LIFE SCIENCES TEACHERS' UNDERSTANDING OF THE NATURE OF SCIENCE WITHIN THE CONTEXT OF TEACHING EVOLUTION

by

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PREFACE

The work described in this dissertation was carried out in the School of Education, University of KwaZulu-Natal, from January 2010 to August 2013 under the supervision of Dr M. Stears (supervisor) and Dr J. Coleman (co-supervisor).

This study represents original work by the researcher and has not been submitted in any form for any degree or diploma to any other tertiary institution. Where use has been made of the work of others, it is duly acknowledged in the text.

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Abstract

The introduction of evolution in the 'new' Grade 12 life sciences curriculum in 2008 has created many challenges for life sciences teachers. The curriculum requires teachers to integrate evolution in all aspects of their teachings. The literature reveals that many life sciences teachers teach the concept of evolution in isolation and fail to integrate the topic as the underlying principle of Biology. Various studies conclude that teachers' understandings and beliefs about the NOS no doubt influence their classroom instruction. This study explores life sciences teachers' understanding of the NOS when teaching the theory of evolution. The NOS is used as the framing concept of the study. My research is a case study of three experienced life sciences teachers. Data was obtained from questionnaires, classroom observations and interviews with the teachers. This data provided valuable insight into the teachers' understanding of the NOS as well as the way in which this understanding influences their pedagogical practices. Furthermore I was able to develop some understanding of why teachers teach evolution in the way that they do. The instruments were analysed qualitatively. The findings were reported as narratives and reveal that the teachers have different levels of understanding of the NOS. These different understandings have a profound influence on their understanding of evolution, however their understanding of the NOS did not have the same effect on the manner in which they taught evolution. While all three teachers had some misunderstandings, two teachers were able to teach evolution without demonstrating these misconceptions, while one teacher was not. Furthermore, there are also a number of additional factors such as exam-driven approaches, teacher identity, controversy surrounding the theory of evolution, and finally, lack of resources that impact negatively on the way evolution is taught. In conclusion I offer strategies to improve life sciences teachers' understanding of the NOS and evolution and highlights areas for further research.

TABLE OF CONTENTS

CHAPTER ONE

ORIENTATION OF THE STUDY

1.1 Introduction

The teaching of evolution has always been a contentious issue, particularly in the United States of America where curriculum decision-making is decentralised and local school boards may decide if evolution is to be taught or not (Stears, 2006). Prior to 2003, evolution was never included in the South African curriculum and therefore was not an issue at all. With the introduction of the National Curriculum Statement (NCS); (DoE, 2003), evolution has now become a contentious issue as teachers are required to teach evolution as part of the curriculum. This poses a major challenge for many teachers who teach in the Further Education and Training (FET) phase as they never studied evolution before and have limited knowledge of the process (Stears, 2006).

My study aims to investigate the ways in which teachers teach evolution. I propose to do this by exploring their understanding of the Nature of Science (NOS) in the context of teaching evolution, as there is evidence that educators who lack understanding of the NOS have difficulty teaching evolution for scientific understanding (Eick, 2000; Rutledge & Warden, 2000). This chapter will provide the context and overview of the study. A discussion of the background will provide more insight into how South Africa's new FET curriculum was introduced. The chapter unfolds by providing the purpose, focus and rationale for the study.

1.2 Background

During the apartheid era in South Africa, Christian National Education (CNE) was used as an instrument of cultural and political control (Abrahams, 2000). Under the apartheid regime, schools were instrumental in dividing society and therefore many people deemed the curriculum irrelevant and monocultural (Msila, 2007). Schools had no choice but to teach Bible Studies as part of the curriculum although it was not a subject in Grades 10, 11 and 12. This meant that the educator to a large extent played a role in perpetuating an irrelevant curriculum. Apple (1993) points out that the school, by the very nature of the institution, involved educators (whether consciously or unconsciously) in a political act.

