditation etc. On the other hand, Beyers describes religion as a human’s way of representing reality and as the “continual participation in traditions (myths and rituals) passed on from one generation to the next” (Beyers, 2010, p. 342).

According to Beyers (2010) main characteristics of religion include belief in a Supreme Being, belief in spirits and divinities, the cult of ancestors and the use of magic, charms and spiritual forces. Similarly, Allgaier and Holliman (2006) suggest that most forms of creationism are often based on creation myths that are linked to spiritual beliefs involving supernatural powers. However, in Christianity, some believe in literal interpretation of the Biblical account about the origins of life and the universe. Christianity has different denominations and versions with a variety of practices all over the world and other religions.

Looking at South Africa for example, according to the census statistics in South Africa, (Statistics South African Census, 2001), there are various major faiths that are practiced namely, Christianity, Islam, Hinduism, traditional African religion, Judaism, Buddhism and other diverse religions in other countries as well. Hence South Africa is called a rainbow nation because of its variety of people, cultures and religions. Most people around the world and in South Africa value their religions and traditions and as such believe deeply in practicing and teaching their children about their religion and traditions. Hence all religions and their followers are respected by the state, by the state institutions and by all citizens as advocated in the South African constitution. Statistics South Africa Census (2001) reported that about 63% of South Africans are Christians, and this can be attributed to the fact that during the twentieth century, the South African government has actively promoted particular Christian beliefs. However, after 1994 (post-apartheid), teaching of diverse religions was allowed in public schools with the aim of uniting the diverse people of South Africa and learning about one another’s religion. For example, learners in intermediate phase are taught various aspects of different religions: their founders, sacred places, rituals, festivals, stories and songs (Revised National Curriculum Statement Grades R-9, 2002).

2.4 Debates on teaching the theory of Evolution in science classrooms (Science vs. Religion)

Science and religion are very complicated concepts to address and yet very critical in science education. Tenets of Evolutionary theory such as, 'common descent' have been a major source of controversy among religious communities, and general public because they believe them to be contradictory to their religious beliefs (Meadows, Doster, & Jackson, 2000).

Holliman and Allgaier (2006, p. 264) agree that these conflicting accounts (evolutionary theory and creationism) of the origin of life "have coexisted in wider society since Darwin published *On the Origin of Species*". The Evolutionary account for the existence of life and the biblical account of creation are very different. Evolution suggests that all life is connected and can be traced back to one common ancestor, whereas the literal interpretation of biblical creation suggests that life was created by an all-powerful, supernatural being (God).

Lerner (2000) describes the debate over Evolution as more complicated and interesting as it is influenced by various people in the society. He points out that while "scientists are more or less unanimous about the science itself, those who oppose teaching of evolution to school children are a surprisingly diverse group" (Lerner, 2000, p. 8). He further added that there are creationists who believe that the Earth arose approximately 6000 years ago as described in the Bible. On the other hand, proponents of intelligent design argue that certain complex biological structures and processes could not have arisen through natural selection. Whilst others simply believe that what is taught in science classrooms goes far beyond what has been proven by scientists and it includes uncertain claims on behalf of science that disrespect religious views. Creationists accept evolution being taught in science classrooms so long as religious explanations are also taught.

The various accounts of the origin of life have created a huge controversy among the public and in the science community including science teachers and learners since Darwin published his book. This controversy has led to a huge debate in many countries over the years as to whether religious explanations about origin of life should be taught in science classrooms in addition to the scientific accounts (Allgaier & Holliman, 2006; Nehm, Kim, & Sheppard, 2009). This conflicting debate of teaching evolutionary theory/creationism and their relationship thereof in science classrooms have been very prominent particularly in United States of America. The teaching of evolution/creationism in United States has always been controversial both socially and legally. Taking for example the case of the state of Tennessee vs. John Scopes, a high school biology teacher charged with teaching the Theory of Evolution illegally and other similar cases that involved prohibition of the teaching of evolution such as Arkansas vs. Epperson in 1968 and Edwards vs. Aguillard in 1987. The American resistance to accepting evolution according to Coyne still remains. This is evident in the conclusion reached by Berkman and Plutzer after having analysed the results of all polls regarding the teaching of evolution/creationism in various countries including the United States of America.

They concluded that:

"Even if the actual percentages might differ from poll to poll, there can be no doubts that the large majority of Americans want creationism taught in the public schools…" (p. 62).

Contrary to the results of the polls, the United States National Association of Biology Teachers argue that creationist ideas do not belong in the science classrooms and that science and religion should not be mixed as they are contrasting. However, a scholar like Nord (1999) disagrees with the view that religion has no place in the science classroom; he believes each has its own method. He further argued that learners in the science classrooms are taught to use only the scientific conceptual understanding to understand nature, yet it is possible that there might be more to nature than scientific understandings or scientific ways of knowing. He further proposes that learners must be provided with opportunities to engage and think critically about alternatives of knowing and or various worldviews. In other words, learners must be taught about conflicts that exist on how to make sense of nature, possible limitations of science and about its relationship to various religious traditions. Similarly, proponents of creationism like Scott and Branch (2003) argue that to teach Darwin's Theory of Evolution is teaching one side of the story and as such suggest that creation must be posed as an alternative theory for a balanced account in the science classroom.

Unlike in other countries such as United States of America, where teaching of Evolution has had a huge influence on the schooling system, in apartheid South Africa, this was never an issue as it was assumed that Evolution had no place in education. This was due to the fact that a previous curriculum was mainly influenced by the philosophy of CNU, where Evolution as a biological concept was not considered at all because education was based on Christian principles (Ngxola & Sanders, 2009; Abrie, 2010; Holtman, 2010). However, some South African universities and research institutes did some evolutionary research and taught evolution (Dempster & Hugo, 2006). After 1994, when the new curriculum, National Curriculum Statement (NCS) (Department of Education, 2003) was introduced, it aimed at redressing educational imbalances of the past and to produce learners who are informed and empowered as South African citizens. In order to achieve these goals, many innovations were included in the NCS, such as learner-centred approach to teaching, inclusion of Indigenous Knowledge Systems (IKS) in science teaching and learning, inclusion of some content concepts such as biological evolution in Life Sciences and the nature of science (DoE, 2003).

The inclusion of the latter meant that biology teachers (both experienced and inexperienced) must for the first time teach the nature of science and Evolution, and this was a major challenge as most of them never even had formal training in Evolution before 1994 (Holtman, 2010). Some of the major concerns that biology teachers raised in the study conducted by Ngxola and Saunders (2003) included, inadequate or lack of content knowledge, what to teach and how to teach it, the controversial nature of evolution and the conflict between Evolution and creationism within teachers themselves. Despite the concerns of teaching Evolution in schools, science curriculum reform, NCS (DoE, 2003) encouraged teaching of Evolution in science classrooms. For example, the NCS in life sciences clearly stipulates the following aspects in the teaching of Evolution specifically in Grade 12:

- History and the nature of science.
- Alternative Explanations (beliefs about Evolution and religion)
    - Conflict that existed and still exists between religion and science with respect to Evolution.
    - Cultural and religious explanations for the origin & development of life on earth.
    - Science is limited to explaining physical structures and events but not spiritual or faith-based matters and that both are important to humans, but in different ways.
- Changes of knowledge through contested nature and diverse perceptions of evolution.

(DoE, 2003, p. 40)

The above aspects emphasises the need to recognise and address alternative ways of knowing, including faith-based and indigenous knowledge systems in science lessons particularly in teaching evolution and “places all knowledge domains in an equal footing” (Abrie, 2010, p. 106).

In view of the evolution/creation debates, the teaching of Evolution requires that it must be “understood in its social, intellectual and pedagogical context that is multifaceted, complex and influential” (Anderson, 2007, p. 664). Apart from the multifaceted complex context highlighted by Anderson, there are also other implications around teaching of Evolution such as teachers’ and learners’ religious beliefs system, their varied worldviews and whether or not these should be addressed in a life science classroom.

These debates create a huge conflict amongst life sciences teachers and learners who possess cultural and or religious beliefs about the origin of life (Meadows, Doster, & Jackson, 2000; Holtman, 2010; Abrie, 2010; Stears, 2012). This therefore makes the teaching of evolution very challenging and not an easy theme for learners to understand, hence Dempster and Hugo (2006) suggests that in order for science teachers to teach the theory of evolution effectively, they need to have a thorough understanding of what science is as well as acknowledge the issues related to religious and cultural beliefs.

2.5 Challenges facing South African teachers in teaching evolution

Since the inception of the new curriculum in South Africa (2003), Life science teachers are not only required to change their classroom practices so as to accommodate the new principles of the curriculum such as outcomes based approach, they were also faced with a new theme, Evolution which they never taught. In addition to this they were required to translate a curriculum and make it meaningful for learners in a classroom and further decide on what learners must know, how to teach it and why should learners learn it. Rutledge and Warden (2000) argue that the majority of science teachers do not possess adequate or necessary content knowledge about evolution. In agreement, Holtman, (2010) highlighted that data from surveys of teachers in the Western Cape and Northern Cape regions of South Africa indicate that most teachers lack teacher content knowledge, specifically, in evolution. Stears (2012) revealed similar results in her study of 24 final-year students in biology education. It therefore seems appears most teachers in South Africa who completed school and went to teacher colleges had little or no training in the concept of evolution and yet they are expected to interpret and teach the curriculum efficiently. The lack of or little understanding of curriculum, policy and content subject knowledge by the majority of South African Life Science teachers makes teaching of evolution very challenging as teachers cannot implement what they are not familiar with (Sanders & Ngxola, 2009; Holtman, 2010; Stears, 2012).

For instance, according to the life science curriculum and evolution literature, the goal of teaching evolution is to develop learners' understanding of Evolution as a scientific theory and how its constructs fit together as a whole. In addition, teaching of evolution according to Cavallo and McCall (2008, p. 529) enable learners to "practise the process of science, to experience the tentative nature of science and to logically and thoughtfully analyse scientific evidence gathered today or throughout history, to support and or refute any scientific theory". The achievement of these goals and the success of the current reform require teachers to have an ability to integrate philosophy and practices of the science reform with their existing philosophy and practice (Levitt, 2001). Also, Shulman (1986) argues that for teachers to teach effectively, they need to possess multiple kinds of knowledge:

> Teachers must not only be capable of defining for students the accepted truths in a domain. They must also be able to explain why a particular proposition is deemed warranted, why is it worth knowing and how it relates to other propositions, both within the discipline and without, both in theory and in practice. (p. 9)

Lombrozo, Thanukos and Weisberg (2008), also cautioned that science practice is far more diverse and dynamic than suggested and portrayed by most science textbooks. For example, much of what we know about the mechanisms of evolution and evolutionary trends was discovered through field observations, museum research, examination of fossil records and molecular biology. All this evidence was collected and documented over many years by various scholars and scientists. This shows how science works in relation to acceptance of scientific explanations based on evidence, and also how knowledge is contested and accepted depending on social, religious and political factors.

The other challenge facing life science teachers in South Africa is the controversy and conflict of teaching Evolution and or creationism in science classrooms. This controversy makes effective teaching for the understanding of Evolution as a scientific theory the most crucial and daunting task. Firstly, teachers never had an opportunity to differentiate between scientific and religious beliefs with regards to Evolution as this concept was never in the biology curriculum (Stears, 2012).This therefore poses a huge challenge to Life Science teachers who are expected to not only address Evolution as a biological concept, but to also create a learning atmosphere that mediates conflicting ideas around the concept of Evolution (Holtman, 2010). Cavallo and McCall (2008) point out that there must be a recognition of the 'context' in which teaching and learning of evolution occurs which include cultural, political, personal, religious, epistemological and scientific influences. Even though South African Life Sciences curriculum particularly in Grade 12 addresses some aspects regarding creationism, acknowledges various worldviews and indigenous knowledge systems, the conflict between the scientific importance and religious beliefs makes proper teaching of evolution a huge challenge to science teachers.

Holtman (2010) and Dempster and Hugo (2006) point out that teachers, themselves must face their own conflict between their personal beliefs or worldviews and evolution are also faced with a challenge of guiding the development of learners' prescientific conceptions towards a scientific viewpoint without undermining their values, cultural and religious beliefs so a further challenge for life sciences teachers. Cavallo and McCall (2008) believe that learners' beliefs serve as the lens of how they see the world and this then can impact on their learning.

Based on the challenges facing Life Science teachers in teaching evolution, as mentioned before, teachers need to respond to conflicts between science and religious or cultural beliefs and at the same time deepen learners understanding of biological evolution (Meadows, Doster, & Jackson, 2000). Also teachers should ensure that they promote learners' understanding with regard to, knowledge that is contested and accepted (depending on social, religious and political factors) and limitations of scientific models and different theories (DoE, 2003). Discussions about science and religion, contested knowledge and what science is or is not enhance learners' understanding of NOS and Evolution.

In teaching the theory of evolution in science classrooms, Sanders and Ngxola (2009) argue that teachers require particular teaching approaches for dealing with potential controversy and also to encourage open-mindedness and tolerance of other viewpoints. Similarly, Holtman (2010) suggests that teachers must change their pedagogical strategies and approach their teaching in a manner that will develop critical thinking skills (Abd-El- Khalick & Lederman, 2000). Furthermore, teachers must adopt a pedagogical content knowledge (PCK) (will be explained below) approach over and above their understanding of content knowledge (Shulman, 1987; Abd-El-Khalick & Lederman, 2000). Hence, the emphasis that if Life Sciences teachers want learners to understand evolution as a biological concept, a more practical picture of the nature and process of science is essential.

Several scholars in science education seem to believe that the understanding of NOS is a prerequisite for the understanding of the theory of Evolution as a scientific theory (Lederman, 1992; Gess-Newsome & Lederman, 1999; Schwartz & Lederman, 2002; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003; McComas, 2008).

2. 6 Nature of Science

In an attempt to define the construct 'Nature of Science', various viewpoints are explored and considered. The exploration of literature below draws on recent curriculum reforms in America and in South Africa on the inclusion of the nature of science in science education. These curriculum reforms include National Science Education Standards (National Research Council, 1996) and National Curriculum Statements (DoE, 2003). Finally the review explores in more detail the construct of NOS in relation to teaching of a specific topic, for example, Evolution and the role teachers' play in translating a written life science curriculum into an expected classroom practice.

2.6.1 What does the construct "NOS" mean?

The construct Nature of Science (NOS) has been used to refer to the "epistemology of science", or "science as a way of knowing" or the "values and beliefs inherent to the development of scientific knowledge" (Abd-El-Khalick, Bell, & Lederman, 1998, p. 418). McComas et al. (1998) define the Nature of Science as a field which combines aspects from social studies of science like history, sociology, philosophy and psychology. Similarly, Dekkers & Mnisi (2003) considers issues addressed by philosophy, history, psychology and sociology of science part of the NOS. Although it appears that the majority of scholars in science education accept NOS, there seems to be no consensus among philosophers of science of one definition of the nature of science and its epistemologies. There are certain characteristics of the Nature of Science that are relevant and accessible to school science learners. In the research literature, the issues of understanding scientific enterprise, in particular, how scientific knowledge develops, scientific knowledge that is in principle tentative and subject to change as new evidence becomes available, are infused as some of characteristics or principles of the construct, nature of science. These characteristics or principles of the Nature of Science as mentioned in the National Science Education Standards include an understanding that;

- Scientific knowledge while durable, it is tentative and subject to change.
- Scientific knowledge is partly the product of human imagination and inference, creativity (involves the invention of explanation)
- Scientific knowledge relies on empirical evidence (derived from observations of the natural world)
- Science is socially and culturally embedded.
- In science investigations, there is no fixed method or set of steps that are always followed.
- Validity of science claims is eventually resolved by referring to observations of phenomena.
- Relationship between theories and laws (National Research Council, 1996, p. 171)

Even though these are very common views amongst scientists and philosophers of science, there is still lack of complete agreement of what constitutes the nature of science, yet there is some consensus that NOS should be taught in schools (Abd-El-Khalick et al., 1998). While NOS forms an important part and considered essential to scientific literacy in the science curriculum, there are various ideas in the literature as to what exactly is NOS and what it means to have a concrete understanding of NOS.

In spite of lack of consensus amongst philosophers of science, the main issue of concern is the value and significance of including and teaching NOS in science curriculum rather than the disagreements about philosophical details of the specific definition of NOS. Learners do not need to understand the philosophical underpinnings of the definition of NOS, what is crucial is for them to understand how science knowledge develops, relationship between a theories and laws, validity of science claims, no fixed method in science investigations, science as subjective, durable while tentative, involves creativity and imagination (Hanson & Akerson, 2006; Sadler, 2004; MacDonald & Gustafson, 2006). McComas et al. (1998), claim that science teaching is required to address issues concerning NOS where learners are expected to gain an appropriate understanding of the big picture of science: its history, philosophical assumptions and implications, its interaction with culture and society, etc.

McComas (1998) explained how scientific inquiry and processes of science work, using the following example:

> ….consider two teachers that have been scientifically trained on making observations and inferences, when asked to observe the same natural phenomena and make inferences. On observation they are more likely to come up with the same descriptive statements through use of their senses, however, inferences, go beyond the senses, and as such these two teachers are likely to develop different explanations or inferences about the same phenomena and this might be due to their previous experience or knowledge about the natural phenomena. (p. 16)

This means when questions such as, what is the nature of observation, what is the nature of inference, are asked, teachers will realise that there is no one way of knowing and consequently there is no one truth. This then shows how the two teachers came to know and be aware about science. Understanding how science works allows one to easily distinguish science from non-science.

It is therefore expected that learners will leave school with not just the knowledge of science, but also with knowledge about science. In order to promote such understanding of science, Martin-Diaz (2006, p. 1172) suggests that questions like "what is science, how does science develop over time, what are scientific theories, how are they constructed, what are characteristics of science: Tentativeness, Objectivity …" should form an integral part of discussions in science teaching (Abd-El-Khalick et al., 1998; Abd-El-Khalick & Lederman, 2000; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003). By acquiring understanding of science concepts, theories and 'ways of knowing' that characterize NOS, Cavalli and McCall (2008) believe that learners may become more scientifically literate citizens with the ability to think and reason. The above framework has been chosen to be used in this study as a guidance of what an understanding of NOS should entail. The reason for such a choice is the fact that it is less controversial and it describes what concepts of NOS, science teachers are required to teach their learners.

2.6.2 NOS in science education

NOS is considered a very important goal and critical educational outcome for learners in science education (Lederman, 1999).The importance of NOS in the science curriculum is evident from the research done by various scholars in science education. McComas et al. (1998) acknowledged the importance of teachers understanding of NOS as they argued that the general public' poor understanding of scientific literacy is due to science teaching which emphasises the factual recall of science content and facts, ignoring science as a process. They further highlighted that science teachers should not only be able to define what propositions are accepted in the science field, but must be able to also explain why they are accepted, why are they worth knowing and how they relate to other propositions both in theory and in practise. If the goal for science education is to teach for scientific literacy, Schwartz and Lederman (2002) suggest that the teaching of NOS should be an integral part of science teaching in the classroom. They further emphasise the importance of solid and in depth understanding of NOS and its characteristics by science teachers.

Teachers generally are perceived as people with major source of information; therefore it is important that they should possess adequate knowledge and understanding of what and how to teach (Liu & Lederman, 2007; Akerson & Hanuscin, 2007). Although current curriculum reforms consider the teaching of NOS critical in science education, many teachers are struggling with understanding and teaching thereof of the NOS characteristics especially concerning the topic of Evolution. (Brickhouse, 1990; Lederman, Schwartz, Abd-El-Khalick, & Bell, 2002). In addition to the inadequate understanding of NOS and its implementation in science teaching, most South African teachers also lack the understanding of content knowledge of Evolution as a scientific theory and teaching approaches to use when teaching this concept (Sanders & Ngxola, 2009; Holtman, 2010; Stears, 2012). Various misconceptions and misunderstandings amongst most science teachers of what defines scientific theories such as the evolutionary theory may be one of the artefact of teachers' inadequate knowledge and understanding of NOS (McComas, 2003).

In light of the above, studies done by several scholars indicate that science teachers have a poor or limited knowledge of the history and philosophy of science (Abd-El-Khalick & BouJaoude 1997; Koulaidis & Ogborn 1995; Dekkers & Mnisi, 2003; Lederman, 1992) and, as a result have inadequate or naïve conceptions of the nature of science (Abd-El-Khalick & BouJaoude, 1997; Murcia & Schibeci, 1999; Linneman, Lynch, Kurup, Webb, & Bantwini, 2003; Khishfe & Lederman, 2006; Hoh, 2013). Although various methods and instruments were used to assess teachers' understanding of different aspects of NOS, nevertheless research report that teachers' conceptions of NOS is not consistent with the current scientific practices (Murcia & Schibeci, 1999).

For example, Koulaidis and Ogborn (1995) conducted a study with a sample of fifty-four beginning teachers and forty pre-service science teachers and their findings indicated that teachers perceived the scientific method as what defines science and construction of scientific knowledge. The teachers also viewed science as not different from other forms of knowledge. Similarly in the study done by Murcia and Schibeci (1999) on primary teachers' understanding of the NOS, using a questionnaire with open-ended questions formulated using a newspaper science report, they reported that their respondents had limited understanding of NOS.

Using questionnaires, concept maps and interviews, Abd-El-Khalick and BouJaoude (1997) in their study also reported that out of twenty-five practicing teachers, all with science background some had naïve and incoherent views which are not consistent with the more current conceptions of NOS. Again, in a case study conducted by Aguirre, Haggerty and Linder (1990) to assess pre-service science teachers' understanding of NOS, they concluded that these teachers did not possess adequate understandings of NOS.

In an attempt to find out if the results of the international studies on secondary science teachers' understanding of NOS, would be the same or not in South Africa, Dekkers and Mnisi (2003), conducted similar investigation. Their sample comprised teachers in preservice or in-service professional development programme and they used open-ended questionnaire followed up by semi-structured interviews. They reported that most of their participants did not have "a fully adequate understanding of the NOS" (Dekkers & Mnisi, 2003, p. 31). Their conclusion was mostly based on the responses made by their participants with regards to certain concepts of NOS. For example, their participants did not acknowledge that theories can be refuted; secondly they believed that science relies only on experiments which serve as proof rather than to support claims. Also their participants believed that human inference, creativity and imagination do not have a significant role in the construction of scientific knowledge.

These results were similar to those of Abd-El-Khalick (2001) wherein the majority of the participants believed that scientists only use available data to answer questions and that human creativity, imagination and inference do not play a role in scientific investigations. In agreement of the above studies in the South African context was an investigative study conducted by Linneman et al. (2003) which focused on 135 intermediate and senior phase science teachers. They used questionnaires and focus group interviews and their findings indicated that science teachers do not have adequate conceptions of NOS. This therefore implies that both nationally and internationally, science teachers have limited understanding of NOS which then have an impact on how Evolution is taught.