With the demise of apartheid, South Africa's new FET curriculum was introduced to address the social injustices of the past. This new curriculum aimed to equip learners with the required skills, attitudes and values so that they may function as productive members of society. In doing so, the inclusion of the *Theory of Evolution* in the new FET curriculum is considered to be of crucial importance to learners. As the unifying theme of the Life Sciences, the inclusion of evolution in the curriculum is essential for the development of scientific literacy. One of the main goals of teaching evolution is to help learners understand the model of natural selection and use it in the interpretation of biological phenomena (Department of Education, 2008). An understanding of natural selection is also of benefit to society in general as it enables the understanding of various phenomena in the field of medicine and agriculture.

1.3 Purpose and focus of the study

The purpose of this study is to explore teachers' understanding of the NOS and the influence of this understanding on their pedagogic strategies within the context of teaching evolution.

A teacher's knowledge-base is the most significant factor in determining the degree to which a teacher places emphasis on evolutionary theory. The social controversy associated with the theory of evolution has no doubt been carried into the classroom by both the teachers and learners. Teachers who lack understanding of the theory of evolution and the basic NOS may present the topic to learners in an isolated manner, leaving room for interpretations and misconceptions. It is, in fact, quite easy for teachers to avoid teaching the theory of evolution, because most life sciences textbooks relegate the topic to one or two chapters, often near the end of the book, and do not integrate evolutionary perspectives throughout the programme, as intended by the DoE (2003).

If teachers are to engage in inquiry-based lessons, then they need to teach the tentative NOS. Learners need to be made aware that science is not simplistic and is constantly changing when new questions and interpretations emerge. The NOS can be defined as science epistemology, the characteristics of scientific knowledge and science as a way of knowing (Bell, 2008). By teaching the dynamic NOS, learners begin to understand science as having levels of generality. For example, teachers can use the theory of evolution to give learners a more sophisticated framework with which to judge claims. Dobzhansky (1973) believed that

the process of evolution was fundamental to an understanding of Biology. Today his argument is as valid as it was when he made it many years ago. Teachers have the important task of illustrating to learners how the theory of evolution is an example of how scientists examine the natural world. Teachers need to view the learning outcomes in National Curriculum Statement of the Department of Education (2003) as being a quest towards understanding the dynamic NOS which ultimately shapes our views and concerns. A review of the literature reveals that not many studies have been conducted in this field in South Africa, as opposed to the extensive American-based literature available. Due to the inclusion of evolution in the curriculum being relatively new, there is a need to research strategies as teachers relate to the teaching and learning of evolution in South Africa.

The focus of this study is on Grade 12 life science teachers teaching evolution. A study of teachers' understandings of the NOS will enable me to develop a focused sense of whether teachers believe that science is a fixed body of knowledge that needs to be transmitted to young minds and in doing so, follow a particular teaching strategy. These sentiments are echoed by Shulman (1986, p. 4) when he says "at the heart of what makes good teaching is what teachers know." According to the Do0E (2003), teachers have to explicitly teach the NOS in the classroom (p. 19). My focus is how teachers use their understanding of the NOS to teach the theory of evolution.

1.4 Rationale for the study

My rationale for undertaking this study is to develop a deeper understanding of the teaching strategies that teachers employ when teaching the theory of evolution, as a result of their understanding of the NOS.

Studies in the field of evolution have suggested that there is a strong correlation between the teacher's acceptance of evolutionary theory and understanding the NOS (Rutledge & Warden, 2000; Rutledge & Mitchell, 2002). Trani (2004) reported that the acceptance of evolutionary theory played a significant role in a teacher's classroom practice. Given the controversial nature of evolution, there is a need to understand the issues that lead to controversies in the classroom by exploring the way teachers approach the topic based on their own understanding of the NOS.

I believe that it is important to investigate whether a teacher's understanding of the NOS influences the way evolution is taught in a South African classroom, as it is in other parts of the world as indicated by several research studies (Rutledge & Warden, 2000; Rutledge & Mitchell, 2002). As a Grade 12 life science teacher, I have become aware of the difficulties learners experience in understanding the theory of evolution. Analysis of the matric quarterly examination results at my school confirms that the learners perform poorly in the questions based on the theory of evolution. This is an important reason for this research. My study is also of a personal nature. As a teacher of Life Sciences at the same school for many years, anecdotal observations show that teachers do not engage in inquiry-based lessons which could help develop the learners' understanding of evolution. Evolution is taught as yet another topic and not as an organising principle. Learners grapple with the understanding of evolution and therefore resort to memorising evolutionary concepts such as *speciation* and *isolating mechanisms* and in the process fail to link evolution with the other topics in the life sciences curriculum. It has been suggested that teachers engage in this type of classroom practice due to their lack of confidence to teach a topic they know little about (Stears, 2006).

Given this scenario, I wish to pursue this study as personal one, as I have noticed gaps in the South African research with regards to the teachers' understanding of the NOS and their teaching strategies when teaching the theory of evolution. Due to time and stress on syllabus completion, many teachers focus on teaching the content and give little consideration to scientific reasoning and the NOS (Trani, 2004). This is most likely to occur if teachers believe that theories are undeveloped ideas, and they may teach evolution as 'only a theory'. Likewise, if teachers believe science is on a par with other belief systems and not subject to the rigours of producing evidence, they may teach evolution alongside other belief systems that do not require such evidence (Trani, 2004). Teachers have the important task of illustrating to learners how the theory of evolution is an example of how scientists examine the natural world by teaching the dynamic NOS. The data obtained will enable me to explore the link between teachers' understanding of the NOS and their teaching strategies. As an experienced teacher, my interest and focus lies in new and appropriate teaching strategies that could make understanding the theory of evolution easier for learners. I believe that I can achieve this by developing an understanding of how teachers use their understanding of the NOS to teach evolution.

1.5 Research questions

The three key research questions in this study are:

1. What are life science teachers' understanding of the Nature of Science within the context of teaching evolution?
2. How do life sciences teachers' understanding of the Nature of Science influence their pedagogic practice (teaching strategies) when teaching evolution?
3. Why do life sciences teachers teach evolution the way they do?

1.6 Overview of the study

This chapter set the scene for the study. The purpose and focus of the study were presented in which I motivated my undertaking for the study. I proposed that I wish to explore life science teachers' understanding of the NOS when teaching the theory of evolution.

Chapter Two presents a discussion of the literature in the field of the NOS. The review comprises of studies conducted in the field of evolution and the NOS, both nationally and internationally. I focus on issues surrounding the teaching evolution and the effect of the teachers' understanding of the NOS on the teaching of evolution. The chapter concludes with a discussion on the NOS that forms the conceptual framework.

Chapter Three discusses the interpretive paradigm used. The case-study design within in a qualitative approach is discussed. The instruments used to collect the data, namely the questionnaire, the classroom observation and the post-lesson interview are also discussed in this chapter. The chapter concludes with a discussion of the sample, data analysis strategy, issues of validity, reliability and ethical considerations.

In ***Chapter Four,*** the findings of the study are discussed. The findings are based on the interpretations of the data obtained from a case-study of three Life Science teachers teaching evolution. The data is analysed using a narrative approach.

Chapter Five presents a discussion of the findings and the conclusions derived from the findings. I respond to the findings by discussing the possible reasons for the way the three teachers teach evolution. One of the major factors discussed is the teachers' understanding of

the NOS and how it affects their teaching of evolution. Furthermore, a number of recommendations are made based on the findings of the study.

1.7 List of acronyms used in the study

CNE - Christian National Education

DoE - Department of Education

FET - Further Education and Training

NCS - National Curriculum Statement

NOS - Nature of Science

PCK - Pedagogical Content Knowledge

1.8 Conclusion

This chapter explained the controversial nature surrounding the teaching of evolution in South Africa and the challenges facing teachers. The need to establish the link between the teachers' understanding of the NOS and their teaching strategies is explained in detail. The next chapter introduces the literature review and conceptual framework that will assist in my research design, analysis, findings and recommendations.

CHAPTER TWO

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1 Introduction

This chapter presents the review of the literature pertinent to my research, conducted both nationally and internationally, as well as the concept used to frame the study. The broad themes of the literature covered focus on issues around teaching evolution and the effect of teachers' understanding of the NOS on the teaching of evolution. Furthermore it presents views of the NOS and attempts to show how the findings of this research could fill some gaps in the existing literature. The chapter concludes with a discussion on the NOS that forms the conceptual framework of the study.