Although most research studies show that science teachers do not have adequate understanding of the concepts of NOS (Abd-El-Khalick, Bell, & Lederman 1998; Osborne et al., 2003; Abd-El-Khalick & BouJaoude, 1997; Bell, 2000; Glasson & Bentley, 2000), few studies actually indicate that some teachers appear to have informed understandings of NOS which are consistent with the current conceptions of the NOS (Abd-El-Khalick, Bell, and Lederman, 1998).

For example, the study by Abd-El-Khalick, Bell, and Lederman (1998) reported that teachers showed an understanding of empirical and tentative nature of science. However, there is evidence that, teacher' conceptions about NOS when compared to survey data do not clearly articulate what teachers will communicate about NOS in their pedagogical practice (Hodson, 1993; Taylor & Dana, 2003). For example, although most of the teachers in the studies mentioned above acknowledged the importance of history and philosophy of science, they lacked knowledge of how to incorporate such topics in their science teaching and classroom practice (Lederman, 1992).

Various methodologies have been followed in the studies of teachers' conceptions of NOS and they show different understandings of what it means to have an understanding of NOS. In most of these studies, teachers' understandings of NOS were measured against complex philosophical perspectives (Kouladis & Ogborn, 1989; Palmquist & Finley, 1997) which narrowed the opportunity of exploring the uniqueness and diversity of teachers' conceptions in science teaching and in the classroom. Although studies by Aguirre, Haggerty, and Linder (1990) have progressed in articulating teachers' thoughts and beliefs about science, and the significance of pedagogical content knowledge in teaching certain topics in science, they have revealed very little on teachers' epistemological framework in the teaching of NOS in the theme of Evolution especially in the South African context.

As alluded to earlier, Levitt (2001) argued that for current science education reform to be successful teachers must be able to integrate philosophy and practices of the science reform with their existing philosophy and practice. Studies by Brickhouse (1989, 1990) articulated the impact of teachers' epistemological beliefs about science on their science teaching. Several classroom-based studies in science education reveal how teachers' beliefs about science are consistent with their teaching strategies (Brickhouse, 1989, 1990; Duschl & Wright, 1989; Appleton & Asoko, 1996; Laplante, 1997). However in the study done by Lederman and Zeidler (1987), they reported that most classroom variables did not correlate with the teachers beliefs. Furthermore, they concluded that possessing valid views of NOS do not always result in articulating them in a way that will improve learners' conceptions of NOS. What teachers teach depends on their scientific understandings and skills on what they are able and willing to teach as well as what they are required to teach (Ambimbola, 1983).Therefore it becomes crucial for teachers to have insight into the effect their own beliefs have on their interpretation of the curriculum and the way they teach science.

Learners' conceptions of NOS were also researched by some scholars such as Khishfe and Lederman (2006) and they revealed inadequate understanding of NOS amongst learners as well. They attributed this to an underlying assumption by teachers that when learners are taught science, they automatically learn and understand issues of NOS. This kind of thinking and teaching is mostly referred to as an implicit approach. Contrary to the implicit approach, Khishfe and Lederman (2006) and several other studies argued that science teachers need to explicitly plan for particular activities which will make learners aware of the aspects of NOS (Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Akerson & Volrich, 2006). In agreement researchers such as Leach and Driver (1999) and Clough (2003) have pointed out that addressing NOS within the science content and using an explicit approach of teaching NOS is more effective in improving learners understanding of NOS. On the other hand, Palmquist and Finley (1997) believe that implicit instruction of NOS do influence conceptions of science.

Evolution is one example where teachers' understanding of NOS is critical and without an in-depth understanding of the NOS, science teachers will likely lack the pedagogical content knowledge required to teach Evolution for scientific understanding (Khishfe & Lederman, 2006). Shulman (1986) emphasises the importance of Pedagogical Content Knowledge in teaching particular and specific topics in order to enhance learners' understanding of the concept. To achieve this, it is clear that instead of transmitting content knowledge in a rigid manner, the emphasis in teaching must be on designing situations and a variety of activities which enable learners to learn actively (Shulman, 1986). Thus, the teacher needs to investigate what the learners already know, identify possible misconceptions, and then design an appropriate instructional approach. This, therefore, challenges teachers to interpret and transmit their understanding of NOS into effective and appropriate classroom pedagogy.

2.7 Pedagogical Practices

2.7.1 Pedagogical Content Knowledge (PCK)

Since the 1980s, efforts have been made to reform teacher development programs in order to emphasise the type of knowledge needed for teaching (Abd-El-Khalick, 2001). Shulman (1986) emphasised different types of the knowledge needed for teaching which include content knowledge, general pedagogical knowledge, curricular knowledge and knowledge of learners, knowledge of educational goals and aims and Pedagogical Content Knowledge (PCK). PCK is defined as "*special amalgam …[or] the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organised, represented and adapted to the diverse interests and abilities of learners, and presented for instruction*" (Shulman, 1987, p. 8).

Pedagogical Content Knowledge is an aspect of pedagogical practices that is generally defined as the knowledge about teaching and learning of a particular content knowledge, taking into considerations specific learning demands. Shulman (1986) introduced PCK as a particular type of knowledge that goes beyond just content knowledge but also to the dynamics of content knowledge for teaching. Under PCK, Shulman also included "the most regularly taught topics in one's subject area", knowledge of learners' misconceptions about these topics and "instructional conditions necessary to overcome and transform those initial conceptions" (Shulman, 1986, p. 10). Simply put, PCK is a type of knowledge that is based on the manner in which teachers relate their pedagogical knowledge to their content knowledge.

After gaining much attention, many researchers studied the PCK of teachers, including science teachers (Van Driel, Verloop, & de Vos, 1998; Gess-Newsome, 1999; Appleton, 2008). Several of these research efforts, however, were based on some assumptions, that PCK is a separate domain of knowledge and that teachers' knowledge of content knowledge directly translates into their teaching practices. According to Van Driel, Verloop, & de Vos (1998, p. 675), "PCK implies a transformation of subject matter knowledge, so that it can be used effectively and flexibly in the communication process between teachers and learners during classroom practice". Some of the main components identified by Schulman (1986) also include knowledge of particular learning difficulties as well as learners' understanding of a specific topic.

Therefore, Van Driel et al. (1998, p. 675) suggest that "the more representations teachers have at their disposal and the better they recognise learning difficulties, the more effectively they can apply their PCK". Similarly, Grossman (1990) believed that pedagogical content knowledge includes knowledge and understanding of particular teaching strategies for certain topics as well as learners' misconceptions and understandings of such topics. Hence in his model of what constitutes teacher knowledge, pedagogical content knowledge is at the centre then general pedagogical knowledge and contextual knowledge.

Appleton (2003) in his study of primary teachers, who lacked content knowledge in science and science PCK, provided them with some hands- on activities to use in class in an attempt to develop their PCK. He further pointed out that even though experienced teachers might have well integrated subject matter but that does not guarantee PCK, particularly when teaching unfamiliar topics. Experienced teachers according to Appleton (2003) tend to draw on their general pedagogical practices. Of importance to note is that, studies above emphasise how difficult it is for teachers to know and understand learners' conceptions and problem areas when teaching a new or unfamiliar topic, and as they struggle to apply relevant or appropriate teaching strategies (Van Driel et al., 1998).

It appears that adequate content knowledge of a particular topic, knowledge of learners' problems pertaining to the topic and appropriate teaching strategies contribute towards the pedagogical content knowledge. Moreover, basic pedagogical knowledge forms a support base for the development of PCK.

2.7.2 Pedagogical Practices in Teaching Evolution

This study intends to explore teacher's conceptual and pedagogical understandings about concepts of NOS in their practice when teaching about evolution.

In the beginning of this chapter it has been highlighted that the curriculum requires science teachers to change their classroom practice so as to address specific outcomes such as understanding of scientific concepts including the nature of science, critical thinking, science as a process and product and so on. This means that science teachers are expected not only to have knowledge of concepts of NOS, they should also have knowledge of how to incorporate concepts of NOS into the science topics, such as, the theory of Evolution. In agreement, Van Dijk (2009) points out that in addition to adequate knowledge of the subject matter, teachers must be able to use this knowledge in their teaching through "analysing the value of different textbooks in relation to the specific topic and also be able to follow various ideas that students express" (Van Dijk, 2009, p. 260).

It is significant to note that even though science teachers may have the knowledge of NOS and subject matter itself; the huge challenge is how to teach these effectively. Osborne and Ratcliff (2004) suggested that in order to address NOS effectively, teachers must consider changing the way they teach. This means that the learning environment must allow for discussions and dialogues, the teacher should facilitate learning; the learning goals should focus more on developing critical thinking skills in addition to acquisition of knowledge and new activities to link content with scientific processes in science. A review of literature on science teachers' PCK shows that content knowledge is necessary for the development of PCK and that PCK develops during the actual teaching practice of teachers.

Shulman (1986) emphasises that teachers need a specific type of knowledge that will enable them to translate their pedagogical knowledge to their content knowledge. Although teachers may have an understanding of the core concepts of NOS and evolution, they need to develop strategies to incorporate their understanding to classroom instruction. Teachers must not only know how to teach but also what to teach and why (Shulman, 1986). As mentioned earlier in this study, the main aim of addressing NOS in science classrooms is to give learners an opportunity to think critically and discuss about NOS, explore what type of evidence can and cannot be used to support its claims.

Thus, science teachers need to translate an understanding of the science enterprise into appropriate classroom experiences and relevant teaching and learning strategies in order to enhance understanding of evolution as a scientific concept. Hence, in order to understand how teachers translate the goals of the science reform, it is important to explore their beliefs about NOS teaching and learning.

2.7.3 Teachers Beliefs about science teaching and learning

Several studies (Brickhouse, 1989, 1990; Laplante, 1997; Levitt, 2001) have shown an influence of teachers' beliefs about science on classrooms. In the study of three secondary teachers conducted by Brickhouse (1990), all three Life Sciences in this study teachers portrayed classroom practice that is congruent with their beliefs for example, one teacher who viewed theories as truths, taught learners about major scientific theories. Laplante (1997) believed that these studies are crucial in understanding what teachers teach and how they teach. According to Ambimbola (1983), how teachers teach and what they teach depend largely on what knowledge and beliefs a teacher has about NOS teaching and learning. Some studies (Brickhouse, 1989, 1990; Duschl & Wright, 1989) indicate that teachers' beliefs about science are in line with their pedagogical practices. However, Lederman (1992) argued that there are complicated factors that also affect the translation of teachers' beliefs into classroom practice:

> The importance of teachers' instructional intentions and students' perceptions of classroom tasks has been virtually ignored in research on the nature of science. It is not adequate to simply observe a teacher and draw inferences without also investigating the teachers' intentions and the reasons for instructional decisions. (p. 352)

In science education, the research on teachers' beliefs has been linked to the constructivist teaching (Tsai, 2002; Wallace & Kang, 2004).

2.8. Constructivism theory

During the apartheid era (prior to 1994) in South Africa, the curriculum was more content based and centred more on the positivist scientific world-view. As a result most science teachers taught in a manner that encouraged memorisation of scientific facts. With the change of government in 1994, changes were made in the education system which included implementation of a new curriculum that emphasised learner-centred teaching through constructivism. This implies that science teachers with traditional style of teaching and learning were expected to apply constructivist teaching strategies and practices in the classroom. This view is based on an assumption regarding teachers' nature of knowledge and their knowledge acquisition and its impact on classroom practices. In order to understand how teachers develop their understandings and practice of NOS, constructivism in this study serves as a meaningful lens through which teachers understandings and practice of NOS can be analysed.

As mentioned before, science teachers need to move from their existing beliefs and practices. Their own existing beliefs about science teaching and learning will influence how they interpret and implement new ideas in science classrooms. Generally, people construct their own understanding of the phenomenon according to their social being, location, prior experiences and their individual identities. Thus, with respect to constructivism, when talking about teachers' understandings, existing beliefs and practices of NOS, it is their constructed meanings regarding NOS that is being observed and explored.

Studies in science education have been influenced by a constructivist view and more recently, social and cognitive constructivism. Cognitive constructivism which is based on Piaget's theory of cognitive development proposes that humans construct their own understanding. Constructivism is a learning theory that emphasises identifying children's alternative conceptions, understanding of how children construct knowledge, understanding and conceptualising teaching and learning from a social perspective. Constructivism does not only focus on how learners learn, it considers ways of facilitating that learning, individually and also in groups (in a classroom). Cobern (1995) describes constructivism as an active process of making sense out of an experience which is much influenced by what one already knows.

Constructivist epistemology recognises the development of a social focus (social constructivism) which is crucial for pedagogical processes in teaching the nature of science. Vygotsky (1996) and other social constructivists argue that meaningful learning is not only about isolated cognitive learning, social and cultural factors must also be taken into account. Although knowledge is individually constructed, this knowledge is influenced by social and cultural environments as a result of individual's interaction with others within that community. For example, learning in school and in classrooms is informed by concepts learned at home, community and in school. Kuhn (1962) also believed that scientific knowledge is acquired through a construction based on previous knowledge that continually evolves and does not exist independent of human experiences. This study adopts more the social constructivism in understanding how the three teachers individually develop understandings and practice of NOS.

Constructivism as a theory has since led to the development of constructivist pedagogy that emphasises ways of facilitating how learners learn as individuals and as groups. Lorsbach and Tobin (1992) in their research indicated that teachers' beliefs (their personal epistemology) about how learners learn often assist them to think about and make sense of their practice. Teaching towards constructivism requires particular pedagogical approaches. According to Appleton and Asoko (1996), a teacher with a constructivist philosophy of learning is expected to reflect the following characteristics in the classroom:

- A prior awareness of the ideas which children bring to the learning situation and or attempt to elicit such ideas.
- Clearly defined conceptual goals for students and an understanding of how learners might progress towards these.
- Use of teaching strategies which involve challenge to, or development of, the initial ideas of the learners and ways of making new ideas accessible to them.
- Provision of opportunities for the learners to utilize new ideas in a range of contexts.
- Provision of a classroom atmosphere which encourages children to put forward and discuss ideas.

(Appleton & Asoko, 1996, p. 167)

Constructivism offered insight with regards to analysis of teachers' personal epistemologies so as to understand the role they play in science classrooms (Van Driel et al., 2001).

Recently constructivism has been closely associated with scientific inquiry by emphasising learners' ideas, questions and their understanding rather than the teacher's delivery of content. Learner's prior knowledge is taken into consideration and addressed during the introduction of scientific concepts. Teaching science using inquiry method is believed to promote learning of scientific concepts and how science works. Several inquiry based activities can be employed in science classrooms in an attempt to develop critical thinking skills as advocated by various science reforms (NCS, 2003; NRC, 1996):

> Student inquiry in the science classroom encompasses a range of activities. Some activities provide a basis for observation, data collection, reflection, and analysis of firsthand events and phenomena. Other activities encourage the critical analysis of secondary sources-including media, books, and journals in a library. (NRC, 1996, p. 33)

2.9 Conclusion

This chapter looked at the conceptual understandings of the nature of science and its characteristics with regard to teaching of Evolution in Life Sciences. The chapter highlights the importance and challenges of incorporating NOS in the classroom teaching and the role of science teachers' identity (epistemology, world-views, beliefs, and knowledge) in addressing aspects of NOS whilst teaching Evolution. The literature in this chapter revealed a need for teachers' understanding of the NOS concepts as well as the pedagogical content knowledge required to teach specific topics such as Evolution. Lastly, the chapter explored constructivist learning theory which is considered critical in realising the nature of this research and the research design.

The following chapter describes the research design and process. It also describes the context in which the study took place, how data was collected and what measures were taken to ensure an ethical and trustworthy data collection process.

Chapter 3

3.1 Introduction

In this chapter, I outline and describe the research design and methodology of the research. This qualitative case study explores how Life Sciences teachers' understanding of NOS influence their teaching of Evolution and it is located within the interpretive paradigm. The context in which the research took place and how the participants were selected is described in detail. Tools used in the research process included questionnaires, lesson observations, interviews, reflective journals and audio and video recordings. Each tool implemented in the research and its purpose is explained. Finally ethical considerations during the research and the limitations of the research design are discussed.

3.2 Context of the study

The research design was to engage in a study of how three Grade 12 Life Sciences teachers understanding of NOS influence their pedagogical practices of teaching Evolution. The study was carried out in the East Griqualand area commonly known as Kokstad. Three teachers that participated in the study are teaching in two different senior secondary schools around East Griqualand. Initially it was thought that these three teachers would ideally come from different schools, however, the criteria of selection, being accessibility of schools and interest and willingness to participate could only be satisfied by three teachers, two from the same school and one from different school. In order to gain access to the two schools, I made an appointment with the principals of these schools and explained my research to them. I then sought their permission to carry out my research through a permission form for principals and different consent form for teachers (Appendix B and C).

The first school, Excelsior High school[1], is a school that is administered under the KwaZulu-Natal provincial Department of Education. It is located in a small town of East Griqualand, commonly known as Kokstad and the school is found in a middle class to upmarket part of the town. The school is well resourced and according to their mission statement, it strives for excellence in all areas. The school engages in various programmes and one of these programmes is the environmental club which is led by the teacher participant in this study.

The second school, St Georges High School[2] is situated about 5 kilometres outside the town of East Griqualand. It is a small private school with very small class sizes of Grade 12. The school is very well resourced and also engages in various programmes including the environmental club.

3.3 The Research Style: Case Study as a methodology

The purpose of this study was to explore, how Life Sciences teachers' understandings of NOS influence their teaching of Evolution, (which is a characteristic of a qualitative research). A qualitative research design was selected to explore the research questions. Qualitative research is described as a "paradigm that allows the researcher to obtain an insider perspective on social action" where the emphasis is on describing and understanding rather than merely explaining social action (Babbie & Mouton, 2001, p. 270). This means that, a qualitative researcher sees concepts and constructs as words that can be analysed to provide deeper understanding of a particular situation (Denzin & Lincoln, 2000). Qualitative research according to Merriam (2009) focusses on understanding of "how people interpret their experiences; how they construct their worlds and what meaning they attribute to their experiences" (p. 5). Several authors such as Creswell (2003), Denzin and Lincoln (2000) and Leedy and Ormrod (2005) have outlined key characteristics of a qualitative research design.

[1] Excelsior High School – A pseudonym for the school at which Dianne teaches

[2] St Georges High School – A pseudonym for the school at which Anne and Reese teach

Taking from these authors, the main characteristics that make a qualitative research approach relevant to this study are;

- It focuses on a phenomenon occurring in natural setting and involves studying the phenomenon in all its complexity.
- It stresses the socially constructed nature of reality.
- It is interpretive in nature, aiming to develop themes from the data and make interpretations.
- It is concerned with participant's beliefs, meanings, thoughts and actions.
- It uses several methods of collecting data where participants are actively involved.
- Data is descriptive and in a form of words rather than numbers.

Qualitative research involves an interpretive naturalistic approach to the world, which means that a qualitative researcher attempts to understand the actions of participants in their natural setting and also understand their actions in terms of their own beliefs, history and context (Babbie & Mouton, 2001). Merriam (2009) agrees and further argues that interpretive research assumes that reality is socially constructed and that there are multiple realities or interpretations of a single phenomenon. Creswell (2007) links constructivism to interpretivism and explains:

> In this worldview, individuals seek understanding of the world they live in and work. They develop subjective meanings of their experiences….. These meanings are varied and multiple, leading the researcher to look for the complexity of views….Often these subjective meanings are negotiated socially and historically. In other words, they are not simply imprinted on individuals but are formed through interaction with others (hence social constructivism) and through historical and cultural norms that operate in individuals' lives (p. 20)

Merriam (2009) suggests a basic qualitative study as a most common form which aims to understand how people make sense of their experiences. In this type of study, data are collected through interviews, observations and documents and are analysed inductively to address the research question posed. There are several other research designs associated with qualitative research which share the same characteristics of a basic qualitative study, although each also has some added dimensions (see Figure 3.1).

Various research designs such as ethnography, phenomenology, critical qualitative research, grounded theory, qualitative case study and narrative analysis are closely associated with qualitative research and all share similar basic characteristics as illustrated by Merriam (2009):

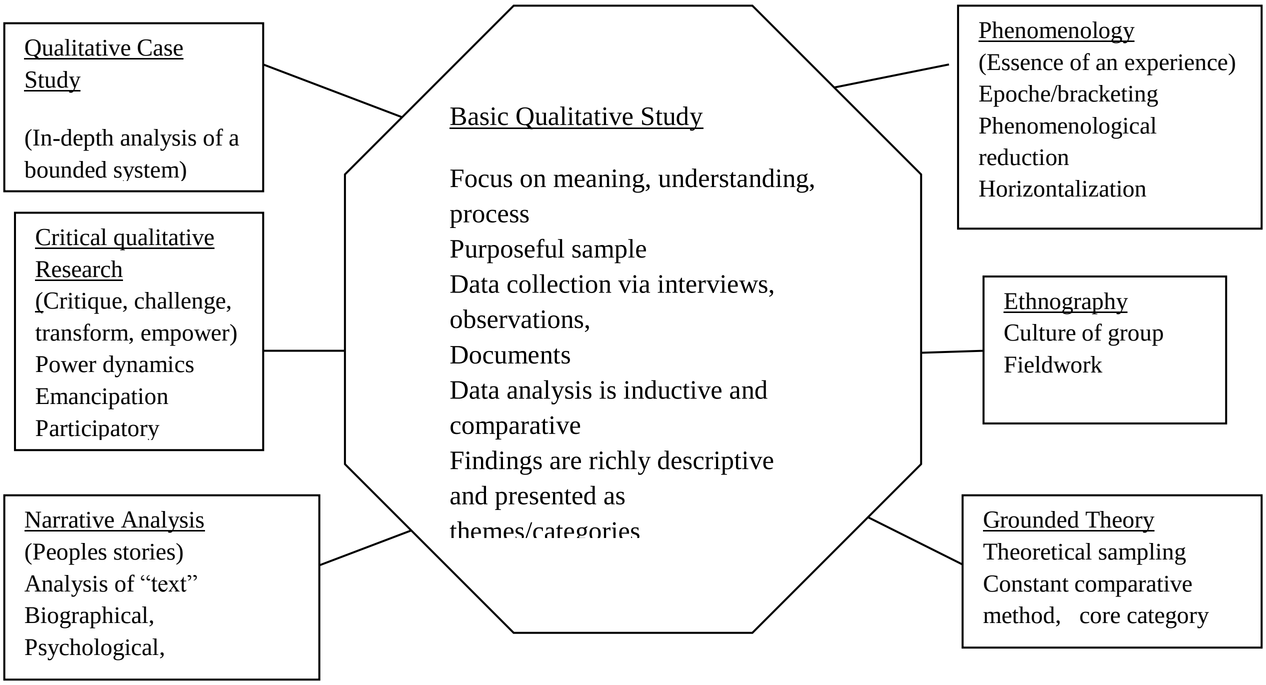

Figure 3.1 Types of Qualitative Research (Merriam, 2009, p. 38)

For this study, I have decided to use a case study which Creswell (1998) describes as an exploration or in-depth analysis of a "bounded system" over a period of time (p. 61). I chose to use a case study because case studies are used as a style by which insights into teacher's personal understandings and experiences can be used to help teachers relate theory to their practice. In most social research literature, case studies are often firmly located within the category of qualitative research although Yin (2003) opposes this pointing out that case studies can be based on any combination of quantitative and qualitative evidence. Qualitative case studies are known to be focussing on a particular phenomenon, having a rich 'thick' description of phenomenon and illuminate the reader's understanding of the phenomenon (Merriam, 2009).