2.2 Review of the literature

Much of the research pertaining to teachers' understanding of the NOS and its influence on their classroom practices has been conducted in the United States of America (USA). This and other international-based literature will form the background against which South African research may be contrasted. Teaching a controversial topic like evolution presents many challenges in South African classrooms even for the 'experienced' science teacher where huge class sizes and lack of resources prevail (Ngxola & Sanders, 2008). Research within the field of teaching evolution is rapidly unfolding since the inception of the FET curriculum. The research has generally focused on teachers not implementing the curriculum in accordance with the NOS (Sanders, 2008; Branch, 2009) and resonates with research done further afield (Rutledge & Warden, 2000; Farber, 2003; Nelson, 2008). However, much of the focus has been on teachers' teaching strategies and curriculum design and very little attention on understanding why teachers teach evolution the way they do based on their understanding of the NOS (Eick, 2000; Trani, 2004). A review of the literature also reveals that not many studies have been conducted in this field in South Africa and in other parts of the world. My study includes a perspective on the NOS, which many studies on evolution do not have. The NOS and its impact on the teaching of evolution requires some discussion as it

is crucial to my study in terms of understanding how teachers' understanding of the NOS influences the way they teach evolution.

2.2.1 Issues concerning the teaching of evolution

Teaching the theory of evolution is a contentious issue around the world. The USA in particular, has been faced with much opposition from the public and religious groups resulting in many law suits and anti-evolution incidents. The one well known case that was most publicised was the Scopes monkey trial in Tennessee in 1925, which attracted global attention (Hermann, 2008). Court cases have ruled in favour of teaching evolution in public schools, however teachers are being pressured to teach the alternative, creationism and intelligent design, instead, as many American citizens are still questioning the validity of the theory of evolution.

In Europe, the situation is less volatile than the USA, although in certain European countries similar problems have arisen. Teachers are encouraged to present evolution as being speculative and questionable. The slogan '*Teach the Controversy'* is aimed at teaching evidence against evolution, thereby promoting creationism (Scott, 2007). It is also common practice in European schools to teach evolution in lower grades and exclude the section in the twelfth grade curriculum, leaving learners with the impression that evolution is not an important topic in Biology (Prinou, Halkia & Skordoulis, 1989).

In many countries in the Middle East, teaching the theory of evolution remains a social controversy. Some Muslim and Christian-orientated communities with strong religious beliefs have accepted the validity of evolutionary science but still maintain that it does not pertain to humans (BouJaoude, Asghan, Wiles, Jaber, Sarieddine & Alters, 2010). According to BouJaoude et al. (2010), this form of thinking has spilled into the classrooms where teachers have resorted to a compromise by integrating evolutionary concepts in the biology curriculum without using the word 'evolution'.

In contrast to many other parts of the world, where evolution has been taught for a long time (albeit with much controversy surrounding it), South Africa only introduced evolution as part of the Life Sciences (previously called Biology) FET curriculum in 2008. Since its inception, the teaching of the topic has raised many concerns in South African classrooms for various

reasons (Ngxola & Sanders, 2008). These concerns are elaborated on in the sections that follow.

2.2.1.1 Teachers' knowledge and understanding of evolution

The lack of knowledge that teachers have about evolution is not limited to the South African context, it is a problem encountered by teachers around the world and consequently impacts on the learners' understanding of evolution (Irez & Cakir, 2006; Lederman, 1999; Rutledge & Mitchell, 2002; Water-Adams, 2006). Much of the literature in this respect relates to the teachers' lack of understanding of the NOS and therefore lack of a thorough understanding of the theory of evolution. Lederman (1999) suggests that "teachers need to internalise the instructional importance of the NOS and their intentions to address the topic firmly in place," (1999, p. 927). The insufficient knowledge of evolution is largely due to teachers not being comfortable with the topic due to its controversial nature (Ngxola & Sanders, 2008).