Yin (1984, p. 23) defines a case study as "an empirical inquiry that investigates a contemporary phenomenon within its real life context using multiple sources of evidence". He further explains case studies as being concerned with how and why things happen. Similarly, Johnson and Christensen (2008), Patton (1987) and Merriam (1988) define a case study as a research that provides detailed account and analysis of one or more cases which aims to understand some particular problem or situation in great-depth. Stake (2005) states that a qualitative case study require a researcher to spend an extended amount of time in the natural setting , interacting face to face with all the different aspects and dynamics of the case, analysing and reviewing actions and descriptions of what is happening on site.

Yin (1984), categorises case studies in three different forms namely, 'explanatory', 'exploratory' and 'descriptive'. Exploratory case study is aimed at defining the questions of a particular case and is undertaken when a phenomenon needs to be understood where very little information regarding the research is not known (Creswell, 2007). In agreement, Babbie (1998) states that exploratory studies are appropriate for three purposes: to satisfy the researchers' curiosity and better understanding of the phenomenon, to explore feasibility of conducting a more intensive study and to develop appropriate methods to be used in subsequent studies. There seems to be very little research on how the understanding of NOS core concepts, particularly in teaching Evolution impacts on pedagogical practices of life science teachers. The best suitable research design for this study which aims to understand how life sciences teachers' understandings of the core concepts of NOS influence their teaching of Evolution is a qualitative, exploratory study in the interpretive paradigm.

In case study research, exploration and description of the case take place through "detailed, in-depth data collection methods, involving multiple sources of information that are rich in context" (Vos, Strydom, Fouche, & Delport, 2005, p. 272). Qualitative methods enable one to gain rich and detailed data as required by this study (Cohen et al., 2007). In order to produce relevant data required to answer the research questions, the researcher had to select participants purposively.

3.4 The Selection of Participants

Defining the number of people who will participate in the study often limit a research project, although there is no precise sample size (Patton, 2002). The sample size according to (Vos, Strydom, Fouche & Delport, 2005), depends on what you want to know, the aim of the study, what will be useful, what will have credibility and the nature of the population that is being studied. This is what Cohen, Manion and Morrison (2007, p. 104) refer to as the "fitness for the purpose". Although the sample size in this study is small, it can still have access to a diverse range of ideas and attitudes, appropriate for a purposive sample as each teacher is assumed to have his or her own identity, expertise and worldviews. Since the goal of the research was not to produce generalizable findings, there was no specific plan with regards to the sample size.

Cohen et al. (2007) identify and distinguish between two main types of sampling: probability (also known as random sample) and non-probability (also known as purposive sample). Probability sampling involves selecting at random a large representative sample of the broader population. Non-probability sampling, on the other hand, is selective as it involves targeting a particular group on the basis of their possession of a particular characteristic being sought and it is not representative of the wider population (Cohen et al., 2007). In choosing between these two main approaches, I was guided by the purpose of the study which is to learn about Life Sciences teachers' understandings of the core concepts of the NOS in relation to a specific theme of Biological Evolution. Purposive sampling allowed me to ensure 'fitness for the purpose' by choosing specific individuals who fulfilled the following selection criteria;

- Life Sciences teachers who are currently teaching Life Sciences in Grade 12 level and were interested and willing to participate in the research study (Johnson & Christensen, 2008). Grade 12 Life Sciences syllabus was chosen because it covers more aspects on Evolution which allowed teachers more time and content to put across to learners who are mature enough to express their ideas and or beliefs of the world around them.
- Life Sciences teachers who taught in schools located in the East Griqualand circuit due to considerations of time and accessibility.

Due to the nature of the research topic addressed in this study it was important that the teacher participants were interested willing to participate and had some expert-knowledge. Hence I selected three Grade 12 Life Sciences teachers based on my intuition with regard to their expert-knowledge. The selection of teachers was based on subjective criteria of researcher's knowledge of "expertise", interest and willingness to participate in the study, and close proximity of schools for accessibility and thus they were purposefully selected.

3.5 Data Collection Methods and Instruments

As mentioned earlier (see Figure 3.1), various sources of data such as interviews, observation and documentary analysis are closely associated with qualitative case study. However, case studies can also involve some quantitative instruments such as questionnaires as is the case in this study. Cohen et al. (2007), state that any data collection instruments may be used in qualitative studies, the important issue is that of 'fitness for purpose'. This by no means implies that any instrument can be used, but it is saying use what is appropriate so as to be able to address the research questions. Therefore to ensure that the research questions posed are eventually answered, it is important to use appropriate data collection methods and instruments to collect data that they were designed to collect. Hence to gain an overview of data collection process a Handbook by Jansen and Vithal (1997) was used in guiding the data collection plan used in this study. The data collection plan with justifications for the choice of method and instruments used in the study is represented in Table 3.1 below.

Table 3.1 Data Collection Plan

Questions	Data Collection Plan	Justification
Why is data being collected	To explore how Life Sciences teachers understanding of NOS influence their teaching of Evolution	Life Sciences teachers seem to have limited understanding of NOS. This inadequate understanding of NOS may have impact on what and how teachers teach about Evolution.
What is the research design?	Interviews and observation of classroom lessons	It will show how teachers address NOS in teaching Evolution and what informs their pedagogical practice.
Who will be the participants (sources of data)	Three Grade 12 Life Sciences teachers will complete questionnaires, be observed in class and pre-lesson interviews will be conducted.	The three participants will represent Grade 12 Life Sciences teachers in the East Griqualand circuit.
Where will the data be collected?	At the schools where Life Sciences teachers teach.	The teacher's natural setting is his or her classroom. Science classrooms are therefore sites where teachers are authentic in teaching and learning environment which makes the research valid.
How often will the data be collected?	One pre-lesson interview for each teacher and then six observations of classroom lessons for each teacher.	An interview explores the level of understanding about NOS. Number of observations of lessons determines richness of data and also allows for in-depth insight on the topic being investigated.
Data collection instruments to be used	Questionnaire, interview schedule and observation checklist	To probe Life Sciences teachers understanding of NOS. Explore the variety of pedagogical practices and strategies used in teaching Evolution. Also to probe why Life Sciences teachers teach the way they do.

3.5.1 *Questionnaire*

To ensure that the research questions posed are eventually answered, a qualitative, less structured, word based, open-ended questionnaire was used to collect data. This type of a questionnaire according to Cohen et al. (2007) is the most appropriate one since it can capture the specificity of the phenomenon. Also, since the study is exploratory and the possible answers are unknown, open-ended questions become very useful (Leedy & Ormord 2005).

In developing the questionnaire, there are basic principles that must be considered and these include information needed, format of the questionnaire, formulating questions and type of questions, data analysis and pilot- testing the questionnaire (Babbie & Mouton, 2001; Cohen et al., 2007). Although a questionnaire is usually associated with collection of questions, Babbie and Mouton (2001) argue that a questionnaire may contain statements especially if the researchers aim is determining the extent to which the respondent holds a particular perspective. It is in this light that the questionnaire also contained some statements. In addition to the statements, open ended type questions that are less structured in order to enable the respondents to write and explain their responses freely in their own terms were included. Neuman (2000, p. 241) highlights that open-ended question, "permit for adequate answers to complex questions, permit creativity, self-expression and richness of detail". Cohen et al. (2007, p. 330) claim that "open-ended questions can capture" authenticity, richness, depth of the response and honesty" all which are elements of the qualitative research. Moreover, given the researchers interest in ensuring that the participants' own meaning and understanding of NOS is portrayed and to avoid misinterpreting participants' responses, open-ended questions were most ideal in fulfilling this objective (Abd-El-Khalick, Bell, Lederman, & Schwartz, 2001).

As the first session of data collection, the three Life Sciences teachers participating in the study were given a View of Nature of Science (VNOS) standardised questionnaire, to verify and explore their level of understanding about NOS and science teaching particularly in Evolution. The administering of the VNOS questionnaire which comprised of seven of the ten items was necessary as base-line information required to confirm teachers' expert-knowledge. The first part of the constructed questionnaire consists of biographical data of teacher participants so as to gain some background information of who they are. This will assist in understanding the type of background training and experience that these Life Sciences have and how these influence what and how they teach Evolution in their classrooms. The second part of the questionnaire comprises of both open-ended questions and statements which attempt to inquire about teachers' views and understanding of the NOS. The purpose of the questionnaire (see Appendix D) was to collect data that serve to offer insight on Life Sciences teachers' views and understanding of teaching Evolution and NOS. As previously mentioned this data will assist in the answering of mostly the first and second research questions.

3.5.1.1 Piloting the questionnaire

Once the questionnaire is constructed, it is of paramount importance that pre-testing should be done before it is administered. According to Cohen, Manion and Morrison (2011), piloting a questionnaire increases the reliability, validity and practicability of the questionnaire.

The questionnaire was piloted with a group of Life Sciences teachers within the district but in a different circuit. As life sciences advisor, I meet teachers for various programmes such as teacher development, school based assessment etc. In one of such meetings, I asked for time after the programme, to explain my research study and the purpose thereof. I explained the importance of their participation for the success of the study and I further made it clear that the participation was voluntary and that they could withdraw at any time if they wished to do so. After getting their permission, I administered the questionnaire and then after the pilot study, seeing that there were no issues with the clarity of the questionnaire items, wording, ambiguities etc., I used the same questionnaire without any alterations.

3.5.2 Semi-structured Interviews

People in general, and science teachers in particular, over the years have developed a personal framework of beliefs, understandings and values with which they build meanings. Patton (2002) explains:

> We cannot observe how people have organised the world and the meanings they attach to what goes on in the world. We have to ask about those things. The purpose of interviewing then is to allow us to enter into the other person's perspective. (p. 340)

The interest in this framework and its real consequences for action is what has prompted me to probe using in depth interviews. As a researcher within an interpretive- constructivist perspective, understanding of the world "through first-hand experience, truthful reporting and quotations of actual conversation from insider's perspectives" (Tuli, 2010, p. 100) is critical. Hence, data collection instruments used should enable rich and detailed description of social phenomenon and allow participants to interact freely with the researcher (Merriam, 1998).

Interviews as data collection method work well in this study as the research questions are designed to explore participants' identities (epistemological framework) as science teachers with regards to their views, understandings, interpretations, experiences and interactions as meaningful entities of their social reality. The instrument or interview schedule (Appendix E) used for this purpose attempted to collect data that would answer mostly the third and fourth research questions. According to Mason (2002), interpretations from an interview involve construction and reconstruction of facts or knowledge as the interview unfolds. Therefore, interviews are very critical tools for data collection within a social constructivist framework which frames this study. As stated by Vos et al. (2005), both the researcher and the participant in an interview process are involved in actively constructing meaning.

Kvale (1996, p. 1) describe qualitative interviews as "attempts to understand the world from participant's point of view, to unfold meaning of people's experiences and to uncover their lived world prior to scientific explanations".

He further suggests key characteristics that a qualitative research interview should do and the ones relevant to this study include (1) engage, understand and interpret the key features of the world as perceived by the participants, (2) Focus on specific ideas and themes, and (3) use natural language to gather and understand qualitative knowledge. Interviews that may be used specifically as research tools can be classified in many ways. Cohen et al. (2007) and various other authors identify several types of interviews such as structured, unstructured, non-directive, focussed, semi-structured, standardised, and group in interviews. Kvale (1996) classify all interviews on the basis of the degree of structure, for example some interviews are well- organised and follow a particular sequence of questioning whereas others are open and have greater flexibility and freedom.

In order to have openness and great flexibility from constructivist point of view, unstructured interviews would have been ideal. However, being a novice, interviewer, I opted for semi-structured interviews because they allow for a guide or an interview schedule to follow with pre-determined questions but at the same time has some degree of flexibility.

Yin (2003) refers to this type of interviewing as a guided conversation rather than a well-structured interview. According to Plooy (2001) semi-structured interviews allow the interviewer to deviate and ask follow-up or probing questions based on the respondent's replies. Follow-up questions are useful to clarify the response given by the respondent or to obtain explanation or to elicit examples.

Each teacher participant was interviewed once in a pre-lesson interview and a tape recorder was used to record teacher responses to questions posed. All teacher participants were asked the same questions and transcripts of interviews were given to respective teachers for proof reading to ensure accuracy. The pre-lesson interviews for the three teacher participants took place on the 1st of March 2011, 30th and 31st of May 2011. The purpose of the pre-lesson interviews (see Appendix E) in this study was to probe Life Sciences teachers understandings of NOS in teaching Evolution and why they understand NOS and Evolution the way they do. In order to try and understand such a framework, interviews become necessary as we cannot observe how people interpret the world around them. Open- ended questions are a great way of encouraging participants to express their views and understandings in their own words. Also, the individual interviews were used to substantiate and explore further the researcher's interpretations of participant's responses as will be presented in Chapter 4.

3.5.3 Observations

Observation as a research process is considered by Cohen et al. (2007, p. 396) to be a very distinctive way of gathering "live data from naturally occurring social settings". According to Leedy and Ormrod (2005), observations in qualitative research are usually unstructured and 'free flowing', however, as a novice researcher, I was not confident to do completely unstructured observation, so I opted for semi- structured observation. The semi-structured observation had an advantage of enabling me to look for most important things but at the same time to note and record the unexpected themes that may arise.

As part of data collection process, all three teachers were observed teaching lessons in Evolution, a theme in Life Science that lends itself to developing deeper conceptions of NOS. Originally it was anticipated that there will be six observations of lessons, but due to the start of mid –year examinations in one of the schools, only four lessons were observed.

Lesson observations for Dianne took place from the 8th of March 2011 to the 16th of March 2011(6 observations). Anne's classroom observations took place on the 31st of May 2011, 1st, 3rd and the 6th of June 2011 (4 observations). Lesson observations for Reese took place on the 2nd, 3rd, 6th and 7th of June 2011 (4 observations). Each lesson was video recorded and this required getting consent from parents of learners through the school principals.

The instrument or observation checklist (Appendix F) used was adapted from a study by (Abd-El-Khalick, Bell, & Lederman, 2001) of pre-service science teachers" knowledge and classroom practice of NOS". The observation checklist was chosen because it allows the researcher to study the behaviour or attitude as it happens. The checklist comprised of core concepts of NOS which were used as descriptors during the observation of lessons. For example, each time a teacher used a particular aspect of NOS to explain, describe and support a certain concept or phenomenon in Evolution, I recorded it under the relevant NOS descriptor by using a tick(✓). However if the teacher failed to address the relevant concepts of NOS, during the lesson, a cross (X) was recorded under all the descriptors that were not mentioned. The lessons were then analysed according to the evidence of the core concepts of NOS used during teaching. This analysis served to identify Life Sciences teacher's conceptions of NOS and in what way/s they address these conceptions when teaching Evolution. This instrument therefore attempted to collect data that would answer the second research question.

3.6 Data Analysis Methods

Data from the questionnaires, semi-structured interviews and classroom observations was used to answer the four research questions posed. The conceptual framework regarding the core concepts of NOS under the theme of teachers understandings of core concepts of NOS outlined within chapter two was used to gain deeper insight into the three Life Sciences teachers. These core concepts of NOS derived from the VNOS, a standardized questionnaire, were used to analyse teachers' responses, from questionnaires, observations and interviews and then identified seven categories of NOS and how teachers addressed these categories in teaching the Theory of Evolution. In an attempt to explain the Life Sciences teachers understandings of NOS, I used the terms ‘informed’ if there was a good match between teachers knowledge and the category identified, that is a strong evidence based relationship, ‘mixed’ if some aspects within the NOS category were understood, and some were confused, then ‘naïve’ if there was incorrect understanding or misconception about an NOS concept. Furthermore, classroom observations, behaviour and interactions, as well as what was presented to the learners was analysed according to their relevance to the concepts of NOS.

The core concepts of NOS communicated during the interviews and observations were also used to identify and explore attributes of NOS in teacher’s classroom practice, teachers’ beliefs, experiences and values were also identified.

In addition, characteristics of features of constructivist teaching advocated by Appleton and Asoko (1996) were also used to analyse the epistemological frameworks that inform Life Sciences pedagogical practices. Teacher responses from interviews were analysed using the features of constructivist teaching to explore Life Sciences teachers’ epistemological beliefs.

In my data analysis I used assertions which are statements derived from participant teachers responses. The assertions were inductively synthesized from the emerging data. These were discussed with my supervisor. The assertions provide a clear statement of the findings of the study.

3.7 Research Rigour

Rigour of research and trustworthiness are communicated and demonstrated by means of reliability and validity (Cohen et al, 2007). The data collection instruments used in this study are fit for the purpose to ensure that the data collected is trustworthy. Also the study used open-ended questions in the both the questionnaire and in interviews in order to probe for in-depth data of teachers understandings and practices. To ensure that the most accurate representations of teachers’ realities are expressed, triangulation of data collection methods such as questionnaires, interviews and observations was employed. Secondly, teacher participants were offered full access to all transcripts so as to review them for accuracy. Also in order to gain rich data, a small sample that was appropriate and knowledgeable was used in the study.

Given my position as a Life Sciences advisor in the district, I acknowledge that my biases, values and personal experiences may influence the research process and therefore warrant identification in a study (Creswell, 2003). My perspectives on religious beliefs and evolution have roots grounded in growing up in a Christian home. Since the study of Evolution was never part of basic education curriculum before the post-apartheid era, I was not exposed to Evolution. It was only at the university where I was taught about biological Evolution and I was not comfortable with some aspects of it. Later on as a teacher I came to accept Evolution through reading books on Evolution and Creationism. Like many naturalistic research, this study aims to represent phenomena from participants' point of view (Merriam, 1998). However, my personal experiences and changed perspectives on Evolution played an important role in designing the study and interpreting the data that represented teacher participants' experiences.

3.8 Ethical Considerations

3.8.1 Ethical issues involved and Participants access

Ethics is defined by Cohen et al. (2007) as "a matter of principled sensitivity to the rights of others, and that, while truth is good, respect for human dignity is better" (p. 58). This research study involved teacher observations of their teaching in the classroom and as such I obtained ethical clearance from the University of KwaZulu-Natal. I also obtained permission to conduct the research in the one of the schools from the Department of Education of KwaZulu-Natal. The principals of each school signed permission letters (Appendix B). The three Life Sciences teachers also signed informed consent letters (Appendix C) before the start of the research process and data collection. Informed consent refers to a decision made to participate in a particular activity after full information regarding the process, which may influence the decision itself, is given to the deciding participant (Cohen et al., 2007). Participants were informed prior and during the data collection period of their rights to withdraw certain information should they feel uncomfortable or even withdraw from the entire study if they wish to do so. Teacher participants in the study were also ensured full anonymity. The names used in this study, Dianne, Anne and Reese are pseudonyms.

3.8.2 Confidentiality

All participants were informed and assured of their right to confidentiality and anonymity and about their voluntary participation, meaning that they could withdraw from the study at any time. They would have right to privacy and were assured that their identity would be protected by using pseudonyms. I made sure they understood that any information they provided would be treated with utmost confidentiality and respect. Furthermore, to encourage honesty and openness, I ensured participants that the information they would give would only be used in this study and not for other purposes.

3.9 Limitations of the study

This research study is clearly limited in terms of the number of participants and due to the small number, the findings may not be generalised to the Life Sciences teachers in South Africa. In light of the diversity in terms of teaching experience which ranged from 20 to 43 years that was obtained as a result of sampling process, these teachers might not be representative of other Life Sciences teachers in the country. The variety of personal values, experiences and background that the teacher participants naturally brought to the study provided a rich understanding of each individual teacher and a holistic picture of all the participants.

3.10 Conclusion

This chapter focused on the research design of the study. Firstly the contexts in which the data was generated and how these three teachers within their contexts were accessed and elaborated on. I discussed and explained the research approach of the study, data collection techniques and analysis and the rationale behind my choice. I also explained the sampling procedures and indicated how I selected my participants. Ethical considerations regarding the access of the teacher-participants were described. The following chapter analyses the three teacher-participants' understandings and practice of core concepts of NOS. This analysis highlights the teachers understanding of the core concepts of NOS as well as the beliefs, feelings, values and considerations that these three teachers have regarding the teaching of Evolution, a theme in Life Sciences.

CHAPTER 4

4.1 Introduction

The purpose of this chapter is to explore the data generated and present the findings of this study. Within this chapter I present evidence of the assertions made in trying to answer the four research questions cited below.

In this study, several data collection namely; the questionnaire, semi-structured interviews and observations were used to gather data from the three participants. Data collection served to establish how the three participants understood and practiced NOS when teaching Evolution. An analytic inductive approach was used in the study in order to develop some themes or categories and a set of emergent themes was generated from participants' responses. This chapter is organised into four sections. The first section (section 4.2) looks at the three participants and their academic backgrounds; the second section (4.3) addresses teachers' understandings of the NOS. In this regard four assertions were identified (section 4.3.1- 4.3.4) and examine each participant's data using all the instruments.

4.2 An introduction to the three participants

This brief description of the three teachers called by pseudonyms serves to provide insight into each teacher's academic and teaching background. Dianne teaches in the so called former 'model C' school that is currently under the administration of the KwaZulu-Natal Department of Education.

The school offers grades 8 to 12, with learners from various race groups (e.g. Africans, Indians, Coloureds and Whites). Few of the learners have parents who are business people, most parents are professionals, others-semi-professional and the rest of the parents are of the working class (assistant workers) where they are employed. The average learner numbers in each grade 12 class is about forty-five and the teacher has to teach in two languages (English and Afrikaans) in one of the classes, since some learners are English medium and very few are Afrikaans medium.

Dianne teaches all her classes in the biology laboratory which she uses both for teaching and conducting practical work. When you enter Dianne's class you can easily tell that it is a

Biology/Life sciences class as it has a lot of visuals (biology charts) covering the three walls, and in the side tables there are various specimens of bones, plant material and models showings various human organs. Dianne is a Christian with an Anglican upbringing but presently she is a Methodist. She has been teaching biology and now Life Sciences for 31 years, and twenty of those years she has been teaching in this school. She is currently teaching in Grades 10 - 12. In her studies to become a teacher, she majored in Botany, Zoology and Plant pathology.