Locally, many teachers feel insecure with regard to the teaching of evolution as they have never been taught the topic themselves (Stears, 2006) and therefore lack the pedagogical content knowledge (PCK) to teach the topic effectively (Sanders, 2008). Focusing on teachers' preparedness for teaching evolution, Stears (2006) and Sanders (2008) are of the view that learners have a poor understanding of the theory of evolution due to their teachers' lack of understanding of the topic. Farber (2003) in his study emphasises the 'fortress mentality' strategy used by teachers to present evolution to learners. The study reveals that teachers are often inclined to teach evolution as if they are required to defend it. Sanders (2008) illustrates the importance of teachers acquiring the PCK as well as the subject knowledge by summarising Shulman's (1986 & 1987) *Model of Pedagogical Reasoning and Action* to improve their teaching of the topic. Much of the focus mentioned above is based on the teachers' PCK and their understandings of the NOS.

2.2.1.2 Lack of professional development

The lack of teachers' knowledge of evolution is a clear indication that life sciences' teachers are in need of professional development. However, much of the success of professional development programmes depends on the quality of what is being offered. Eick (2000), Rutledge and Mitchell (2002) and Shah (2009) concur that professional development programmes are only effective if they promote the understanding of the NOS and its role in

evolution. This understanding may then lead to more effective classroom practices. Shah (2009) strongly suggests that teachers should also have follow-up support in their classrooms as professional development programmes may not prepare teachers for the ‘‘uncertainties, challenges and situational factors’’ they may encounter in a realistic classroom environment. The lack of adequate training for South African teachers by the Department of Education (DoE) has added to the teachers’ insecurities (Ngxola & Sanders, 2008). More quality professional development programmes together with follow-up classroom visits that Shah (2009) alludes to, may improve the situation (the teaching of evolution) not only in South African schools but globally. However, if evolution is the underlying principle of Biology, all Biology should be taught with evolution in mind. Most teachers have not yet received this kind of biology education and this raises the question if knowledge and understanding of evolution can be developed by short ‘in-service’ add-on courses.

2.2.1.3 Resistance to teach evolution

In addition to inadequate training, teachers are faced with a topic associated with extreme controversy. Like the controversy in the USA where education authorities have been faced with resistance (Moore, Jensen and Hatch, 2003), South Africa is no different. The controversy has resulted in teachers omitting the section on evolution or paying little attention to it (Moore, Jensen and Hatch, 2003). Teachers fear teaching evolution as they do not want to undermine learners’ beliefs in the classroom as well as antagonise parents (Ngxola & Sanders, 2008; Sanders, 2008; Stears, 2006). Teachers themselves are guided by their own knowledge and beliefs when it comes to their classroom practices, which in turn often hinders the teaching process (Van Driel, 1998 & Rutledge & Mitchell, 2002).

2.2.1.4 Poor understanding of the NOS

Teachers who have a poor understanding of the NOS teach evolution in isolation as content knowledge and do not integrate evolutionary perspectives throughout the programme (Rutledge & Mitchell, 2002; Rutledge & Warden, 2002). The same applies to most South African teachers in their implementation of the FET curriculum. This results in learners having a poor understanding of science and the theory of evolution. A poor understanding of the NOS also results in teachers not being able to differentiate between science and their strongly-held religious views (Rutledge & Mitchell, 2002; Rutledge & Warden, 2002). This

results in teachers making poor curricular and instructional decisions when faced with the topic of evolution.

2.2.1.5 Religion

The historian Wills (1990) was of the opinion that the evolution/creation debate will never subside because the Bible remains the central book of Western culture. Religious beliefs are entrenched in the Bible's Old Testament book of Genesis which focuses on morality and human behaviour. Creationists view evolution as contradicting the existence of a God and its teachings as the promotion of moral decline in society (McInerney, 1997; Sanders, 2008). A study by Asghar (2010) revealed that muslim science teachers accepted evolution of living beings except human beings as human evolution contradicted their Islamic beliefs. The study concluded that the muslim teachers lacked a clear understanding of biological evolution.

Extensive research has shown that science teachers are no different from the general public in terms of their understanding of evolution. Their abilities to understand and accept the theory of evolution are also often mediated by strongly held religious beliefs (Jackson, Meadows & Wood, 1995; Dagher & BouJaoude, 1997). These beliefs, according to Jackson et al. (1995) can prevent the complete and scientifically grounded teaching of evolutionary theory. Teachers with strong religious beliefs compromise the strategies they use to teach evolution and teach the controversy based on their creationist views. The challenges faced by teachers may lead to the explicit teaching of alternative conceptions of evolutionary theory and the role of theory in science.

However, Reiss (2008) is of the view that teaching aspects of religion in science lessons has its merits. He believes that it may help learners to better understand the NOS and its limitations thus emphasising the importance of social contexts for science. Scott (2007) disagrees with this view, as engaging learners in the controversy may inevitably allow learners to believe that scientists are questioning the theory of evolution. This 'evidence against evolution' misinforms learners about the NOS and adds to the uncertainty and misconceptions surrounding the topic of evolution.

2.2.1.6 Misconceptions

Many of the misconceptions associated with evolution originate from a poor understanding of the NOS (Sanders, 2008). Due to the controversy, one of the most commonly held misconceptions is that evolution contradicts religion. This misconception implies that one needs to make a choice between believing in evolution or the existence of God (Sanders, 2008). While evolution does in fact contradict religion, there is no scientific evidence supporting creation, God, or supernatural forces. This initiates many debates in classrooms which demonstrate a lack of scientific understanding. According to Sanders (2008), since evolution is referred to as a 'theory', it creates room for speculation and therefore the topic is not given the seriousness it deserves as being the cornerstone of Biology. The theory of natural selection itself is misunderstood. Many people believe that the process of natural selection involves organisms trying to adapt, demonstrating a poor understanding of the concept of 'genetic variation'. The missing pieces of fossil evidence also create the misconception of evolution being disproved, adding to the uncertainty associated with the topic (Sanders, 2008).

The teaching of evolution raises many concerns for Life Sciences teachers. Many teachers disagree on how to address these concerns (Ngxola & Sanders, 2008). This study therefore explores the teachers' understanding of the NOS as a possible way forward in addressing concerns about the teaching of evolution. Dobzhansky (1973) believed that if learners are to understand Biology (now called Life Sciences in the South African curriculum), then the theory of evolution is most appropriate to illustrate that Biology is a 'quest for understanding the natural world' and not a body of facts to memorise. Teachers need to link the NOS to the learners' social and cultural world if learners are to understand and relate the theory of evolution to their daily lives. However, this can only be achieved if teachers understand the NOS (Trani, 2004).

2.2.2. Teaching evolution through inquiry

Due to the many misunderstandings about the NOS, teaching evolution using inquiry-based lessons may promote better scientific understanding as learners will discover that the scientific evidence can be gathered using other methods besides the laboratory method and therefore have a better understanding of the theory of evolution. Inquiry-based learning is a process where learners are involved in their own learning, formulate questions, investigate

widely and then build new understandings, meanings and knowledge (Alberta Education, 1990). Research suggests that using inquiry-based learning can help learners to become more creative, more positive and more independent (Kuhne, 1995). This type of learning can dispel the negative attitudes and biased thinking associated with the topic of evolution. Kuhne (1995) explains that inquiry-based learning encourages learners to be independent thinkers. This would prevent teachers from telling their side of the 'evolutionary story' as this type of learning encourages learners to construct their own meanings. Evidence has also been reported that inquiry-based teaching is an effective means of fostering scientific processes, vocabulary knowledge, conceptual understanding and critical thinking (Lindberg, 1990; Loyd & Contreras, 1985 and 1987). Teaching evolution through inquiry requires a new form of skill and instructional activities. However, teachers are only able to provide these instructional activities if they have a thorough understanding of the NOS. Inquiry-based learning is a process that requires teachers to follow five steps (Adapted from Bybee, 1989) as discussed below.

Teachers have to *engage* with the learners to elicit their prior knowledge which in turn raises interest and motivation. This leads to the *exploration phase* in which learners receive instructional or hands-on activities. This phase promotes learning and leads to the *explain phase* in which the teacher asks the questions and facilitates interactive discussions about the activities. The *elaborate phase* follows in which the learners apply their newly acquired knowledge and skills in real life contexts. The approach concludes with the *evaluation phase* in which the teacher assesses the learning.

If learners are to genuinely understand scientific practices and if they are to become equipped with the ability to think scientifically through everyday issues, then inquiry-based lessons may need to be a prominent feature of their education in science.