The second teacher is Reese who teaches in a private school which offers Grade R to Grade 12. The population of learners in this school consists also of mixed racial groups and the number of learners in each class is very minimal, for example, the largest grade 12 class has a maximum of ten learners. Reese is a Christian (Non denomination) who has been teaching biology and now Life Sciences and mathematics for 20 years, in the same school. She teaches mathematics in grades 9 and Life Sciences in grades 10 - 12. In her studies to become a teacher, she has done Bachelor of Science (BSc) and Higher Diploma in Education (HDE) and her majors were Botany and Zoology. Reese uses a normal classroom to teach her learners and it is not easy to tell what subjects are taught in the class because of the variety of charts in the walls.

The third teacher is Anne who also teaches in the same school as Reese. Anne is a Christian (Anglican) and has been teaching general science/ natural science, biology and now Life Science for 43 years. She has taught grades 7 and 9, and presently she teaches Life Sciences in grades 10 – 12. She studied BSc and her major subjects were Zoology, Chemistry and Biochemistry. Anne uses the biology laboratory as her classroom and it is very evident that the class is a life science class because of the biology visuals on the walls, models of various parts of human organs, live specimens of certain plants and animals, displayed biology projects that have been done by learners.

The data analysis as previously mentioned is divided into four main themes as indicated in Figure 4.1 below:

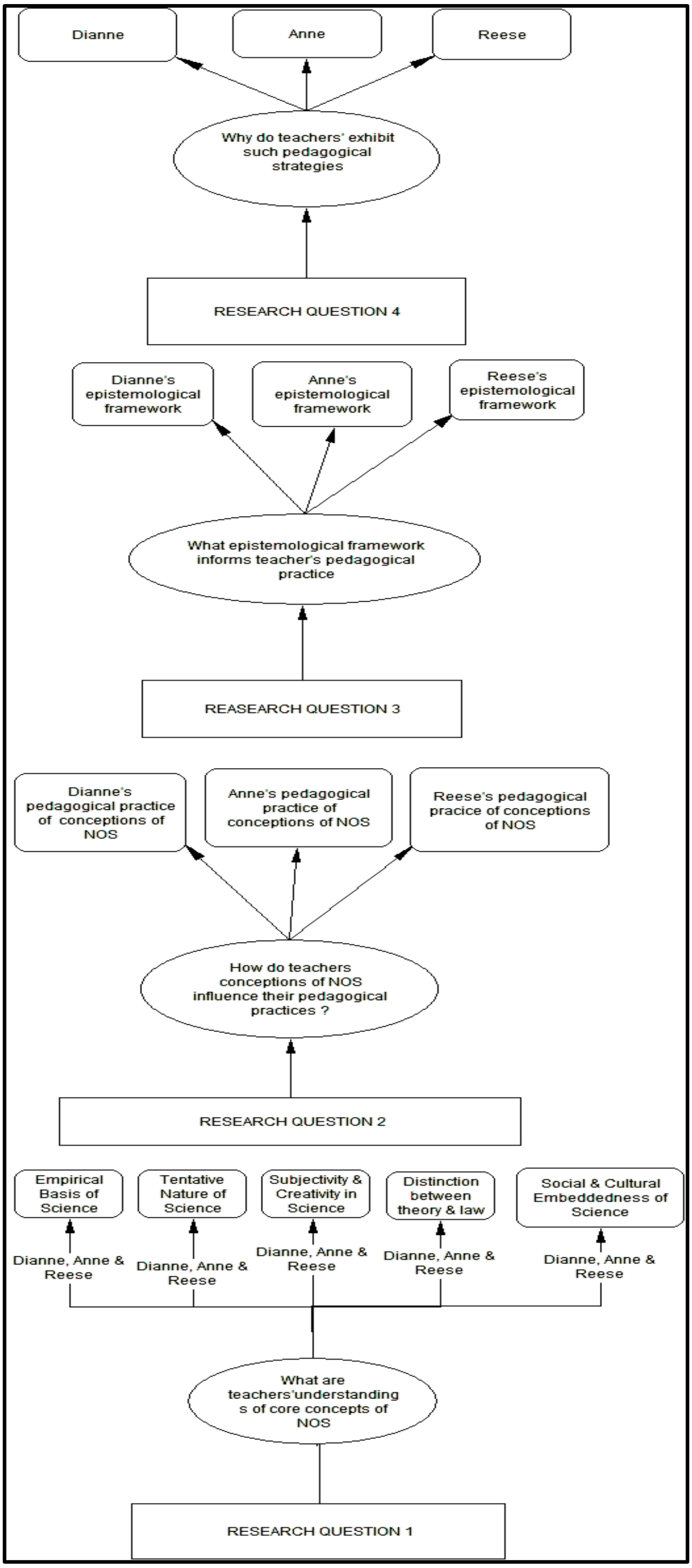

Figure 4.1 An overview of data analysis

The first research question explores the three Life Sciences teachers' understandings of the core concepts of NOS. This research question was necessary as base-line information required to confirm teachers' expert-knowledge. A VNOS standardised questionnaire was used identify and evaluate the responses from the participants with regard to the core concepts of NOS. These core concepts of NOS were used to analyse teachers' responses, from questionnaires, observations and interviews and then identified seven categories of NOS and how teachers addressed these categories in teaching the Theory of Evolution (as shown in Figure 4.1). The findings of the first question relate to the second question which addresses teacher participant's classroom practice of the NOS core concepts. The second assertion is then made in this regard followed by presentation of each teacher participant pedagogical practices in relation to core concepts of NOS. The third research question link teachers' pedagogical practice to their epistemological framework. Each teacher participant's epistemological framework with regard to the choice of pedagogical strategies is presented. Lastly a fourth assertion which relates to the reasons why the three teachers reflect such epistemological framework is made. Then each teacher participant beliefs about science teaching and learning and possible reasons for their epistemologies is presented.

4.3 Teachers' Understandings of the Nature of Science

The data was collected from the questionnaires, semi-structured interviews and classroom observations. In chapter 3 it was stated that the questionnaire was used to explore teachers' understanding of the core concepts of NOS. With regards to the questionnaire, in particular, the teachers were asked to respond to the VNOS standardised open-ended questions adapted from Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) (see Appendix I). A VNOS-C (see Table 4.1 below) form was used in identifying and evaluating the three teacher participants' responses.

Table 4. 1

NOS core concepts and descriptions that serve as a basis for evaluation of VNOS responses

Core Concepts of NOS	Description
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 basis	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.
Creativity	Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world.
Social/cultural embeddedness	Science is a human endeavor and, as such, is influenced by the society and culture in which it is practiced. The values and expectations of the culture determine what and how science is conducted, interpreted, and accepted.
Observations and inferences	Science is based on both observations and inferences. 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.
Theories and laws	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 Lederman, Schwartz, Abd-El-Khalick, & Bell, (2002).

4.3.1 Assertion 1: Teachers have varying understanding of the concepts of NOS

4.3.1.1 Conceptions of the core concepts of NOS

This assertion is an attempt to answer the first research question as mentioned above and the following themes were identified when analysing teachers' responses. An in depth analysis of teachers' responses to the open-ended questionnaire, semi-structured interviews and classroom observations indicated that the teachers' views of the NOS were, in general more or less consistent with those identified in the current reforms in science education (NRC, 1996 ; NCS, DoE, 2003). The three teachers displayed informed views in some core concepts of NOS, mixed views within some and naïve or inadequate views in others. The conclusions of varying understandings of the three teachers' core concepts of NOS are explained in further details and substantiated with quotations in the subsections that follow.

The empirical basis of Science

Science generally relies on empirical data that has been generated through the observations of the natural world. Several questions regarding what science is were asked in order to assess teachers' views regarding science as a discipline, the role of science in providing explanations for the natural world, the significance of empirical evidence in the development of scientific knowledge and also the role of investigative processes in science. All three teachers appear to have similar views of what science is and how science works. This is evident in the following representative statements:

"*Anthropologists may use cave art, dance stories passed by word of mouth, religious practices etc., to gain insight into human past practices. However science is mostly about evidence whereas religion tends to be faith based and more subjective than objective"* (Dianne, Questionnaire).

"….science involves more than just careful and numerous observations, but rather a combination of observations and inferences…" (Dianne, Lesson Observation).

"Science tries to explain the world around us. It asks how and why certain phenomena occur. Science knowledge is never absolute and is always subject to further testing/ questioning. Religion, for example, is a set of given tenets which are accepted and believed with faith and are held to be absolutely true" (Anne, Questionnaire).

"I try to make it clear the difference between a belief system which is not based on scientific facts at all … I try to tell the pupils what I honestly believe that you look at the facts, you evaluate them and you come to a conclusion. That conclusion is only based on the facts that you have at hand at that time…" (Anne, Interviews).

However Reese's views about NOS with regard to how science works are far narrower and inadequate as shown by comments she made. She believes that science is study of 'proven facts' and uses only an objective process, such as 'scientific method' to discover and develop scientific knowledge. This is evident in her responses which show an understanding that science is based on scientists' observations of the natural phenomenon.
"Science is about study of facts that have been proven through scientific method and working within limits, what is proven. Art creativity and interpretation with absolutely no boundary at all and currently the more these boundaries are challenged the more popular or esteemed it appears to be. Religion is a set of belief and values that one would choose to live according to" (Reese, Questionnaire).

For more insight on the teachers' views of how science knowledge develops, the three teachers were further asked whether the development of all scientific knowledge require experiments. Once more Reese's views are very clear as she pointed out that "*Yes - to prove theories/ and verify facts as irrefutable*", (Reese, Questionnaire). Dianne on the other hand portrays to some extent a different view: *"No, for example, Palaeontology, collection of fossils and other data from other scientists needs probably more discussions and debate than actual experimentation…"* (Dianne, Questionnaire).

Anne appears to share similar ideas with both of them as she believed that science does to certain degree need experimentation as it is a hands and minds on field. However she also acknowledged that experimentation might not always be applicable in all scientific endeavours. Anne displays this view in the following quote:
"Generally yes, science is a practical subject- in fact often a series of experiments needs to be performed until an acceptable theory results. But mathematical models as well as other models are sometimes useful in elucidating problems. On some occasions, experimentation is not possible and theories are drawn up on "circumstantial" (inferential) evidence which can be extrapolated /interpolated to support a given idea, for example, theory of evolution…" (Anne, Questionnaire).

The tentativeness of Science

Another aspect of NOS that the teachers articulated clearly was the tentativeness of scientific knowledge including, facts, hypotheses, theories and laws. They closely linked the tentative nature of science with its empirical basis, collection of new data, new discoveries, experimentation and technological advances. These were some of the main reasons that teachers believed contribute to the tentativeness of scientific constructs. In order to assess teachers' understanding of the tentative nature of scientific theories and the reasons why science is tentative, they were asked to express their views on whether scientific theories change or not. The following are representative of the teachers' comments:

"Yes, theories can change because new evidence, collected by many scientists all over the world may change the way people view any situation or set of circumstances. Some theories remain valid for a long time and eventually may even become accepted as fact, truth. For example, Mendel's Laws of genetics have remained valid for many years even though new microscopic evidence was discovered long after the laws were formulated" (Dianne, Questionnaire).

"…this knowledge changes constantly, especially with the development of new technology. As new information comes to light…. usually as technology advances e.g. structure of cells revolutionised by electron microscope, but often by accident (when investigating a totally different idea),…. theories will change. Theories are dynamic or organic and are essential progression in our quest for knowledge" (Anne, Questionnaire).

"Yes- they change with new discoveries. "Old theories need to be adjusted as knowledge accumulates" (Reese, Questionnaire).

Subjectivity, inferences and creativity in Science

Science is greatly influenced by the currently accepted scientific theories and laws. This implies the subjective nature of science that allows it to progress and remains consistent. Subjectivity also contributes to change of science when previous evidence is re-looked from the perspective of newly discovered evidence or knowledge. In addition, personal subjectivity with regards to personal values and prior experience is also unavoidable as it influences how scientists conduct their work. To assess teachers' understanding of what influences data interpretation including personal preferences and bias (personal subjectivity) to various theoretical commitments, they were asked if it was possible for various scientists to have access to and use the same set of data but come to different conclusions. Anne and Dianne clearly recognised that subjectivity and creativity cannot be separated from the development of scientific knowledge and this can be deduced from the following comments:

"After 65 million years, is it possible to have all the evidence needed to draw a definite conclusion? There are probably gaps in the evidence used by both groups. Creativity and imagination could have been used by the two groups in different ways to fill the gaps as it were" (Dianne, Questionnaire).

Dianne also communicated how scientists sometimes have to make inferences that are not based on specific evidence and she explained this using an example of a definition of a species:

"…and I would like you to start off with these two words here; species and population because scientists are beginning to change their minds about these things, but what have we always thought of as a species? ……so scientists are beginning to question their definition of a species now… perhaps we shouldn't be so hard and fast and rigid about our definition of a species….we often use to say that unless the mating produces a viable offspring it's not part of a species, but now they are beginning to see some situations sometimes where you can get like sub-species and staff...now do you see that our definition of species can be blurred at times.." (Dianne, Lesson Observation)

"…. we are also scientists and therefore we follow the scientific method, we evaluate what facts we have and we come to a decision, but different scientists come to different decisions using the same information… when a scientist pronounce on it (evidence) even then it is their own opinion and other scientists may well disagree and that scientist at a later stage, having access to more knowledge, perhaps through better technology will change his own ideas" (Anne, Interviews).

Contrary to Anne and Dianne's aforementioned understandings about the role of subjectivity and creativity in developing scientific knowledge, Reese argued that if the data (evidence) is the same and accurate, any differences in conclusions make such conclusions unreliable. This was evident in the following example that she cited:

"..The whole sort of strata thing with the fossil evidence… I don't want to say that it's the only flawed evidence, but I mean there are also other fossils that have been … that cross over all those strata ……., I don't think it's complete evidence of evolution…….. I think also with all that carbon dating, there is so much... variation within the sort of answers with carbon dating, but we are using it as fact in the textbooks, and in fact there is a huge variation,.... if you are sending one set of data of fossil or evidence from one site, apparently they can get ....you know… variation of millions of years on a single fossil to different places, so I don't know, I just don't think it's reliable if there is so much variation within the answers from the data that they are using" (Reese, Interviews).

When specifically asked whether scientists use their creativity and imagination during their investigations, Anne and Dianne emphasised the role of creativity, imagination and subjectivity in scientific investigations especially when it comes to planning, guiding data collection and formulating conclusions. They further gave examples in order to clarify their understanding:

"Yes*, all stages of planning may need creativity and imagination, but maybe more so after data collection, for example, several pictures, drawings etc. of the Dodo have been found, but these gave conflicting ideas about the appearance of the animal. All scientists have is the skeletons, so skin, feathers etc. have to be creatively imagined, using comparisons with birds of today and the environment of the extinct Dodo"* (Dianne, Questionnaire).

"I think with the new ideas of nature of science, like imagination and eh.., sort of creativity introduced which were not introduced before, I think that also has given us a tool, because if one looks at the (cinema) films of dinosaurs….., you have to explain to pupils that we cannot know what the sounds of those animals were like, we cannot know what the outside surfaces were necessarily because one can seldom find soft tissues fossilised, so in order to create some sort of an idea of what the past was like we have to use concrete evidence from the bones, size of them, the weight of them and compare them with modern day things to try and get some concept of what things are like so I definitely think that there is a place for creativity and imagination, but certainly it shouldn't take centre stage. I think we still have to have evidence to back it up" (Dianne, Interviews).

"Very often investigations do involve a lot of "fact-slogging" or "number crunching" but often it requires insight (imagination) to carry on and find new applications or even to carry

out the investigation in the first place. Analysis needs to be followed by synthesis. Examples: Rutherford's scattering experiment was pointless unless he had some idea that atom was not solid. Mendel's experiments with peas- he could not have got the results he did without thinking carefully about how and why he was doing them" (Anne, Questionnaire).

Although all participants agreed on the role of creativity and imagination, there was no consensus when it came to which stages of scientific investigation used creativity and imagination. Dianne thought that *"all stages of planning may need creativity and imagination, but maybe more so after data collection..."* Anne on the other hand, thought that *"investigations… require insight (imagination) to carry on and find new applications or even to carry out the investigation in the first place. Analysis needs to be followed by synthesis".*

For Reese, the emphasis was more on the fact that scientific conclusions must be based only on data collected even though she acknowledged that creativity is sometimes an issue. This is illustrated in the following data from the questionnaire.

"Yes, creativity is an issue, maybe not entirely the fault of the scientists, but in the interpretation of their conclusions e.g. "hominids with whites in their eyes. There is no evidence of this, but the scientist interpretation of these hominids definitely makes them appear considerably more "human-like" because of this. Science should have conclusions only based on data" (Reese, Questionnaire).

Distinction between scientific theory and law

Science places high value on theories that have a largest explanatory power. The greater the number of various observations that can be explained by a theory, the more likely it is to be accepted by the scientific community. No scientific conclusions are accepted without careful analysis of evidence supporting and or refuting the claim. When asked to define the term "theory", the teachers all showed fairly consistent and well-articulated views on of scientific theories.
"A collection of ideas to explain a certain phenomenon or place or process" (Dianne, Questionnaire).
"Theories are the best possible explanations with the knowledge we have to hand" (Anne, Questionnaire).

"Ideas to explain currently with the knowledge we have accessible, certain phenomena in our world" (Reese, Questionnaire).

As a follow up to the clear articulation of their understanding of a theory, the three teachers were asked why scientific theories have to be learnt. They commented as follows:

"Some theories remain valid for a long time and eventually may even become accepted as fact, truth, for example, Mendel's Laws of genetics have remained valid for many years even though new microscopic evidence discovered long after the laws were formulated" (Dianne, Questionnaire).
"Theories are dynamic or organic and are essential progression in our quest for knowledge" (Anne, Questionnaire).

In an effort to probe their views on the relationship between a hypothesis and a theory, the teachers were further asked to agree or disagree with statement that 'scientific theory is a hypothesis that has not yet been proven' and a specific reference was made to an evolutionary theory. From the teachers' responses, their understanding of a scientific theory is clear, but when it comes to describing the development of and relationship between scientific theories, hypothesis and laws, they had varying views. Comments typical to the following were made:

"I do believe in evolutionary theory as there is so much evidence to support it, but I also believe in the creator" (Dianne, Questionnaire). *"Not true. Only once a hypothesis has been tested can a theory be postulated (a theory is higher in the hierarchy)"* (Anne, Questionnaire).

*"I believe that there really is insufficient evidence to prove macro-evolution, micro-evolution …I do not have a problem with at all" (*Reese, Questionnaire).

Dianne seemed to believe that evolutionary theory can be classified as a theory and not a hypothesis because of the amount of evidence that supports the theory and that with the accumulation of more evidence; it might eventually even be accepted as fact. On the hand, Reese argued that there is not much evidence supporting the theory to make it valid as some facts have not been proven, for example macro- evolution.
Anne's point of view was based on the existence of a hierarchical relationship, wherein according to her, once a hypothesis has been tested, then it becomes a theory.
The following comment portrays Reese's view of the theory:

"I teach macro-evolution and say to them that if there was enough evidence then possibly it would be there, but I don't see the evidence for it, so it's still a theory" (Reese, Interviews).

Social and cultural embeddedness of Science

Science is not value-free. Dianne and Anne recognised that various cultures and belief systems could affect the use of science and also the way in which scientific investigations are conducted. Reese, however, believed that science should be based only on observed and proven empirical evidence.

"In medicine, for example, social factors like poverty, malnutrition etc. may play a big role in the spread and severity of the disease being studied but previous scientific knowledge about the pathogen and its life cycle is essential. Logic thought processes are necessary to draw conclusions as how one best should treat the disease" (Dianne, Questionnaire).

"Jenner could not have done his vaccination against small pox without previous knowledge and the social climate of his day. Charles Darwin would not have looked at animals on Galapagos Islands in the way he did unless he had been influenced by his grandfather Erasmus Darwin. More generally- the wheel was a major influence in the development of culture and science in the "old world" while in the "new world" it never got beyond the status of a toy. In societies where culture and religious rituals dominate, critical and inventive thought cannot flourish. (Anne, Questionnaire).

4.3.1.2 Summary of the teachers' conceptions of NOS

In Table 4.2, I have presented summary of findings which shows that two out of the three teachers of this study expressed clearly informed views on some of the concepts of NOS. Dianne and Anne explicitly articulated informed views of empirical, tentative nature of scientific knowledge, the role of subjectivity, inference and creativity in science and social embeddedness of the scientific knowledge. Furthermore, they both believed that subjectivity, inference and creativity are unavoidable in scientific investigations. To this regard, they pointed out that subjectivity, including scientist background, environment, experience and beliefs play a huge role in the planning of investigation, interpretation of data, drawing inferences and formulating conclusions. Reese on the other hand portrayed mixed views and inadequate understanding regarding some concepts of NOS. She clearly articulated informed views of tentativeness and empirical nature of science, and she showed naïve views in subjectivity, creativity and inference. All three teacher participants portrayed mixed views of the relationship between theories and laws. Although all of them were able to define the two science constructs; theories and laws, they were less successful in articulating the distinction. They all expressed in one way or another a hierarchical view between these constructs in which laws hold a higher status in the hierarchy than a theory based on the availability and amount of evidence.

Table 4.2

Summary of the three participants' conceptions of NOS

Core concepts of NOS	Dianne	Anne	Reese
Tentativeness: Science is subject to change with new observations and with the reinterpretations of existing observations.	✓	✓	✓
Empirical basis: Scientific knowledge is based on and/or derived from observations of the natural world.	✓	✓	Mixed
Subjectivity: Science is influenced and driven by the presently accepted scientific theories and laws.	✓	✓	X
Creativity: Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world.	✓	✓	X
Social/cultural embeddedness: Science is a human endeavor and, as such, is influenced by the society and culture in which it is practiced.	✓	✓	X
Observations and inferences: Science is based on both observations and inferences. Observations are gathered through human senses or extensions of those senses. Inferences are interpretations of those observations.	✓	✓	X

Theories and laws: Theories and laws are different kinds of scientific knowledge. Laws describe relationships, observed or perceived, of phenomena in nature.	Mixed	Mixed	Mixed

✓= Informed view of NOS X = Naïve view of NOS

'Informed'- a good match between teachers knowledge and the category identified

'Mixed'- some aspects were understood, and some were confused

'Naïve'- incorrect or misconceptions

4.3.2 Assertion 2: Teachers' conceptions of NOS do not necessarily influence their classroom practice

This assertion is addressing the second research question of the study which looks at the influence of NOS in classroom practice, with specific reference to a particular topic of Evolution.

During lesson observations, the observation checklist (Appendix F) was used for each teacher participant. The data analysis focussed mainly on specific instances of either explicit or implicit nature in which the participants addressed the aspects of the NOS. Explicit or implicit statements and or discussions and activities related to the Life Sciences lessons about Evolution, means that NOS was embedded within science content. Discussions and activities that explicitly addressed one or more aspects of NOS were noted and regarded to be explicit instances. References to aspects of the NOS such as isolated statements and examples which formed part of the teaching sequence were however regarded to be implicit instances. In addition, activities that were given to learners which addressed a particular view of science, but did not explicitly draw learners attention on the NOS, were also considered implicit instances. In order to answer the research question about the influence of core concepts of NOS on teachers' pedagogical practices in teaching Evolution, it is important to see how each teacher addressed core concepts of NOS in their classrooms. This is important because it will show whether these core concepts of NOS were addressed explicitly or implicitly in everyday life sciences lessons. Only core concepts of NOS that were observed in the classroom are discussed below so that the research question on teachers' pedagogical practices could be answered. The following NOS views were recorded for Dianne during her four lessons.

Dianne's pedagogical practice of concepts of NOS in teaching Evolution.

Table: 4.3 Dianne's NOS views addressed in the lessons.

Core Concepts of NOS	**Lesson 1**		**Lesson 2**		**Lesson 3**		**Lesson 4**	
	E	**I**	**E**	**I**	**E**	**I**	**E**	**I**
Tentativeness	✓						✓	
Empirical basis			✓		✓			
Subjectivity	✓		✓					
Creativity, inferences	✓				✓			
Social/cultural embeddedness			✓				✓	
Observations						✓		✓
Theories and laws		✓						✓

Explicit = E   Implicit = I

<u>Lesson 1: Introduction to Evolution, differences between hypothesis, theory and law.</u>

<u>Tentative nature of science</u>

Dianne discussed diversity and change with examples of classification of organisms as an introduction to Evolution. She also discussed the scientific method and emphasising the differences between hypothesis, theory and laws and consolidated this with examples of each.

Dianne explicitly communicated and incorporated the ideas of NOS using some concrete examples to make learning meaningful and relevant to the learners. In the very first lesson in which Dianne was introducing the concept of change over time, the aspect of *tentative nature* *of science* was explicitly articulated using various examples that are related to science content. This is evident in the following statements made by Dianne in various lessons:

".....if you go back not as far as Aristotle, but back in your school career, you may have certainly in grade 08 dealt with a certain number of kingdoms of classifications.....so you had five kingdoms, in my schooling career I had just two kingdoms... It was only plants and animals, and then people started to question these because they didn't really fit into plants and they did not really fit into animals, so they kind of started to think, well, there probably is another group and then they start to look at it further and then decided on the five kingdoms. So what I am trying to point out to you is once again, you can see that science is changing all the time, it has to because we are learning new stuff, researching new stuff all the time" (Dianne, Lesson Observation).

"I think there is nothing so sure about science as the fact that it changes all the time and I think I've mentioned it to you before how right at the end of my school career, the teacher came in and said ' oh you got to write this down' , it was all about the DNA molecule and Watson & Crick and all of that, and in my very first year of teaching it was already in the syllabus and no-one had ever heard about it before, ...so constantly science discover new things and as the syllabus catches up and change, we implement those changes as well.."

(Dianne, Lesson Observation).

Again in another lesson, Dianne made an example of a coelacanth where she read an article on how and where this living fossil was found and yet it was believed to have been extinct.
"...although scientific knowledge might last for a while, there is always a possibility that new research will come along and change what we knew and therefore it is subject to change.."

(Dianne, Lesson Observation).

It is clear by the analysis of the concept of NOS mentioned above that Dianne attempts not only to teach learners about Evolution as a scientific theory but also to broaden their understanding of the philosophy of science by emphasising on how scientific knowledge is constructed and is developed over time. Moreover, by communicating the tentativeness of scientific knowledge, it seems Dianne is developing learners' conceptual understanding of the topic and their views of science as they become aware of what scientific ideas mean. Furthermore, incorporating the concept of tentative nature of science during a lesson does not only enforce the idea of how science works but it also addresses the misconception that learners might have that science is a body of 'literal truths'. Learners will now perceive "science as a process of improving our understanding of the natural world" (McComas et al., 1998, p. 12).This view is consistent with Lederman (1992) as he points out that scientific knowledge changes all the time and as such it must not be regarded as absolute 'truth' that will never change.

Lesson 2: Extract about evidence of early human existence.

Empirical Basis

Dianne read an extract about the evidence of early human existence. She then explained modern theories about Evolution and scientists involved. Dianne went through some questions on this topic with her learners.

In this lesson Dianne articulated the aspect the fact that *science relies heavily upon empirical evidence.* Dianne explicitly emphasised the importance of evidence in the construction of knowledge and also clarified how some scientific concepts like Evolution are mostly theoretical, that is, they are derived mainly from logic and reasoning. However, she quickly pointed out that observations and experimentations are still central in all scientific ideas. Dianne's ideas were articulated when she was addressing how various fields contribute to the construction and development of scientific knowledge. She read an extract about evidence of early human existence dating back some 15 000 years, such as pieces of leather, fire sticks, and plant food remains that was discovered by archaeologists in the Melkhoutboom caves in Grahamstown, in the Eastern Cape province. Archaeologists, anthropologists and palaeontologist believed that some of the plants remains must have been used by Khoisan people as medicines while others were used as arrow poison.

Dianne then asked her learners to work out how the archaeologists, anthropologists and palaeontologists knew that some of the plants were used as arrow poison. Learners came up with various answers and this is how she consolidated at the end of the learners' input;

….could they not have found remains of arrow tips and then gone and tested the little chemicals on them and maybe found out what chemicals they contain……..yes they would talk to people, but they would also need to go and have other evidence such as testing as well and not just the word of mouth…". (Dianne, Lesson Observation).

<u>Lesson: 3</u> <u>Case Study on geneticist and fossil researcher and Darwin's theory of natural selection and an activity on natural selection (see Appendix H).</u>

<u>Creativity and inference</u>

Dianne read a case study on different scientific fields, the geneticist and the fossil researcher. She briefly discussed Darwin's theory of natural selection and consolidated it with the activity.

In this lesson Dianne explicitly addressed how scientists use *human inference, creativity and imagination* in developing scientific knowledge. The following are some of the examples that were discussed in class which clarify the role of human inference, creativity and imagination in the construction of scientific knowledge.

> A case study looking at two scientists, Paulette a geneticist and Marion a fossil plant researcher. Marion a few years ago was asked to identify fragments of fossil wood that came from the Sterkfontein cave hominid site. Some of the conclusions Marion came to during and after her investigations are:

- Sterkfontein valley was much denser than it is today.
- Presence of fossil rodents and bovid show that there were grasslands nearby.

Learners were then asked to discuss how Marion would have come up with such conclusions and after the discussions Dianne again emphasised the role of human inference, creativity and imagination:

"*Now do you see how all these scientists are not only using scientific method to prove this whole thing? What else are they using? Their thought processes, their imagination, their creativity, they can't know it all from evidence……they've got to piece things together and try and build a story around it……in the future other scientists might be able to fill in the gaps*" (Dianne, Lesson Observation).

In the examples and statements that follow, Dianne clearly articulated how scientists do not only rely on evidence but also use their inferences, imagination and creativity during investigations especially in guiding data and in formulating conclusions. Moreover Dianne appears to be highlighting the point that science involves more than just numerous careful observations, but rather a combination of observation and inference and she explains inference as using imagination to draw conclusions from the observations since not all the facts are available at the time:

"…now when you come to evolution studies, you will realise that you can't apply all those scientific steps to the studying of a fossil, it becomes very difficult. You can't plan necessarily experimentation on the fossil that you've just found, sometimes one has to diverge away from this rigidity and study your fossils, study the past fossils compare them with others, compare them with modern day things….so what I'm trying to point out to you is unless you use a little bit of imagination in order to fit these things together, it's very difficult to study fossils in the same way ….so man has got to put these pieces together somehow, so he uses his imagination and in the past that never used to be accepted by science unless there was hard and fast evidence, nobody would accept it". (Dianne, Lesson Observation).

"according to Darwin, human beings, apes and monkeys descended from a theoretically constructed common ancestor" so do you see theoretical constructed, he was using his imagination, inferences and his creativity in thinking somewhere down the line there may have been a common ancestor for us because he saw similar characteristics…"

(Dianne, Lesson Observation).

In the two statements above, Dianne addresses how scientists employ various approaches in generating scientific knowledge rather than following a specific or universal scientific method as advocated in some science textbooks. Also Dianne explicitly articulated how scientific knowledge relies on empirical data derived from observations. She presented learners with an activity wherein they had to match different kinds of birds (that are identified by their beak type only) to the different types of food found on the island called Feather Isle [see Appendix H]). In this activity, learners had to observe the different beak types of birds and make inferences and then using their imagination and logical reasoning, they had to try and figure out which beak type matches which food type and then come up with the conclusions.

Lesson 4: Darwin's 'origin of species'and Darwin's biography

Social/cultural Embededdness

Dianne read a book about Darwin's 'origin of species' and reaction to it. She further discussed other theories about Evolution during the time of Darwin. She also read Darwin's biography.

Another aspect of NOS that was addressed by Dianne in her lesson was that *scientific knowledge is subjective and socially and culturally embedded*. This was evident in the statement that she made:

…all scientists are influenced by other scientist's theories and their own personal experiences ….Darwin had a grandfather who greatly influenced his ideas…"

(Dianne, Lesson Observation).

She then read an extract of conversation between Darwin and his grandfather to further clarify this concept of how Darwin was influenced by his grandfather. She read an article with Charles Darwin's biography in an attempt to explain to learners that Darwin's ideas were greatly influenced by his background and the environment:

".. so you see those of kinds of thoughts were already planted in the head of Darwin long before he started doing what he was doing…..so you do not want to get the idea that this was only Darwin's sudden thought, he was brought up in a scientific household, it was obvious that he had a background that was suited to this kind of research that he was doing….so does that give you an idea about how some scientists are started off, it's your environment, it's what you are exposed to that gives you ideas and the chance to do these things…"

(Dianne, Lesson Observation).

Anne's pedagogical practice of concepts of NOS

The following NOS views were recorded for Anne during her four lessons.

Table: 4.4 Anne's NOS views addressed in the lessons

Core Concepts of NOS	**Lesson 1**		**Lesson 2**		**Lesson 3**		**Lesson 4**	
	E	**I**	**E**	**I**	**E**	**I**	**E**	**I**
Tentativeness	✓							
Empirical basis			✓					
Subjectivity				✓		✓		
Creativity, inferences								✓
Social/cultural embeddedness			✓					
Observations						✓		✓
Theories and laws		✓		✓				

Explicit = E   Implicit = I

<u>Lesson 1: Introduction to Evolution: Diversity and Change</u>

<u>Tentativeness</u>

Anne explained the definition of the two terms, diversity and change. She further discussed how scientific knowledge also changes with time using several examples.

Anne like Dianne also addressed some aspects of the nature of science although not as explicitly at times as Dianne did. In her first lesson, Anne explicitly addressed the *tentative nature of science*, where she clearly articulated how scientific information is not static, but grows and changes as technology advances. In this regard she made an example of the atomic theory and how it has changed from the time an atom was first discovered.

"…think back to how the idea of how an atom looked like evolved, remember it was Democritus that Greek philosopher who put forward the idea of atoms, then it was forgotten and it was Dalton after 2000 years who came up with the spherical solid atoms and then you

had another structure, the planetary one and then the wave motion like….so ideas do change like theories….” (Anne, Lesson Observation).

In addition, during the interviews, Anne had mentioned that as a way of clarifying how science is subject to change in her class, she often quotes how in her schooling years they were taught something only to realise years later that it has changed "*when I was at school and I was taught in matric that in photosynthesis, carbon combined with water to form carbohydrate, but then at university, a couple of years later, I had to re-learn because I did Biochemistry, that it wasn't like that, it was the hydrogen that came from water that combined with carbon dioxide…".* (Anne, Interviews).

Again with regard to tentativeness of science, Anne also made an example haemophilia (a condition in which clotting factor is missing). This is how she explained how the effect of this condition has changed from the Victorian times: *"..today we find it's not such a problem because we have genetically modified organisms that manufacture the clotting factor and people who have a disease can use that, so today it is not the problem as it was in the past, because they had no way of treating it at all…"* (Anne, Lesson Observation).

Lesson 2: Evidence for Evolution (differences between facts and beliefs) and theories.

Empirical Basis

Anne discussed how science is different from other disciplines. She further explained how science is based on observations. She emphasised this aspect of NOS by giving examples of several theories such as the theory of meteorites.

During this lesson, Anne emphasised how science is different from other disciplines because scientific claims should be supported by empirical evidence. This view is consistent with one of the concepts of the nature of science that *scientific knowledge is based on and or derived from observations of the natural world*. In this regard Anne explained that theories are supported by evidence and she further made an example of the theory of meteorites in explaining the extinction of species and also carefully explained the evidence that goes with it:

"…so you can see these are theories and they are backed up by facts….. what you need to concentrate on in science because biology is science, is what evidence have you got and what are different ways of interpreting that evidence" (Anne, Lesson Observation).

Lesson 3: History of science (theory of Evolution)

Social/ cultural embeddedness and Subjectivity

Anne explained the history of the theory of Evolution, specifically discussing the time when the ideas of 'organisms descended from a common ancestor' started to develop.

In this lesson Anne addressed the aspects of *subjectivity of scientific knowledge; social embeddedness of science and the role of and human creativity and imagination.* During the interviews and in the questionnaire responses, Anne recognised that scientist's prior knowledge, personal background and other elements influence how a scientist interprets empirical evidence. The following representative quote indicate how she tried to elucidate the fact that scientists might reach different conclusions from the same data because they might have interpreted it differently due to their background, prior experience and knowledge. "*…when you look at evidence you are looking at it not from fresh eyes, you are looking at it with the whole lot of background of information, your training, your thinking…"* (Anne, Lesson Observation).

This idea also came through during the interviews when she was asked how she deals with learners contestations of some aspects of the theory of evolution and she responded that in her class she often say to learners, *"… we are also scientists and therefore we follow the scientific method, we evaluate what facts we have and we come to a decision, but different scientists come to different decisions using the same information…"* (Anne, Interviews).

Lesson 4: Evidence of Evolution

Creativity and inference

In this lesson Anne, explained in greater details the evidence of Evolution mainly from fossil records, anatomy, biogeography and molecular biology.

With regards to human creativity, imagination and inferences, during the lesson observation, Anne tried to communicate the idea that science requires creativity, imagination and inferences as evident in the following quotation: "…*this is human related isn't it, so do you remember how plants and animals do not classify themselves, we classify them for our own convenience…so there were obviously events that happened that scientists would classify an era by that event, in fact the extinctions did not define an era or an epoch, but you can certainly say they occurred in that time period…"* (Anne, Lesson Observation).

Anne also addressed the social embeddedness of scientific knowledge using history of science although implicitly as she did not make any reference or emphasis on NOS. In her discussions she highlighted how ideas about the Earth (God created everything and earth is a few thousand years old) that were dominant through teachings of the church were questioned during the time of Erasmus Darwin which is when the ideas of 'organisms descended from a common ancestor' started to develop:

"…*the church's idea that God created everything without change, the Earth was only a few thousand years old, was dominant and that was propagated within monasteries where teaching took place as well as from pulpit to the laymen like you and me…..then in the 1700 we got this whole idea of questioning, by that stage ships have travelled to different countries and the vast amount of information coming back as to the difference between living organisms was now beginning to build up. The natural history museum in London was started and people can now go and see for themselves all these different types of plants and animals and people then began to question the church's view on it and two names that you need to know are Charles Darwin's grandfather, Erasmus, probably that is where Charles Darwin got his ideas from in the first place because he looked at all his information and the idea that 'organisms descended from a common ancestor' ...He (Erasmus) also that the species must have changed but he didn't know how or why they have changed…"* (Anne, Lesson Observation).

In this discussion she also pointed out the fact that Charles Darwin first got his ideas from his grandfather who said that species must have changed but didn't know how and why and then he worked from there and eventually came up with the theory of evolution by natural selection. Again in this discussion Anne failed to explicitly address the issue of subjectivity which allows science to progress and remain consistent, but at the same time plays a role in dynamic nature of science when new knowledge comes up.

Reese's pedagogical practice of concepts of NOS

The following NOS views were recorded for Reese during her four lessons.

Table: 4.5 Reese's NOS views addressed in the lessons

Core Concepts of NOS	**Lesson 1**		**Lesson 2**		**Lesson 3**		**Lesson 4**	
	E	**I**	**E**	**I**	**E**	**I**	**E**	**I**
Tentativeness						✓		
Empirical basis			✓					
Subjectivity								
Creativity, inferences		✓						
Social/cultural embeddedness								
Observations								✓
Theories and laws		✓						

Explicit = E Implicit = I

Lesson1: Introduction to Evolution, alternatives to Evolution (specifically creationism).

<u>Inferences</u>

Reese started this lesson with an introduction to Evolution where learners' prior knowledge with regards to Evolution was probed. Reese then presented Evolution as a 'theory' and creationism as an alternative point of view. She explained in details micro-evolution.

It is important to note that from the beginning I made some interesting observations about Reese's classroom practice and her viewpoints with respect to Evolution. From the very first lesson, she was upfront with her views and belief system as a creationist and as such in her lessons she often argued and discredited some facts in evolution. Reese started her first lesson by asking learners to say anything they remember about Evolution from the previous grades. As mentioned before, the conflict she had within herself about the theory of Evolution was clearly evident. Her creationist belief came through so strongly in her lessons as evident in the following statements:

"….what do you think I believe in? ….so there is micro evolution because I believe from the Christian aspect that God created the species…..this is where we are going to get the little bit of discrepancy that we have with evolution or that I have with evolution….so we are going to realise now that I still believe that there is actually a super being that I believe that is God who created us and this is where the problem comes for me but we still going to have to learn the facts…"(Reese, Lesson Observation).

During this lesson after having briefly discussed macro evolution as the change from species to species, Reese started to introduce some arguments against evolution. For example she argued how the two fossils (Archaeopteryx and a coelacanth) are cited by scientists as evidence of transitional or in-between species. Again she argued the claim made by the evolution theory that life started very simple (unicellular organisms) and through time and evolution has now become complex (multicellular organisms) pointing out that bacteria has the most diverse adaptation to habitat compared to humans which according to her makes bacteria more complicated. Hence she felt strongly that learners need to be introduced to both views of scientists and creationism when it comes to the teaching of evolution and her strong views came through clearly in her statements; *"all I'm saying to you is just think because so much of what you are taught, you have to be careful, why were you taught archaeopteryx, why were you taught a coelacanth, it is because it's what appears to be possible missing links.. ..but can you see what I'm saying , can you see that we've got to be careful, can you see that maybe we might have been brainwashed ….so what you need to be aware of is that this is still a theory…"* (Reese, Lesson Observation).

Lesson 2: Evidence of Evolution- fossil record

Empirical Basis

Reese explained in details the evidence used by scientists for Evolution. She discussed how fossil are dated and the controversy around fossil record as evidence of Evolution.

During her lesson, Reese did address some core concepts of the nature of science such as *science relies heavily on empirical evidence.* Reese believed that science is facts that have been proven through objective observation or experimental evidence. This view was clearly articulated firstly in the questionnaire when she was asked whether ever use imagination and creativity in scientific investigations and her response was *"science should have conclusions only based on data"* (Reese, Questionnaire). Secondly in her lesson as clearly indicated by her statements:

Reese: What are the evidences that are used by scientists for evolution?

Learner: Fossils, those in between things.

Reese: Missing links in the fossil record, what else did they use?

Learner: Stuff that they can't prove.

Reese: So you are being a bit fictitious just like me, the stuff that they can't really prove. Do they know that, that fossil actually existed at a particular age …so they are generalising and estimating…. …but once again I am saying to you think, the evidence for evolution can also be evidence for creation, so all I'm saying to you is just be careful, we are going to learn a theory and can you see where I'm having a problem" (Reese, Lesson Observation).

The above excerpt suggests that Reese does not recognise the role of human inference, creativity and subjectivity in the process of the generation of scientific knowledge. She used words such as 'generalising' and 'estimation' rather than emphasising that the generation of scientific knowledge involves aspects of human imaginations and logical reasoning which are based on observations and inferences of the natural world. Reese's naïve understanding of this aspect of the nature of science is also evident in her questionnaire response when she was asked whether scientists use their creativity and imagination during scientific investigation:

"Yes, *creativity is an issue, maybe not entirely the fault of the scientists, but in the interpretation of their conclusions e.g. "hominids with whites in their eyes. There is no evidence of this, but the scientist interpretation of these hominids definitely makes them appear considerably more "human-like" because of this"* (Reese Questionnaire).

<u>Lesson 3: Speciation (allopatric and sympatric) and Evolution in present</u>

<u>Tentativeness</u>

Reese started by defining the terms species and population and then presented a detailed account of speciation. She further discussed evolution in present times with examples including DDT and malaria and XDR/MDR TB.

In this lesson, the only aspect of NOS that was communicated was the tentativeness of the scientific knowledge and this was addressed with regard to the definition of the species.

Lesson 4: Difference between Theory and Law and Scientific Method (experimentation)

Observation and empirical basis

Reese explained the scientific method step by step emphasising the importance of empirical evidence. She then further discussed the difference between a theory, hypothesis and a law.

Reese's lessons put a strong emphasis on experimentation rather than multiple methods of investigation such as experimentation involving controlled variables, correlational studies and descriptive investigation. It appeared that Reese's views of investigative processes in science are mainly centred on the scientific method or a set of pre-established logical steps requiring a testable hypothesis.

*"..so what did I say to you , the first thing, what do we have in scientific method….so the first thing is that you must have a hypothesis,(this is what I think is going to happen) then you test your hypothesis, then you have apparatus, then the method , results and your conclusion…*what *is important about your conclusion? Where do you get your conclusion from? So if your bread did not rise and you said that it was the yeast that made the bread rise, then what was your conclusion? The yeast did not make the bread rise, so you are actually working out a conclusion from what you have actually observed..."* (Reese, Lesson Observation).

Again to emphasise Reese's view that science is empirically based and that evidence must be absolute and be proven during the lesson on fossils and how they were dated, when one of her learners asked how the scientists knew that the fossils they found were of the animals that they claim and not something else. She responded *"there's long enough evidence and they cannot necessarily use something that they can't prove, it would have to be proper evidence for example, the trilobites that they used for relative dating. There is enough evidence that they were there, physical evidence and I mean fossils have existed"* (Reese, Lesson Observation).