2.2.3 The Nature of Science (NOS)

"The Nature of Science refers to the epistemology of science as a way of knowing or the values and beliefs inherent to the development of scientific knowledge," (Lederman, 1992, p. 331). The works of Hodson (1991) and Lederman (1992) have contributed to a greater understanding of NOS. Their work has highlighted the understanding in the scientific community of the NOS as a process of doing science (scientific method). Dewey (1916) for

example believed that the scientific method was more significant than the gaining of scientific knowledge. Conant (1951) in agreement with this view suggested that students understand the tactics and strategies of science. I agree with this view that not only one method exists, but that a number of strategies assists scientists in obtaining information.

The NOS has also been extensively viewed from both social and historical perspectives. Karl Popper's (1963) idea of falsification was a meaningful contribution to a better understanding of NOS. According to Popper (1963) scientific theory and human knowledge generally are irreducibly conjectural, and is generated by the creative imagination in order to solve problems that have arisen in specific historic-cultural settings. This view brought the notion of objectivity to the fore. My experience is that scientific knowledge is interpreted differently, depending on the socio-cultural background in which this knowledge is generated. This means that scientific endeavours cannot really be objective. Kuhn's (1962) examination of the history of science fore-grounded the tentative NOS. The understanding of the NOS traces back to the early 1900's where emphasis was already being placed on the scientific method. Scholars were already listing the NOS objectives in their work and delivering lectures that advocated a historical approach to science instruction. (Lederman, 1992). While it is therefore necessary for life sciences teachers to teach the content knowledge in science lessons, it is also important for them to illustrate to learners that science is more than a body of knowledge. They need to be aware that scientists are continuously doing investigations, debating the truth and beliefs of how scientific knowledge became accepted by the scientific community. Science lessons should therefore incorporate the construction of scientific knowledge, the tentative Nature of Science and how scientific knowledge can be changed or modified when new evidence becomes available.

An extensive body of literature exists which discusses the different aspects of the NOS. I will discuss three views, Bell (2008), Kimball (1968) and Almazoroa (1998) to illustrate how the NOS may be defined. Bell (2008) defines seven key concepts within the context of school science. According to Bell (2008), the goal of science education is to develop scientifically literate learners. Scientific literacy entails learners having an understanding of the NOS if they are to function as productive members of society. Bell's seven key ideas are viewed as one of the more useful working ideas in developing scientific literacy (Lederman, Abd-El-

Khalick, Bell and Schwartz, 2002; Osborne, Collins, Ratcliffe, Millar and Duschl, 2003; Bell 2008).

The first key idea is the *tentative* nature of scientific knowledge. One of the main areas that has surfaced in the literature regarding teachers' and learners' understanding of the NOS and evolution is that science is commonly perceived as being unchangeable. Learners therefore need to be taught that although science is based on facts, scientific knowledge is also tentative. As new evidence emerges, scientific laws do change (Bell, 2008). There are a number of examples in the life sciences curriculum that illustrates this point. My understanding of science is based on the belief that is science is factual. Science is dynamic because it forces one to ask questions. These questions eventually bring about solutions which serve as new scientific knowledge. The second key idea is *empirical evidence.* One of the misconceptions that arise is that scientific laws are products of experimental data, when in fact; empirical evidence may be obtained from a number of methods (Bell, 2008). This concept can be applied when teaching Darwin's theory of natural selection. For example, Kettlewell's (1959) experiments with 'peppered moths' in Britain, allowed Darwin to formulate his theory of natural selection. This also applies to the study of fossils where experimental methods cannot be implemented to obtain information. The third key idea is *observations and inferences*. Learners need to be made aware that the theory of natural selection originated from many observations and inferences. Empirical evidence is obtained through observation and inference. It is important to differentiate between observations and inferences. Inferences are making decisions based on experiences from observations. The fourth key idea deals with *theories* and *laws*. The misconceptions that have surfaced in the literature regarding the formation of theories and laws reveal that these two concepts are not taken seriously by learners due to their general use in the English language. This applies especially to 'theory'. However, both concepts are underpinned by substantial evidence, but are nevertheless subject to change if new evidence emerges. According to Bell (2008), these concepts are fundamental tools of the scientific community. 'Theory' in everyday life refers to speculation. It is this meaning that has been associated with a scientific theory. In a scientific context, the word 'theory' is based on the scientific method and principles to explain phenomena. The fifth key idea is the *scientific method.* The scientific method, a systematic way of doing science, is poorly understood by teachers and hence incorrectly presented to learners (Farber, 2003). Abd-El-Khalick et al., (2002) emphasises that teachers