Another aspect of the nature of science that I observed in Reese's classroom was her view of what a theory is. This particular aspect of distinction between theories and laws was not

explicitly addressed in Reese's lessons, however she kept referring to theory of evolution as 'just a theory', for example she used the phrase, *"What you need to be aware of is that this is still a theory*". The same views that Reese communicated in her classroom were clearly articulated in the interviews as evident in the following representative quotations:
"... Evolution is still a theory and the facts have not really been proved..." (Reese, Interviews).

".. I teach micro-evolution as facts because to me it's plausible, but I teach macro-evolution and say to them that if there was enough evidence then possibly it would be there, but I don't see the evidence for it, so it's still a theory" (Reese, Interviews).

These quotations indicate that Reese believed that due to lack of substantive evidence and or proven facts, evolution is just a theory and this implies that in her opinion a theory can be proven correct using supporting experimental evidence. According to McComas (2003), the expression "it's just a theory" emanates from the false belief that "facts are built into theories and theories into laws" an idea which results in a misconception that laws are more valuable than theories (p. 142).

4.3.2.1 Summary of teachers' conceptions of NOS in classroom practice

In general, all the three participants at first glance did not employ an explicit approach to teaching about NOS. However, Dianne addressed briefly and explicitly more concepts of NOS as illustrated in Table 4.3. She also administered activities such as that in Appendix H which addressed explicitly some concepts of NOS and her informed views of the concepts came through in her lessons.

Anne addressed very few concepts of NOS explicitly; mostly she addressed the concepts implicitly as shown in Table 4.4. She articulated some explicit generalisations about the nature of scientific knowledge and practice such as the tentative nature of scientific knowledge, the significance of empirical evidence and socio-cultural factors affecting generation of scientific knowledge. The emphasis on her lessons was mostly on theoretical explanations of the concept of evolution and the concepts of NOS views were implicitly and rarely addressed. Anne engaged her learners in activities that would have allowed her to articulate certain concepts of NOS explicitly; however she employed implicit approach.

Findings from the first assertion indicated that Reese held naïve views of some concepts of the nature of science and these were also revealed in her classroom practice. Reese portrayed the least aspects of NOS, only the significance of empirical evidence was explicitly addressed as illustrated by Table 4.5. What also came through clearly in her classroom practice were her creationist beliefs as well as non-acceptance of the scientific validity of the theory of Evolution.

4.3.3 Assertion 3: Teachers have varying epistemological frameworks that inform their pedagogical practices

With the introduction of the new curriculum in South Africa came a shift from teacher centred, didactic approach to teaching and learning into learner centred teaching that is based on philosophical foundations of constructivism. For teachers, this change of curriculum calls for a new way of thinking about teaching and learning science, it calls for a transition to a teaching practice that supports constructivist approach to learning. Appleton and Asoko (1996) outline some characteristics that a teacher with a constructivist viewpoint of learning is expected to reflect in the classroom:

- A prior awareness of the ideas which children bring to the learning situation and or attempt to elicit such ideas.
- Clearly defined conceptual goals for students and an understanding of how learners might progress towards these.
- Use of teaching strategies which involve challenge to, or development of, the initial ideas of the learners and ways of making new ideas accessible to them.
- Provision of opportunities for the learners to utilize new ideas in a range of contexts.
- Provision of a classroom atmosphere which encourages children to put forward and discuss ideas.

(Appleton & Asoko, 1996, p. 167),

From the constructivist viewpoint, in order to understand the role played by teachers in a science classroom Van Driel et al. (2000) suggest that their beliefs and views must be analysed. The three teacher participants in the study revealed different pedagogical approaches and strategies in their teaching and learning. Although all three teachers were heavily relying on textbooks for their teaching, they used them differently when it came to teaching.

Dianne

Dianne's intentions of science teaching and in particular teaching the theory of Evolution were made very clear during the interview:

"I think that one of the most important things here is to broaden a child's mind into thinking in a different direction from the one that they have been thinking in and to encourage them to go and research for themselves. I think it's terribly important not to confine any part of the syllabus solely to a system which is going to let them pass through examinations. I think it must be a well-rounded education experience and that they must be taught to think in different directions and not just towards the examination and facts" (Dianne, Interview).

In this quotation, Dianne is portraying an epistemological view that is grounded in constructivist point of view. This statement revealed that Dianne believes that science is not the only 'way of knowing'. As such one would expect that in her teaching, Dianne would address the epistemology of science and how science relates to other ways of knowing. Indeed from the lesson observations, Dianne clearly articulated what is science and how it works. This is evident in the following excerpt that she read from the textbook:

"….Charles Darwin was a breeder of fancy pigeons. He kept accurate records, so yes he was applying some of this scientific old system, kept records of the parents and offspring of his pigeon crosses. He also made careful observations during his trip on HMS Beagle which led him to write on the Origin of Species. He also developed a workable explanation of the theory of evolution and proposed that better adapted organisms are more likely to survive and become parents of the next generation. So do you see he had to go on the little that he had and by using his imagination, he put together this theory and as I told you before this is not necessarily fact at all, he had to use his creativity to put what he has seen into some workable explanation for what was going on..". (Dianne, Lesson Observations)

The above statement implies that Dianne is aware that learners develop many ideas on their own, ideas that might not be consistent with what science is and how it works. Hence the emphasis on the importance of assisting her learners, construct their own knowledge in order to understand the world. Most learners come to science classes with pre-conceived ideas about science. During the interview with Dianne, she expressed the importance of understanding learners' perceptions and views and any misconceptions or conflicts they might have about the theory of evolution:

"Well I think one has to start with, what do you know about it? What do you believe as regards to this subject? and then as I said right at the beginning try and find out whether there are any misconceptions. If there are try and deal with them, but never be too prescriptive about this and just try to explain to them that you are trying to explain this theory to them in the best way possible, but you have to ask questions about what do they believe and what do they know about it before you even start on this whole process" (Dianne, Interviews).

Consistent with this view, in her first lesson Dianne gave her learners an activity where they were expected to reveal their views about the Origin of Life, whether they view evolution as a scientific fact or just a theory that can be proven wrong etc. This activity implies that Dianne wanted to know something about her learners' beliefs and values which is an important starting point for establishing a context for constructivist teaching and learning (Anderson, 2007). This activity further shows that Dianne acknowledges that as a science teacher she needs to confront learner's alternative conceptions.

Another aspect of constructivism that Dianne displayed is teaching her learners in various ways rather than being confined to facts and emphasis towards examination. In this regard, most of Dianne's' lesson planning and activities came from the one textbook that she was constantly using. Although Dianne relied on one specific textbook, she did not just focus on content knowledge and facts on the textbook. She also used the facts and activities in the textbook to provide opportunities for learners to make their own meaning. Dianne constantly engaged her learners in various inquiry-based activities. For example, in one of the activities she administered, learners were given data on observations of a kingfisher (a type of bird) that were recorded by an animal behaviourist. Learners had to look at the observations and the make inferences to suggest how these adaptations help the kingfisher to survive in its environment. In this activity, learners worked in groups to make sense of the data given and as such Dianne got to see how learners construct their own meaning. In addition, Dianne's perception about science being based on both observations and inferences was revealed in this particular activity. The other activity that Dianne gave her learners to promote and develop their logical reasoning skills and make sense create meaning was the one in which they matched the food type with a beak type (see Appendix H).

Anne

Anne had particular views about science teaching and learning, and what science should learners learn that she hoped would come through in her teaching. Her views of science teaching and science knowledge are supported by her conceptions of science learning. In her interview response, Anne mentioned thinking, questioning, investigating, finding out things on your own as some of the elements of science learning: *"Learners learn by being given opportunities to think, learning science is not about just being presented with facts but needs to be based on questioning and investigating, querying and arguing-to this end science learners through investigating, particularly practically-finding out something for themselves…"* (Anne, Interviews).

The above statement indicates Anne's perspective that is grounded in constructivism as she emphasise several inquiry related skills. Constructivist viewpoint is closely associated with scientific inquiry. From the constructivist point of view, learners must be taught how to evaluate and interpret evidence and then construct and evaluate scientific explanations (Sadler, 2004; Hanson & Akerson, 2006).This view is consistent with Anne's view of science teaching and learning as she emphasized the importance of evidence in science:
"What you need to concentrate on in science, because Biology is science, is what evidence have you got and what are different ways of interpreting that evidence" (Anne, Lesson Observation).

Anne thought of science as reliable information derived through a structured scientific process. Anne's view was portrayed in the following representation "…*remember from scientific point of view, you take the best information that you have at the time from the tests that you did and then you come up with a conclusion…".* The emphasis of evidence and explanation was evident in one of Anne's lessons where she prompted learners to present evidence and explanations of theories of mass extinctions. To illustrate this point, on one of the lessons, she spent about forty-five minutes discussing the various evidences (theory of meteorites) given by scientists for the extinction of certain species such as the dinosaurs. Noteworthy in these theory-laden activities and discussions is that they opened up an opportunity for learners to question validity of some of the evidence, to argue about certain elements of the nature of science and also develop new ideas from the discussions of the concepts. Her classroom discussions were initiated mostly by open-ended questions driven by learners themselves and she allowed the interaction amongst learners themselves and also between learners and herself. For example, learners debated the fact that theories are "*scientifically proven*" and that they are "*backed up with evidence*". In this regard, Anne engaged her learners in an activity that addressed the importance of the scientific method in formulating theories. As mentioned earlier Anne emphasised the scientific method as one of the processes that separates science from other disciplines of inquiry such as religion, this view was revealed in her teaching. One of the activities that she engaged her learners in was a minds-on activity where learners were required to design an investigation using the given hypothesis, to test whether Charles Darwin's hypotheses were correct or not.

Another teaching strategy that Anne employed in her classroom practice was telling of stories, in other words the history of science. In her lessons she would tell particular stories about the history of science so that learners can understand the dynamic nature of science and the social embedded nature of science. In one of the lessons, she narrated the story of how first Erasmus Darwin, Charles Darwin's grandfather came up with his idea that organisms descended from common ancestor and then later on how Erasmus ideas influenced Charles Darwin. Anne's views and beliefs about the nature of science were consistent with the teaching learning.

Reese

Reese displayed a strong positivist view of scientific knowledge with some elements of constructivism approach, and this I refer to as mixed epistemologies. Her strong positivist view of science learning is evident in the following representative statement she made in her reflection:

"Science learning is taking observed knowledge and making theories once that knowledge is accepted as a fact or proved to be a fact". Reese seemed to think of Life Sciences as a collection of facts about the natural world, which have been proven. She further believed that scientific facts are discovered through the scientific method as she pointed out that scientific method is used to "*prove or disprove hypotheses*". On the other hand, Reese's teaching strategy showed some elements that were based on the constructivist viewpoint, such as eliciting learner views about the theory of evolution, the emphasis on giving learners different point of view and also allowing them an opportunity to question and discuss the nature of

science. For example, when Reese was teaching about the fossil evidence, a learner asked "how did the scientists know that the fossils they found were indeed of the animals they claimed and not something else". Reese allowed an interaction amongst learners themselves and also between her and the learners. Again, when giving evidence for fossil record or theories that explain macro-evolution, Reese would use the same evidence to argue for creationism. This created an atmosphere of debate, arguments, questioning and making sense of how science works. Hence earlier in Table 4.2, I indicated that Reese's teaching revealed mixed epistemologies.

Reese also displayed teaching as an act of transmission of knowledge. This view is supported by her conception of science teaching which she described as "*teaching facts or experiments to prove ideas".* Reese's conceptions about science teaching were also evident in her reliance on a textbook which presented facts. She believed it was important for learners to study facts since they were assessed on them during the exams*:* "*I teach them, the facts that are in the textbook and I obviously use the textbook because that's what they get tested on, it's what they have to know because it's an external exam*.

Reese's views and beliefs were evident in her classroom practice particularly her religious beliefs which had a huge influence on her teaching. Besides the creationist beliefs that were revealed in the classroom, Reese displayed naive epistemology that indicates a positivist perspective which describes science on the basis of observations of reality and independent of personal experiences. This view was clearly articulated in one of Reese's lesson:

Reese: "...so what did I say is the first thing we have in scientific method? So the first thing you would say is, I have a hypothesis (this is what I think is going to happen), then you test your hypothesis, using your apparatus, then the method, results and your conclusion. What is important about your conclusion?

Learner: It answers your hypothesis.

Reese: Where do you get your conclusion from? …So you are actually working out a conclusion from what you have actually observed.

With regards to learner activities Reese gave activities that were content based where learners were expected to learn particular aspect of evolution and answer questions as per the syllabus and or textbook and afterwards the focus was on correct answers. One would assume that

Reese's personal belief system when it comes to the teaching of evolution has a major impact on how she teaches it. During an interview she made this comment about the teaching of evolution*: "It's always a difficult one because it's something I don't believe in so this whole thing with evolution has always proved a bit of a problem for me..."* Indeed as clearly put by Rutledge and Mitchell (2002), science teachers experiences some difficulty when they have to teach a concept like Evolution, which they consider not to be valid based on scientific methods and processes.

4.3.3.1 Summary of teachers' epistemological frameworks

Dianne and Anne both held conceptions of scientific knowledge that is grounded in constructivist viewpoint. Dianne's emphasis of 'broadening learners mind' by encouraging learners to go and find more through research and construct meaning, expressed strong personal constructivist considerations. Similarly, Anne's view of seeing teaching as getting learners to think and an emphasis of inquiry-related skills such as questioning, arguing, and investigation also display a strong constructivist viewpoint. Furthermore, Anne's recognition of the role of theory in producing scientific knowledge, posing questions, making hypothesis and predictions expressed her constructivist view. Reese on the other hand, held conceptions of science that are strongly positivist. She believed the truth exists out there and that scientific knowledge is 'proven facts'. She also regarded her primary task as ensuring that learners learn facts from the textbook.

All the three teacher participants of this study employed learner-centred teaching strategies on various occasions in their lessons. Again all three of them recognised the importance of their learners' conceptions although it was not very clear how they incorporated such conceptions into their lessons. Lastly they all recognised the importance of creating classroom environment that was conducive and supportive of learners' diverse views.

4.3.4 Assertion 4: Teachers' identities and beliefs influence their choice of pedagogical strategies

In an attempt to answer the fourth research questions I explored teachers' epistemological beliefs regarding teaching and learning of science based on the assumption that teachers' own beliefs about teaching and learning can limit or deepen the teaching and learning. As a subject advisor, it was important for me to find out why these teachers with about twenty to forty years teaching experience teach evolution and concepts of NOS (which are newly introduced science constructs in the Life Sciences (grades 10-12) curriculum the way they did. Levitt (2001) argues that for current science education reform to be successful teachers must be able to integrate philosophy and practices of the science reform with their existing philosophy and practice. It therefore becomes crucial for teachers to have insight into the effect their own beliefs have on their interpretation of the curriculum and the way they teach science. In order to gain more insight on the three teachers' identities I will start by giving their professional background briefly.

All three teachers had a Bachelor of Sciences degree majoring in Botany and Zoology. Since they all had university training, it is assumed that they studied about Evolution and what science is and what science is not, in other words Nature of Science. Dianne taught in South Africa in three public high schools and one private school before coming to the school where she is currently teaching. Anne has taught in nine high schools in South Africa and one high school in Zimbabwe before coming to the current school. Reese has taught in five schools before coming to the current. All the schools that the three teachers have worked in are public schools (also known as Ex-Model C schools and also in private schools. During their teaching experience, they have attended various teacher development programmes such as workshops, conferences, cluster group meetings conducted by various stakeholders and they have been involved in the marking and moderation of the grade 12 final examination.

4.3.4.1 Teachers' beliefs about science teaching and learning

In science education, teacher's beliefs about teaching and learning in general are coupled with beliefs about the nature of science as well as the teaching and learning of science. Studies by Brickhouse (1989, 1990) have demonstrated the influence of teacher's existing beliefs about teaching and learning on their pedagogical practices.

In other words what the teacher knows, understands and their existing beliefs about the nature of science determines largely what science will be taught to a learner (Ambimbola, 1983). In respect of science teaching and learning particularly with regards to the teaching and learning of Evolution, the main interest is what preconceptions teachers have about evolution, how they think about the nature of science and how their knowledge is influenced by their epistemology and worldview.

The teachers' responses from interviews on their existing beliefs on science teaching and learning were consistent with their pedagogical strategies and practices. The following representative statements articulate each teacher's main beliefs about science teaching and learning and also show why these teachers exhibit such pedagogical strategies and practices:

Dianne

"I *believe that learners need to be exposed to hands-on experiences and to make their own discoveries whenever possible, thereafter, theories and facts related to these experiences should be introduced...."* (Dianne, Interviews).

"I think that one of the most important things here is to broaden a child's mind into thinking in a different direction from the one that they have been thinking in and to encourage them to go and research for themselves. I think it's terribly important not to confine any part of the syllabus solely to a system which is going to let them pass through examinations" (Dianne, Interviews).

From the above statements it is clear that Dianne's pedagogical strategies are largely influenced by her constructivist belief system of science teaching and learning. Dianne's beliefs on science teaching and learning and her pedagogical practices have been influenced mainly by her peers from her first school and also other teachers from various schools in the marking centre. This is confirmed by the following statement she made about her pedagogical strategies over the years:

"At first, I used a 'safe' and factual approach. More experienced teachers in my first school showed us how hands-on experience and discover are important for understanding Life Sciences and for subsequent learning….colleagues are essential to one's progress. Discussions in class became easier to control with more experience, resulting in more meaningful discussions which could include life's experiences more successfully.

Marking matric papers gave opportunities to meet with educators from other schools and one could learn from their knowledge and experience…" (Dianne, Interviews).

It is obvious that Dianne's way of thinking about science, including the teaching and learning of science has somewhat changed from the time she started teaching. Dianne's belief system reflects what is emphasised by Levitt (2001) that in order for teachers to integrate the ideas of the current science reform, they must adapt their existing beliefs such that they are in line with the philosophy of the reform.

Anne

Anne's beliefs about science were very clear and obvious in the way she introduced the topic in her first lesson. Anne was not only concerned about what learners know about Evolution, but she was also constantly helping them to come to an understanding of alternative ways of knowing and what science is and what it entails (Anderson, 2007). For example, she discussed the two ways of looking at the world which according to her were the scientific point of view that is based on the scientific method and then the belief basic point of view and encouraged learners to constantly question their ideas or views and beliefs as they go along. She further emphasised how science is different from belief system as it require empirical evidence as evident in the following representative quotation: *"... what you need to concentrate on in science because biology is science, is what evidence have you got and what are different ways of interpreting that evidence.."* (Anne, Lesson Observation).

She also wanted her learners not to necessarily accept a scientific worldview, but they must at least have an understanding of it (Reiss, 2009). This was also evident in the interview question when she pointed out that "*science is not judgemental; science investigates the world for its own sake*". The excerpt below indicate that Anne believes in teaching that does not only focus on transmitting facts about the theory of evolution but she is trying to help learners "appreciate the way science is done, the procedures by which scientific knowledge accumulates, the limitations of science and the ways in which scientific knowledge differs from other forms of knowledge" (Reiss, 2009, p. 1940).

"*…there are two ways of looking at the world, one is from a scientific point of view and that follows the scientific method and the other one is belief basic point of view….you remember I* *said we would look at facts that go with evolution, you can evaluate those facts and you can interpret those facts as you want to…I may interpret them my own way and someone else in another way..”* (Anne, Lesson Observation).

Anne: What is a difference between a belief and a fact?

Learner: A fact is something you can prove.

Anne: How can you prove a fact?

Learner: By using a scientific method.

Anne: Ok, scientific method, what do we do in a scientific method that is going to prove it?

Learner: Experiments

Anne: Experiments, ok, so unless something can be tested, then basically we can't call it a scientific fact. So you've got to be able to put forward a hypothesis and you need to gather your information and then you need to be able to test whether the hypothesis is correct or not.

Anne: What we need to look at is not the belief systems, you need to look at evidence and evidence comes from different places.

During the teacher interviews, Anne's beliefs and understanding of science teaching and learning were also displayed and expressed in representative comments such as:

"*science learning is the ability to look at all aspects of the world around us with an understanding of the 'how' and' why' things happen and the relationship between events/phenomena….learners learn by being given an opportunity to think. Learning science is not about just being presented with facts but needs to be based on questioning and investigation, querying and arguing-to this end science learners learn through investigating-particularly practically, finding out something for themselves not just confirming what is already known…investigating scientific literature, critically analysing opinions about theories etc. should be used (remember that pupils cannot verify the facts themselves, so careful guidance is needed...science teaching seeks to give pupils hands-on experience, it should be geared to always making them think..”* (Anne, Interviews).

Anne highlighted that to her, Evolution is the *best theory to fit the facts as we learn them*" and "*also an excellent way to teach pupils the way in which scientific method works, for example, using evidence from fossils, but realising as new information comes to light theories can be changed or modified. Old theories were not wrong but simply based on the facts at hand at that time…*" (Anne, Interviews).

In respect to the above statements, it becomes clear why Anne employs such pedagogical approaches in her teaching of Evolution. Her main ideas about science seem to be based on hands-on discovery through scientific method, developing learners' critical thinking, and analysing and evaluating evidence, hence her lessons were centred on giving evidence for the phenomena such as evidence of the meteorites for extinction of species and evidence of natural selection. In the case of Anne it would appear that her beliefs were influenced by the type of education system that was used in Zimbabwe, community of practice of teachers and experience. This is evident in the following statement that she made when reflecting:

"I only taught 3 years in South Africa before moving to Zimbabwe, where I taught A-level Biology. The O and A-level system was years before S.A introduced Outcomes Based Education (OBE), a far more 'practical' subject and when I returned to S.A I brought that approach with me. Even in S.A before I left for Zimbabwe, I taught in Johannesburg with Mrs Dunte (pseudonym) who was very keen on practical work….she organised for us to attend demonstrations etc. at Witwatersrand University when the Biochemistry was first introduced. So I've always been keen to do as much practical work as possible both in the classroom and outdoors …" (Anne, Interviews).

Anne's belief about teaching and learning science which is practical work is confirmed again by the activity on scientific investigation that she gave her learners to do.

Reese

Reese's viewpoint about science and in particular, Evolution a scientific theory was very apparent in the interviews that were conducted prior to lesson observations, and teacher reflections. These are some of the comments she made regarding the teaching of evolution:
"I think that micro evolution is absolutely acceptable, it is the adaptation within the species and I have no problem with that at all, but the macro-evolution- from one species to the next is where I have a problem, evolution is still a theory and the facts have not really been proved and I mean I think that's the unfortunate part for me .There are lots of things that are written up as facts in the textbook and I don't think that…, that is entirely true.. it is very difficult to teach particularly for me because I do see that my readings say that there are flaws in the theory…" "I think just the lack of facts. I know that some facts that evolution uses as proof of evolution for example, fossils can also prove creation" (Reese, Interviews)

Reese's further beliefs and understanding of science teaching and learning are articulated in the following representative statements:

"Science teaching is about teaching facts or experiments to prove ideas. This is where Evolution is difficult for me as I believe it is still a theory, with interesting patterns which they use to 'prove' ideas…My Christian belief influence my teaching, micro-evolution is easy to teach as there is no controversy .Macro- evolution is more difficult as speciation" (Reese, Interviews).

"It's always a difficult one because it's something I don't believe in so this whole thing with evolution has always proved a bit of a problem for me, but I actually have taken it as an opportunity to…, because I believe that in evolution…., so much of what we are teaching in evolution is actually disputing the fact there is a God and saying that it just happened by chance?. So I look at it from both of those sides and I teach them, the facts that are on the textbook and then I teach them also another view point" (Reese, Interviews)

From the above statements, Reese's beliefs about science come through and also her religious beliefs are very evident. Reese's pedagogical approach and emphasis in her lessons about scientific knowledge being proven facts through experimentation and the idea that evolution is just a theory is influenced largely by her beliefs. Of importance to note is that Reese, just like Dianne and Anne has also acknowledged the role played by the community of practice of teachers and experience in making teaching science easier for her. However her learning experience from her peers seems to be geared more towards content knowledge rather than influencing her existing beliefs and pedagogical approaches as is the case with Dianne and Anne. This is evident in the following representative statement: "*Marking matric papers is invaluable learning time…content knowledge and familiarity has made teaching much easier and far more interesting. Evolution being a new topic and a difficult one for me to teach as fact definitely makes this more difficult to teach..."* (Reese, Interviews).
Reese's beliefs confirms Berkman and Plutzer (2010, p. 182) who reported on how biology teachers' "personal beliefs" have an impact on teacher's willingness to teach about evolution.

Of interest to note is that although all three teachers relied mostly on the textbook, but they found ways to incorporate other teaching and learning material that is in line with their belief systems of science teaching and learning. For example, Reese exposed her learners to articles and material that would also advocate for creationism for instance, readings from a book called “Bones of Contention”. Similarly Dianne exposed her learners to a broader worldview by exposing her learners to various articles such as an article from National Geographic titled “Was Darwin Wrong?” Anne exposed her learners to a variety of scientific theories such as the history of the atomic theory, the Malthus theory of population growth which are not necessarily part of the Grade 12 syllabus. Based on Anne, Dianne and Reese pedagogical approaches one would assume that their choice of textbooks and other teaching and learning resources is also influenced by their underlying beliefs of science teaching and learning.

4.4 Conclusion

This chapter served to provide insight into the three teachers’ understanding, practice of NOS and epistemological frameworks that informs their teaching of Biological Evolution. The chapter also revealed the reason why teachers teach in the way that they do. In this chapter I made four assertions in an attempt to answer the four research questions. The first assertion referred to teachers varying understanding of the core concepts of NOS. The second one looked at how teachers’ conceptions of the core concepts of NOS influence their classroom practice. The third and the fourth assertions referred to teachers varied epistemological frameworks and their pedagogical practice and the influence of such epistemologies (beliefs) in their choice of pedagogical strategies.

Chapter 5 which follows highlights the main synthesis of the findings of my research in relation to the four research questions posed. It also alludes to the limitations and implication of my research study as well as recommendations for future research in the field.

Chapter 5

5.1 Introduction

This chapter serves to bring together the main findings of the research which contribute toward answering the four research questions:

- What are Life Sciences teachers' understandings of NOS in teaching Evolution?
- How do Life Sciences teachers' understandings of the core concepts of NOS influence their pedagogical practices in teaching Evolution?
- What epistemological framework informs Life Sciences teachers' pedagogical strategies in addressing core concepts of NOS in teaching Evolution?
- Why do Life Sciences teachers' exhibit such pedagogical strategies in addressing core concepts of NOS in teaching Evolution?

The chapter also identifies some major findings that emerged from the data. One such major idea is that teachers do not always plan to teach the core concepts of NOS when teaching Evolution. This was interesting particularly that firstly; the development of the aspects of NOS by teachers is clearly articulated as one of the learning outcomes in the Life Sciences curriculum document such as the National Curriculum Statement, Life Sciences (DoE, 2003). Secondly, Evolution is one of the themes, in Life Sciences that allows for the opportunity in teaching and learning to confront issues of the nature of science. Another idea revealed that teachers' epistemological framework and beliefs do influence what they teach and how they teach in their science classrooms. The chapter concludes by listing limitations of the research and the recommendations for further research.

5.2 Addressing the Research Questions

The main findings that serve to answer each of the four research questions were extracted from the data analysis in chapter 4. The response to the research questions was guided by the conceptual framework of the core concepts of NOS presented in Table 4.1. In answering the first research question, the study analysed and interpreted a standardised VNOS questionnaire (Appendix D).

Then for answering research questions two, three and four, the study analysed the data sourced from the questionnaire, semi-structured interviews and classroom observations.

5.2.1 Teachers' understanding and practice of the core concepts of NOS

This section serves to answer the first research question as indicated above. The answer to this question has been formulated using the main findings revealed in the standardised VNOS questionnaire. The main finding revealed in the above instrument is that two of the three teachers in this study have informed understanding of NOS. This confirms Abd-El-Khalick et al., (1998) claims that some teachers appear to have informed understandings of NOS which are consistent with the current conceptions of NOS.

5.2.1.1 Discussion

Although most research studies show that science teachers do not have adequate understanding of the concepts of NOS, several studies actually indicate that some teachers appear to have informed understandings of NOS which are consistent with the current conceptions of the NOS (Abd-El-Khalick, Bell & Lederman 1998; Osborne et al., 2003; Abd-El-Khalick & BouJaoude, 1997; Bell, 2000; Glasson & Bentley, 2000). The findings of this study based on the questionnaire, semi-structured and classroom observations seem to concur with the findings of the studies mentioned above, specifically the study by Abd-El-Khalick, Bell and Lederman (1998) which reported that teachers showed an understanding of empirical and tentative nature of science. Amongst the participants in this study, there was an overwhelming agreement on the role or significance of empirical data in the generation and justification of scientific knowledge.

All three teachers pointed out that empirical evidence plays a major role in science. Anne and Dianne were also quick to emphasise that evidence is not the only factor in the construction of scientific knowledge. This finding is also consistent with the reports of other scholars such as Bell (2000, p. 367), who reported that "an understanding of NOS regarding evidence emerged" in both groups as one of the various reasoning patterns. Again similar results were identified by Osborne et al. (2003), in their study, wherein the participants noted the importance of addressing methods of science such as experiments, critical testing, questioning, creativity, analysis and interpretation of data in order to enhance NOS in the science teaching. Again, the results of the study by Glasson and Bentley (2000, p. 20) on practicing scientists, articulated teachers views that "science is essentially experimental and empirical". On the other hand, Reese strongly believed that science should only rely on available data, a view consistent with the findings of Dekkers and Mnisi (2003) and Abd-El-Khalick (2001) in their studies.

Similarly, with regards to the tentativeness nature of science, all teachers acknowledged that scientific theories do change because of new discoveries brought about by technology or new information based on new evidence and through re-interpretation of existing data. In this aspect of NOS, the results were similar to other studies (Akerson, Abd-El-Khalick, & Lederman, 2000; Lederman, 1999) and were also consistent with the current conceptions of NOS. All teachers expressed clear understanding of the tentative nature of all science knowledge including theories. For instance, they all explicitly pointed out that *"...There is nothing as sure about science as the fact that it changes all the time…"* (Dianne, Lesson Observation). The same result was communicated in the study conducted by Abd-El-Khalick and Lederman (2000), their participants, preservice teachers in particular, clearly ascribed to tentative nature of science. Similarly, Schwartz, Lederman and Crawford (2004) in their study of preservice secondary science teachers reported that teachers showed huge improvements or developments in knowledge of NOS especially with regards to tentative nature of science.

Abd-El-Khalick et al. (1998) found that all their participants recognised the role of human creativity imagination and subjectivity in science. Furthermore, they strongly opposed the view that science is objective; they believed that scientist individuality, scientist background and beliefs play a huge role during scientific investigations. These results are consistent with the findings of my study for Anne and Dianne who both reflected informed understanding of the role of subjectivity, creativity, imagination and inferences in generating scientific claims. They further advanced this concept of NOS by explaining that science involves explanations and inventions of theories using imagination and creativity in all stages when (planning, designing and interpreting data). Moreover, they both cited the scientific method as one of the techniques followed during scientific investigations but also emphasised that it is not the only way of knowing about the world around us.

On the contrary, Reese strongly believed that creativity although sometimes unavoidable does not play a role in the generation of scientific knowledge and also suggests that science follows a particular method, for example she pointed out that "*Science is about facts and working within limits, what is proven".*

Reese's view is similar to the view held by majority of the respondents in the study of Abd-El-Khalick (2001) who believed that scientists only use available data in formulation of scientific knowledge and that creativity; imagination and inference are not significant. In the question addressing the role of social and cultural factors in scientific investigations, all three participants in my study acknowledged that scientist background, experience, environment and personal beliefs influence what scientists do and how they do it.

Lastly what is surprising is the fact that although Anne and Dianne in particular showed an informed understanding of most of the concepts of NOS as explained above, when it came to the distinction and relationship between hypotheses, theories and laws, their understandings were not communicated clearly enough. All three participants expressed a clear understanding of scientific theories; however, they all wavered in describing scientific laws and the value and status of each (hypothesis, theory & law).

Dianne defined the difference between hypothesis and theory, yet she was less successful in explaining the value of each. On the other hand, Reese in this statement *"...Evolution is still a theory and that the facts have not really been proved..."* (Reese, Interviews) portrayed naïve understanding of the scientific theory. In addition, Anne articulated a typical 'hierarchical' perspective about theories being superior to hypotheses and those theories depend on availability of substantial amount of evidence to become laws.

The teachers' views in this regard are in line with what Abd-El-Khalick, Lederman, Bell, and Schwartz (2002, p. 8) describe as a "simplistic hierarchical view of the relationship between theories and laws whereby theories become laws depending on the availability of supporting evidence". This is evident in the following representative statement made by Anne;
"..Only once a hypothesis has been tested can a theory be postulated (a theory is higher in the hierarchy followed by law depending on the amount of evidence" (Anne Questionnaire).

5.2.2 How do teachers' understandings of NOS influence their pedagogical practices in teaching Evolution?

In answering the second research question of this study, findings from lesson observation were the main sources of data used. In the Life Sciences curriculum, nature of science has been highlighted as an integral component of scientific literacy and as such science teachers need to play a central role in addressing NOS conceptions in science classrooms. Schwartz and Lederman (2002, p. 206) argue that "to teach NOS a teacher must have not only a firm understanding of NOS but also knowledge of effective pedagogical practices relative to NOS and the intentions and abilities to merge those two elements" (p. 206).The findings from the number of lesson observations revealed that the three teachers in the study portrayed different pedagogical practices. In general, all the three participants at first glance did not employ an explicit approach to teaching about the nature of science. However, Dianne and Anne articulated some explicit generalisations about the nature of scientific knowledge and practice such as the tentative nature of scientific knowledge, the significance of empirical evidence and socio-cultural factors affecting the construction of scientific knowledge.

5.2.2.1 Discussion

Consistent with previous research (Abd-El-Khalick et al., 1998; Abd-El-Khalick & Lederman, 1998; Brickhouse, 1990), classroom observations, and questions asked in the questionnaire and in semi-structured interviews done on the three teachers seem to suggest that teacher participants' understanding of NOS do not necessarily influence their pedagogical practice. Dianne and Anne, both of whom possessed views of NOS that are consistent with the current reforms in science education, differed widely in their teaching contexts; however Dianne's understanding of the nature of science was much more explicit in her classroom teaching compared to Anne. On the other hand, Reese, who displayed naïve views of the concepts of NOS, exhibited pedagogical practices that were consistent with her naive views about the nature of science. This finding is consistent with the results of Lederman (1998) study wherein he concluded that two most experienced teachers portrayed pedagogical practices consistent with their professed views. The same findings seem to also apply to Dianne and Anne who exhibited classroom practice that was consistent with their views of NOS.

With regards to the relationship between teachers' understanding of NOS and their classroom practice, several, studies suggests that in order to teach NOS effectively and achieve the desired outcome, teachers need to address the aspects of NOS explicitly rather than implicitly (Abd-El- Khalick, 1998; Abd-El-Khalick et al., 1998; Akerson et al., 2000; Khishfe & Abd-El-Khalick, 2000; Akerson & Volrich, 2006). In this study, Dianne's classroom practice is consistent with this view as she attempted to address most NOS concepts explicitly. On the other hand, some authors such as Palmquist and Finley (1997) believe that implicit instruction of NOS do influence conceptions of science. This particular view about implicit instruction in this study, is consistent with Anne's' findings that she employed implicit approach in addressing most NOS concepts. Abd-El-Khalick and Lederman (2000) explain the difference between implicit and explicit approach as the extent to which learners are assisted to assimilate and understand concepts in this case specific concepts of NOS which would then allow them to think more and reflect on activities in which they are engaged in.

Of importance to note is that in addressing social and cultural embeddeness of scientific knowledge, Dianne and Anne used the history of science to demonstrate that science is a human endeavour which is influenced by the culture in which it is practiced. The use of history of science in enhancing learners' understanding of scientific is highly emphasised in the study conducted by Abd-El-Khalick and Lederman (2000). Moreover, the National Curriculum Statement (DoE, 2003) for Life Sciences clearly stipulates the development of scientific enterprise and, in particular, how scientific knowledge develops. Dianne furthermore explicitly articulated how the values and expectations of the culture determine what and how science is conducted, interpreted and accepted.

Most research studies argue that implicit approach assumes that by doing science or inquiry oriented activities, learners will come to understand scientific enterprise without any specific reference to NOS (Kishfe & Abd-El-Khalick, 2002; Akerson & Hanuscin, 2007; Schwartz et al., 2004). For example, Akerson and Abd-El-Khalick (2003, 2005) found that despite numerous inquiry-based activities, the fourth grade learners' views of NOS were not improved when the student teacher did employ explicit instruction of NOS. During her lessons Anne engaged her learners in activities that would have allowed her to articulate certain concepts of NOS explicitly; however she was less successful in this regard. The first activity required learners to describe major assumptions that scientists make in presenting evidence for evolution and also to describe five ideas that have come out of scientist's interpretation of the fossil record. In this activity Anne could have emphasized the fact that inferences are interpretations of observations as implied in her response to the questionnaire. The second activity that Anne administered employed implicit approach. Learners were given an inquiry based activity where they were required to test Charles Darwin hypotheses and state whether they are correct or not.

Reese's teaching differed from Dianne's and Anne's as she focussed more in ensuring that the learners were taught facts of evolution than helping learners come to an understanding of the processes of science. As noted earlier on, Reese held naïve views of some concepts of the nature of science and these were also revealed in her classroom practice. Reese's creationist beliefs and her beliefs about the nature of science appeared to greatly influence her pedagogical practice. For example, her responses in the questionnaire and during the interviews indicated that she believed science to be "*facts that have been proven through scientific method*" and that the development of scientific knowledge requires experiment in order to *"prove theories and verify facts as irrefutable*". Furthermore Reese pointed out that *"science should have conclusions only based on data*" which implies that scientific knowledge is proven facts that should be presented without any kind of human interpretation. Reese's view is captured clearly in this except from one of her lesson:

"*So let's go to what I taught you in grade 10, scientific method…..what is the first thing in scientific method…. hypothesis… then you test your hypothesis, then … your method, then apparatus, then results and then conclusion. What is important about your conclusion? Where do you get your conclusion from? So if your bread didn't rise and you said that it was the yeast that made the bread rise, so you are actually working out a conclusion from what you have actually observed"* (Reese, Lesson Observation).

From the above excerpt, it is clear that Reese's beliefs about what science is are also communicated to her learners during her lessons. Similarly, Brickhouse (1989) in her study reported that what teachers know and understand about the nature of science do have an impact on their decisions about what they teach. Contrary, in the study conducted by Mellado (1997) of four preservice science teachers revealed that there was no relationship between teachers NOS views and their pedagogical practices.

Another aspect that was interesting to note with Reese was her attitude towards the teaching of evolution, unlike Dianne and Anne (also Christians) who seemed comfortable with teaching evolution as a theory with well supported evidence. One can assume and attribute the acceptance of evolution displayed by Dianne and Anne to their informed views about the nature of science as advocated by several studies (Lombrozo & Thanukos, 2008; Holtman, 2010). The statement made by Reese during the interviews clearly shows conflicting views between evolution and her religious beliefs:

"I'm not teaching what I still believe is a theory as a fact and I give them my opinion as well as the theory of evolution so that they are getting two sides, some facts that evolution uses as proof of evolution for example, fossils can also prove creation" (Reese, Interview).

Various studies conducted in South Africa (Ngxola & Saunders, 2009; Holtman, 2010) revealed that religious conflicts within teachers themselves do pose a challenge when it comes to effective teaching of evolution.

In view of all the data from questionnaires, semi-structured interviews and classroom observations it is obvious that what teachers know and understand about NOS do not necessarily influence what and how they teach in their classrooms (Abd-El-Khalick et al., 1998; Abd-El-Khalick & Lederman, 1998; Brickhouse, 1990; Lederman, 1992). Lederman (1999) in his study of five biology teachers concluded that although all five teachers possessed views that were consistent with current science reforms, but they differed in terms of experience and teaching contents. This was the case for Dianne, Anne and Reese, whom two of them possessed views of NOS consistent with those, advocated in the current reform of science education and yet had very diverse classroom practices.

As portrayed in the three teacher participants' conceptions of NOS, each teacher had a particular set of nature of science beliefs. Several researches proposed that teachers' views about NOS are closely related to their general beliefs about teaching and learning (Abell & Smith, 1994; Aguirre, Haggerty, & Linder, 1990). Moreover, Laplante (1997) adds that these general beliefs may have an impact on teaching and learning. However, Southerland, Gess-Newsome, and Johnstone (2002) argue that teacher's views of NOS are only indirectly translated to classroom practice.

5.2.3 What epistemological framework informs teachers' selection of appropriate pedagogical strategies for teaching core concepts of NOS in Biological Evolution?

This section serves to answer the third research question of this study. The answer to this question has been formulated using the main findings revealed in the interviews and lesson observation. Ambimbola (1983) argues that knowledge, beliefs and theories a teacher has determines what science will be taught to the learner. Hence if we can understand deeper the teachers' own beliefs, this can limit or deepen what and how learners learn. The teachers' epistemology seemed to be central in the manner in which the teachers approached their teaching of NOS in evolution. The findings revealed that Dianne and Anne appeared to reflect a pedagogy that is grounded in constructivist epistemology, whereas Reese reflected mostly positivist views of science teaching and learning with minimal elements of constructivism.

5.2.3.1 Discussion

From the findings discussed above, one can conclude that the teachers' epistemological beliefs do influence and informs what teaching takes place in their classroom. This view is consistent with studies by Brickhouse (1989, 1990) which demonstrated the influence of teacher's beliefs on their teaching. Similarly, Tobin and Espinet (1989), in their study, concluded that teacher's existing beliefs about teaching and learning are consistent with their pedagogical practices. However some studies (Lederman & Zeidler, 1987) concluded that teacher's epistemological views are not clearly related to their teaching.

Dianne believed in a broader sense of science education teaching and learning. She spent a lot of time on the topic because her focus was not only the understanding of content knowledge but also on 'broadening the child's mind'. During her teaching, she constantly encouraged her learners to go and read more, research for themselves and come up with their own viewpoint on how science works. Cognitive constructivism which is based on Piaget's theory of cognitive development proposes that humans construct their own understanding. The idea that learners actively construct their understanding of facts is well accepted by most research (Powell & Kalina, 2009; Cobern, 1995). Dianne's epistemology is consistent with the constructivist view, which states that a complete education for learners requires attention to varied epistemologies, learner's personal views and formulating content knowledge in a broader context that facilitates the kind of learning that will ensure that the goal is achieved.

Anne also appeared to portray a pedagogy that is grounded in constructivist epistemology. During her teaching, Anne was aware of her learners' conceptions and she employed several strategies to elicit their ideas. One of the strategies she used was co-operative learning where learners worked together in answering questions and during discussions. Furthermore, Anne allowed her learners to express their knowledge and understanding of a concept first as individuals through a question and answer method and then with her guidance and assistance, they constructed their own understanding of what is being taught. Looking at the pedagogical strategies employed in her teaching, and findings from the interviews, one would conclude that Anne accommodated only "those aspects of constructivist teaching which fitted closely with her existing beliefs and practices" (Appleton & Asoko, 1996, p. 171).

Reese displayed a positivist perspective, describing science as proven facts that have been generated through an inductive scientific method. Reese's view implies a traditional thinking which is empirist-inductivist. However, in her teaching strategy there were some elements that were based on the constructivist viewpoint, such as eliciting learner views about the theory of evolution, the emphasis on giving learners different viewpoint and also allowing them an opportunity to question and discuss the nature of science. Hence earlier I indicated that Reese's teaching revealed mixed epistemologies.

In this section, I concluded that beliefs do influence teaching. Anne and Dianne appear to hold constructivist views of teaching and Reese showed minimal elements of constructivist viewpoint. Earlier in this section, I outlined five points determining the features of constructivist teaching. I am now going to look at whether Anne, Dianne and Reese showed some of these characteristics as advocated by Appleton and Asoko, (1996).

a) A prior awareness of the ideas which children bring to the learning situation and or attempt to elicit such ideas

All three teacher participants did ascertain the learners' views about evolution and also about the controversy that is associated with evolution. Dianne addressed this aspect in a form of a written activity and then addressed those preconceptions and misconceptions during teaching. Dianne Anne and Reese addressed these preconceptions through class discussions.

b) Clearly defined conceptual goals for students and an understanding of how learners might progress towards these goals

As indicated somewhere in this study, what seemed to be lacking in all three participants was that none of the teachers was explicitly thinking about or planned to teach in a way that was reflecting their views of the NOS (Lederman, 1999). Hence concepts of NOS only received an emphasis when a learner asked a question relating to it or when they were discussing a particular concept. It is only Dianne who appeared to have specifically planned activities.

c) Use of teaching strategies which involve challenge to, or development of, the initial ideas of the learners and ways of making new ideas accessible to them

Dianne and Anne employed various teaching strategies in their classroom practice such as lecture method, reading of articles, group work and inquiry-based activities which challenged learners, For example in Dianne's case, Feather Isle and the Kingfisher activities and Anne's minds-on activity. Even though all participants showed lack of planning but when it came to activities they seemed to be well-planned in advance.

d) Provision of opportunities for the learners to utilise new ideas in a range of contexts

In this regard Dianne, Anne and Reese provided very few opportunities for learners to use their new ideas in various contexts. This might have been caused again by unclear goals which were not thoroughly planned for.

e) Provision of a classroom atmosphere which encourages children to put forward and discuss ideas

Classroom discussions and the sharing of ideas amongst learners and the teacher in all the classes of the three participants was very supportive, encouraging and promoted critical thinking. This was done as individual learners, groups of learners and the whole class.

Based on the discussions above one is justified in concluding that indeed Anne and Dianne demonstrated "those aspects of constructivist teaching which fitted fairly closely with their existing beliefs and practices" (Appleton & Asoko, 1996, p. 178).

I also concluded that Reese reflected strong positivist views of science teaching and learning that considers science as a body of knowledge consisting merely of a collection of observations. Reese's positivist view is consistent with findings of the study conducted by Aguirre, Haggerty and Linder (1990).

5.2.4 Why do teachers' reflect such pedagogical strategies for teaching core concepts of NOS in Evolution?

In answering the fourth research question of this study, findings from interviews and lesson observation were the main sources of data used. Levitt (2001) argues that teachers hold educational beliefs and global beliefs and these have a major impact on teachers' classroom practice. Similarly the findings of this study revealed that Dianne, Anne and Reese belief systems have an impact on their curriculum implementation and pedagogical practices. The findings further implied that teachers' belief system might be influenced by their experience and the community of practice of teachers.

Lastly, Dianne and Annes'approach to teaching and their underlying beliefs were partially conducive to the intended goals of the current curriculum. They both administered classroom activities that required their learners to formulate their own understanding from the data and class discussions.

5.2.4.1 Discussion

Teacher identities and epistemology are becoming more relevant for the change in the implementation of current science education reform to make an impact. Several classroom-based studies in science education reveal how various aspects of teachers' belief about science are consistent with their teaching strategies (Brickhouse, 1989, 1990; Duschl & Wright, 1989).This is evident in the findings of the three teachers' epistemology and beliefs and the impact they have on their curricular implementation and pedagogical practices. Research in science, and particularly this study shows that teachers' beliefs and experiences strongly influence their teaching and implementation of alternative forms of pedagogical practices (Gess-Newsome, 1999; Appleton & Asoko, 1996; Levitt, 2001). Again the research on teachers' beliefs has been closely linked to the constructivist practice (Tsai, 2002; Wallace & Kang, 2004). For example, in a study conducted by Wallace and Kang (2004) they revealed how the beliefs of six experienced teachers influenced the degree of implementation of inquiry-based activities in their classrooms. This result is consistent with the findings of this study because Dianne and Anne epistemological beliefs which are grounded in constructivism had an effect in their pedagogical approaches in the classroom.

As previously mentioned, it is important for people who are involved in teacher support programmes and teacher development programmes to know what science is being taught in the classrooms. In this research study in particular, it is important to know what facts about Evolution are communicated in class, since the topic is a very controversial and to what extent do the teachers' beliefs about religion influence their pedagogical practices. Reese for example, is one of the many science teachers who have a personal conflict between religion and science (Ngxola & Saunders, 2003). Reese's statement that "*I also teach them another point of view, creationism"* has raised issues and conflicting debates.

The conflicting debate of teaching Evolutionary Theory/creationism and their relationship thereof in science classrooms have been very prominent particularly in United States of America. The personal religious beliefs that science teachers have with respect to Evolution cannot be ignored as the South African community is relying on science educators to communicate and teach science in a manner that will enhance learners understanding of science enterprise.

5.3 Implications for the Study and Recommendations

If science knowledge and understanding are to be central in developing scientifically literate citizens as stated in the latest South African science curriculum documents, then teachers' conceptions of NOS needs to be addressed. Also if science teachers as change agents are to meet the challenges of the new curriculum, they need to have a developed understanding and interpretations of NOS and they should reflect on the effect that their own beliefs have on their curricular implementation and pedagogical practices (Linneman et al., 2003). Studies on teacher pedagogy (Lederman, 2000; Levitt, 2001) show little evidence that science teachers are using curricular and pedagogical strategies that are consistent with practices promoted by the curriculum. For example, the Third International Mathematics and Science Study (National Centre for Education Statistics, 2013) revealed a continuing emphasis by science teachers on textbooks and lecture method to transmit science content to learners. This study shows that teachers' beliefs and experiences strongly influence their teaching and curricular implementation. Hence, there is an obvious need to assist science teachers in implementing pedagogical strategies that are consistent with the latest science curriculum documents.

If teacher education programmes and teacher support programmes are serious about the on-going development of science teachers, then the understanding of teachers' identities and the impact of the underlying beliefs on their curricular implementation and pedagogical approaches is critical. As we begin to understand how the beliefs of science teachers form, it can be easier to design relevant programmes to support them in ensuring that they employ pedagogical practices geared towards achieving the goals of the current science curriculum. One of the findings in this study suggests that teachers' need more support with the demands and content of the new curriculum.

Again what came through in the study is the need to have formal structures for a community of practice of teachers where teachers can learn from one another. This is especially helpful for novice teachers who are still struggling to find their feet in the teaching world. I believe that given time, necessary support and relevant resources, science teachers will be capable of overcoming the challenges and demands of the new curriculum. Therefore the main issue is we do not know what teachers teach in their classrooms and as Holtman (2010) pointed out "no one checks whether they do or do not teach what is prescribed in the curriculum" (p. 106). Hence it is of utmost importance that teacher development programmes and teacher support programmes assist teachers in reflecting on their existing beliefs in order to ensure that they align them with the philosophy current curriculum reform.

5.4 Conclusion

This chapter served to present the main findings of this study in response to the four research questions. One of the main findings revealed is that although all three teachers had informed understandings in most of the concepts of NOS, their classroom practice was not necessarily influenced by the understanding of NOS conceptions. Another main finding revealed that teachers' epistemological beliefs are consistent with pedagogical approaches. The last finding revealed that the teachers' existing beliefs about science teaching and learning does influence their curricular implementation and pedagogical approaches. Teachers further revealed that community of practice of teachers played a very important role in shaping up their existing belief and in developing their pedagogical practices. Teachers support one another, by sharing experiences and professional diversity and this idea of community of practice of teachers should therefore be strengthened.

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Appendix A

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07 February 2011

Ms T Fikeni
School of Maths, Science and Technology
EDGEWOOD CAMPUS

Dear Ms Fikeni

PROTOCOL: An exploration of how teachers' understandings of the Nature of Science influence their pedagogical practices of teaching Evolution
ETHICAL APPROVAL NUMBER: HSS/0020/2011 M: Faculty of Education

In response to your application dated 04 February 2011, Student Number: **206520289** the Humanities & Social Sciences Ethics Committee has considered the abovementioned application and the protocol has been given **FULL APPROVAL.**

PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

Professor Steve Collings (Chair)
HUMANITIES & SOCIAL SCIENCES ETHICS COMMITTEE

SC/sn

cc: Dr. N Govender (Supervisor)
cc: Mr. N Memela

Postal Address:

Telephone: **Facsimile:** **Email:** **Website:** www.ukzn.ac.za

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

Appendix B

UNIVERSITY OF
KWAZULU-NATAL

DECLARATION

SCHOOL'S NAME: -----------------------------------

THE PRINCIPAL--

AN EXPLORATION OF HOW TEACHERS' UNDERSTANDINGS OF THE NATURE OF SCIENCE INFLUENCE THEIR PEDAGOGICAL PRACTICES OF TEACHING EVOLUTION.

This research aims to answer the following questions:

- What are the science teachers' understandings of the Nature of Science (NOS)?
- How do the science teachers' understandings of the core concepts of NOS influence their pedagogical practices in teaching Biological Evolution?
- What epistemological framework informs the teachers' selection of appropriate pedagogical strategies for teaching core concepts of NOS in Biological Evolution?
- Why do teachers' reflect such pedagogical strategies for teaching core concepts of NOS in Biological Evolution?

Evolution, an important new theme in Life Sciences, lends itself to developing deeper conceptions of the Nature of Science, and this is central to South Africa's new curriculum. Within the Life sciences, teaching the Nature of Science has been tightly linked with the teaching of Evolution as a way to address misconceptions about and resistance toward evolutionary theory. Findings may also suggest guidelines to teachers regarding how practicing teachers may develop their own understanding and practice towards core concepts of NOS especially in teaching of Evolution.

Research Expectations of Respondents:

(1)The teacher participation will be for the duration of 2 weeks.

(2)Each teacher will be expected to participate in interviews and lesson observations.

I [**Principal Name**]

On behalf of **----------------------------,** school governing body hereby confirms that we understand the contents of this letter and the nature of the research project, and we consent to the research project being conducted in **--**.

SIGNATURE OF PRINCIPAL------------------------------ **DATE**---

Appendix C

Teacher Ethical Consent Forms

Date: ________________

Dear Ms/Mr _________________

I (Tizana Fikeni) am a secondary school teacher studying at the University of KwaZulu-Natal. In part fulfillment of my degree I am required to conduct a research project in my field of interest. I have chosen the following topic for my field of research:

An exploration of how teachers' understandings of the Nature of Science influence their pedagogical practices of teaching Evolution.

This research aims to answer the following questions;

- What are the science teachers' understandings of the Nature of Science (NOS)?
- How do the science teachers' understandings of the core concepts of NOS influence their pedagogical practices in teaching Biological Evolution?
- What epistemological framework informs the teachers' selection of appropriate pedagogical strategies for teaching core concepts of NOS in Biological Evolution?
- Why do teachers' reflect such pedagogical strategies for teaching core concepts of NOS in Biological Evolution?

Evolution, an important new theme in Life Sciences, lends itself to developing deeper conceptions of the Nature of Science, and this is central to South Africa's new curriculum. Within the Life sciences, teaching the Nature of Science has been tightly linked with the teaching of Evolution as a way to address misconceptions about and resistance toward evolutionary theory. Findings may also suggest guidelines to teachers regarding how practicing teachers may develop their own understanding and practice towards core concepts of NOS especially in teaching of Evolution.

Research Expectations of Respondents:

(1)The teacher participation will be for the duration of 2 weeks.
(2)Each teacher will be expected to participate in interviews and lesson observations.

Research Ethics:

(1) There will be no risks to the participants (harm)

(2) The participants will volunteer their responses to questions asked during the interview.

(3) The respondents will be offered confidentiality and anonymity by signing a confidentiality contract. Each respondent will be given a pseudonym and their own code. The respondents will not be aware of the pseudonym and the code for the various respondents.

(4) The respondents will receive feedback on the research process. They will also be asked to respond to transcripts of interviews to verify and confirm the responses given during the interview.

(5) The research data will be used for the purposes of this research only.

Thank you for your assistance. You will be provided with copies of the transcripts of data and research findings. For purposes of transparency you may share these with your principal. If you have any questions you may contact me on the number provided.

Yours sincerely,

Tizana Fikeni

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Appendix D

Questionnaire on the views and understanding of the Nature of Science

Please could you assist by completing the following questionnaire? It is part of a MEd research project which is exploring how teachers' understandings of the Nature of Science influence their pedagogical practices of teaching Evolution. In the Life Sciences curriculum (10-12), teaching the Nature of Science is tightly linked with the teaching of Evolution as a way to improve understanding and to address misconceptions toward evolutionary theory. Thus, through this research we hope to suggest guidelines and or effective strategies to teachers regarding how they may develop their own understanding and practice towards core concepts of NOS in the light of teaching of Evolution.

All personal information provided will be treated as confidential and will not be seen by any unauthorised persons. Completion of a questionnaire is optional. If you have any questions about the project please contact the researcher Tizana Fikeni or her supervisor Dr Nadaraj Govender (Govendern37@ukzn.ac.za).

Instructions to Respondents

The questionnaire consists of two sections. Section 1 contains profile and or biographical data. Section 2 contains questions on the views and understanding of the Nature of Science.

Section 1: Bibliographic data. Please complete the following table.

Surname & Name: *(Identities will not be disclosed) OPTIONAL* *Religious affiliation (optional):*	
Gender:(e.g. Male or Female)	
Teaching Experience : (in specialisation, e.g. Biology or Life Sciences)	

Teaching Qualification (in specialisation, e.g. BEd or BSc or Diploma)	
Major Subjects (subjects studied at tertiary institution)	
Teaching Subjects (e.g. subjects currently taught and grades (e.g. Life Sciences, grades 10-12	

Section 2: Questions on the views and understanding of the Nature of Science

Please answer the following questions and make an effort to answer all questions as there are no correct or wrong answers. If you have run out of the provided space, please feel free to write at the back of the questionnaire.

1. What, in your view, is science?

1.1What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

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2. What is the scientific method?

2.1 What is a scientific experiment?

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2.2 Is the scientific method the only valid method about learning about the world? Explain your viewpoint.

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2.3 Does the development of all 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.

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2.5 What do you understand by the term ‘theory’?

2.5.1 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.

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2.5.2 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.

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2.5.3 Scientific theory is a hypothesis that has not yet been proven, for example evolutionary theory. If you believe this statement about evolutionary theory, please explain why you agree with it and provide examples if appropriate. If you believe that this statement is not true, explain why?

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2.5.4 Should theories (evolution) which are factually based be accepted by all even if it contradicts one's viewpoint/religion?

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3. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring.

3.1 How certain are scientists about their characterization of what a species is?

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3.2 What specific evidence do you think scientists used to determine what a species is?

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4. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypothesis 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.

4.1 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?

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5. Scientists perform experiments/investigations when trying to find answers to the questions they put forth.

5.1 Do scientists use their creativity and imagination during their investigations? If yes, then at which stages of the investigations do 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.

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5.2 If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

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6. How are science, art, and religion similar? How are they different? Explain and provide examples where appropriate.

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7. Scientists work (i.e. observation, selection of data and hypothesis) sometimes is influenced by many factors e.g. previous knowledge, logic and social factors. If you agree with this statement, explain and provide examples if appropriate. If you do not agree with the statement, explain why not.

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Appendix E

INTERVIEW SCHEDULE

1. A team of genetic engineering researchers were involved in break-through research in Parkinson's disease (disease of the human nervous system). A key scientist in the research team claimed, "We are not here to play God, we must leave living things as they naturally are". As a result of her religious beliefs she convinced the other scientists on the team to stop their research on Parkinson's disease and pursue other research which was not in conflict with her religious beliefs.

   As a science teacher do you think a scientist's own religious beliefs should influence what kind of scientific research is undertaken? Why

   Likewise, in Evolution, most people including science teachers and learners believe that the study of evolution in biology is conflicting with their religious beliefs.

   In your teaching of Biological Evolution, how do you deal with the conflict between science and religion within yourself (if there is any) and that amongst learners?

2. "Our ancestors were hominids that probably evolved from chimpanzee like creatures between 5 and 15 million years ago. So it is not entirely surprising that modern humans are relatively similar to modern-day chimps" (Winston R. from the book, Human- the definitive visual guide)

   This statement is one of the most controversial and contested statements in the study of human evolution, in your teaching how do you deal with learner's contestations of and around this statement?

3. Evolution is as well supported by evidence as the theory of gravity or heliocentric theory of our solar system.

   In your teaching of evolution, do you find it easy or difficult for your learners to understand evolution as one of the scientific theories with huge amount of evidence?

   What in your opinion as a science teacher makes it easy/ difficult for learners to understand evolution as a scientific theory?

4.

As a science teacher, what is your critical goal of teaching the theory of evolution, besides the understanding of scientific facts and knowledge?

In trying to teach towards the achievement of your goals, what kinds of teaching and learning materials do you use?

5.

In argument for the theory of evolution, various aspects of biology such as fossil evidence are used; most people argue that fossil record is not that reliable to account for the evolutionary theory.

What arguments are made with regards to fossil evidence as one of the aspects that account for the evolutionary theory?

6.

As a Life Science teacher who has been teaching science for several years what would you say are the most important questions to ask when teaching the concept of Biological Evolution?

Appendix F

OBSERVATION CHECKLIST

Explicit and implicit approach in addressing core concepts of NOS in the context of Evolution.

Opportunities provided for discussions, statements, examples, descriptions and activities on NOS.

Core Concepts of NOS	**Lesson 1**		**Lesson 2**		**Lesson 3**		**Lesson 4**	
	E	**I**	**E**	**I**	**E**	**I**	**E**	**I**
Tentativeness								
Empirical basis								
Subjectivity								
Creativity, inferences								
Social/cultural embeddedness								
Observations								
Theories and laws								

Explicit = E   Implicit = I

Adapted from Lederman, Schwartz, Abd-El-Khalick, & Bell, (2001).

Appendix G

The parent/s

Sir/Madam

<u>Permission to video-tape in your child's classroom during conduction of my research at your child school.</u>

I am Miss Tizana Fikeni a secondary school educator who is currently enrolled at the University of KwaZulu-Natal for Masters in Education (M.Ed) degree with specialisation in Science Education. I am conducting a research study under the supervision of Dr. Nadaraj Govender of UKZN and therefore humbly request permission to collect data at your school.

The purpose of this study aims at exploring how teachers' understanding of the core concepts of the Nature of Science influence their pedagogical practices through examining a theme in Life Sciences namely, Evolution. Within the Life sciences, teaching the Nature of Science has been tightly linked with the teaching of Evolution as a way to address misconceptions about and resistance toward evolutionary theory. Therefore participation in this study should be beneficial to the school at the same time as increasing teachers' understanding of how to improve the teaching and learning process with regards to the Nature of Science and Evolution.

I will be collecting data from Life Sciences teachers teaching grade12. Data will be collected by audio, and, possibly, video recording. Observation of pedagogy, teachers lesson plans and interviews out of school hours if and when convenient for the participating teachers will also be conducted as these are very significant to the study. The data will be stored securely and treated with strict confidentiality: no unauthorised persons will be given access to the recordings, and the school and teachers will be referred to by pseudonyms when the research is reported. When appropriate the data will be destroyed.

The research will be explained to the relevant teachers and their learners, and their consent requested. Participation as a data source is voluntary, and participants may withdraw from the study at any stage and for any reason.

You have my assurance that the research will not infringe in any way to your child normal learning and or have neither any negative effect nor disruptions in the classroom teaching.

Contact information:

Dr Nadaraj Govender
School of Science, Maths and Technology
E-mail:Govendern37@ukzn.ac.za

Miss Tizana Fikeni: Dept. of Education:
E-mail:tizanafikeni@yahoo.com

Hoping that my request will meet your approval.

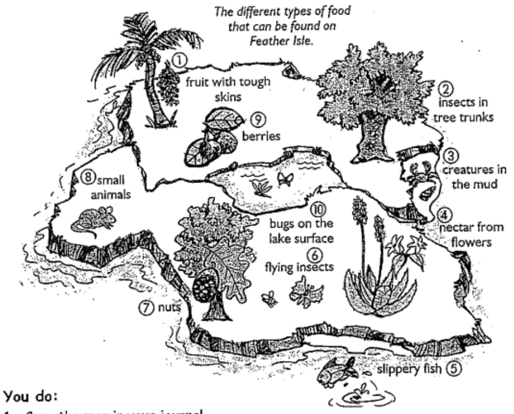
Yours faithfully

Tizana Fikeni Date:---------------------------

Appendix H

ACTIVITY: HOW NATURAL SELECTION WORKS

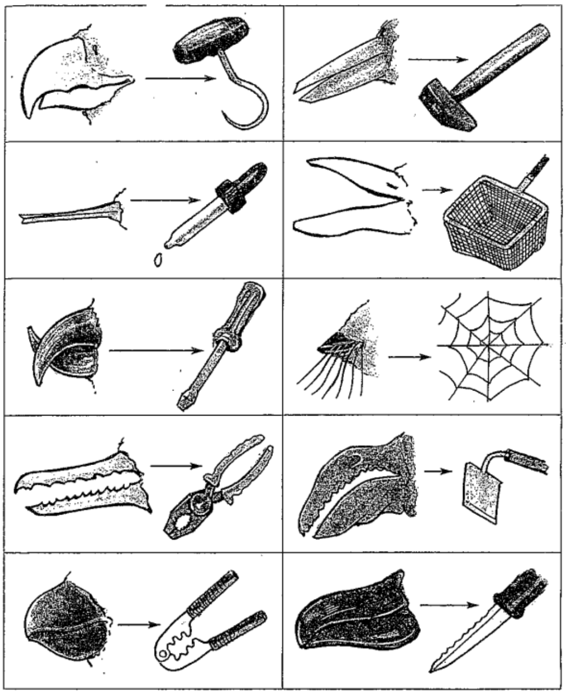
The map below is of a make-believe island called Feather Isle.



You do:

1. Copy the map in your journal.
2. Place a different kind of bird at each of the 10 numbered areas. Each kind of bird will be identified by its beak type only.
3. The different kinds of beaks are shown on the next page.
4. As you can imagine, each type of bird will have a survival problem. The food is different in each area. The only bird in each area that will survive and produce offspring is the one whose beak is best suited for getting and eating the food in that area. The other birds will have to move or starve.
5. Study the beak types and then decide which bird will survive in which area. You will notice that different kinds of tools or structures have been placed next to each type of beak. This is to help you to better understand how each type of beak works.
6. After you have completed the activity, explain to a classmate why you placed each bird where you did.
7. Hold a class discussion on the following topic: 'What will happen to the birds if they cannot eat the available food in their area?'

Can you see how natural selection helps to sort out which animals or plants survive best in which place?



Birds use their beaks like tools.

Artificial selection

You have seen how nature selects the fittest individuals. It also rejects the less fit ones. People can also apply a kind of natural selection. Suppose a farmer has a population of animals or plants. He can select those with good qualities and let them breed. Those with poor qualities can be prevented from breeding. This is called **selective breeding** or **artificial selection** because it is no longer natural

Appendix I

1. What in your view is science and what makes science (or a science discipline such as physics, biology etc.) different from other disciplines of inquiry (e.g. religion, philosophy etc.).What is the scientific method and what is the scientific experiment?
2. Is the scientific method the only valid method of learning about the world, and does the development of all scientific knowledge require experiments?
3. What do you understand by the term ‘theory’?
   After scientists have developed a scientific theory (e.g. atomic theory, evolution theory) does the theory ever change?
4. Scientific theory is a hypothesis that has not yet been proven, for example evolutionary theory. If you believe this statement about evolutionary theory, please explain why you agree with it. If you believe that this statement is not true, explain why?
5. Should theories (e.g. evolution) which are factual based be accepted by all even if it contradicts one’s viewpoint /religion?
6. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is?
7. What specific evidence do you think scientists used to determine what a species is?
8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypothesis 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 their extinction. How are these different conclusions possible if the scientists in both groups have access to and use the same set of data to derive their conclusions?
9. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
10. How are science, art and religion similar? How are they different?
11. Scientists work (i.e. observation, selection of data and hypothesis) sometimes is influenced by many factors, for example, previous knowledge, logic and social factors

etc. If you agree with this statement, explain and provide examples if appropriate. If you do not agree with the statement, explain why not.