need to be explicit when exposing learners to the scientific method by engaging them in a variety of approaches to understand phenomena. This will enable learners to understand that there is no one '*scientific method'.* I believe that scientific methods generate knowledge which is reliable and valid. Based on this understanding, I believe evolution to be a valid scientific theory. Evidence may not be in the form of experimental evidence but rather in the form of observational data. The sixth key idea deals with *objectivity and subjectivity.* Societal influences play a significant role in the development of scientific knowledge, resulting in subjective views of the scientific endeavour. Therefore scientists need to apply self-checking mechanisms to ensure objectivity. The seventh key idea deals with *creativity.* The mindset that scientists are dull and boring people needs to transform. Teachers need to promote the idea of creativity as being the main constituent of innovations and inspiration in the scientific world (Abd-El-Khalick et al., 2000; Bell, 2008). The example of Watson and Crick who described the structure of DNA comes to mind in this regard. The seven concepts discussed best describe the NOS within in a school context and should be infused in the teaching of science so that learners may develop a meaningful understanding of science.

Kimball (1968), on the other hand, produced eight principles for NOS, which were later revised and reduced to six principles by Anderson and Rubba (1978). The National Science Teachers Association (1982) also contributes by stating that science knowledge is empirical, tentative in nature and open to inquiry. The Science for all Americans (1990) advanced three major components for the basic understanding of the NOS. These three major components are: Science is tentative and does not answer all questions; the NOS is based on inquiry and relies on empirical-based observations (creative and human endeavour) and that science has social and political roots. The National Research Council (1996) added that science is based on skepticism and strongly embedded with personal, societal and cultural beliefs.

Having reviewed the multifaceted views of the NOS in the literature, McComas, Clough and Almazoroa (1998) have summarized fourteen consensus views about the NOS. The first view is that scientific *knowledge while durable has a tentative character.* One of the main areas that have surfaced in the literature regarding teachers' and learners' understanding of the NOS is that science is commonly perceived as being unchangeable. This view can be easily interpreted as a contradiction as this view of science is considered to be reliable with theories and laws which form the content of the subject. However, the theories and laws can change

when new evidence emerges from observations. The second view is that *scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and skepticism.* This view implies that scientists formulate scientific theories as a result of observations. These observations may be conducted in various ways. The third view is that there is *no one way to do science*. This view implies that there is no universal step-by-step scientific method. The fourth view explains that *science is an attempt to explain natural phenomena.* The fifth view is that *people from all cultures contribute to science.* This view addresses the stereotypical view that only white western culture has the ability to contribute to science. For example, the Myan cultures have made significant contributions to science with their indigenous knowledge belief systems. The sixth view is that *science is part of social and cultural traditions.* The seventh view highlights that the fact that *laws and theories serve different roles in science*. This view addresses the misconception that theories become laws when new evidence becomes available. The eighth view highlights that *new knowledge must be reported clearly and openly* to avoid possible misconceptions. The ninth view emphasises that *scientists require accurate record keeping, peer review and replicability,* thereby ensuring validity and reliability. The tenth view explains that *observations are theory-laden.* The eleventh view addresses the view that *scientists are creative,* dispelling the myth that scientists are dull and boring people. The twelfth view deals with the *history of science revealing both an evolutionary and revolutionary character.* This view rein forces the dynamic Nature of Science. The thirteenth view discussed the link between *science and technology and how they impact on each other.* This view explains how technology improves scientists or people asking questions, therefore resulting in new scientific ideas, illustrating the tentative Nature of Science. The last view explains how *scientific ideas are affected by their social and historical milieu.*

Research in the field of the NOS indicates that there is no single understanding of the NOS but the fourteen consensus views outlined above, provides a variety of the NOS elements and the degree of consensus for science instruction (McComas, Clough and Almazoroa, 1998).

2.2.4 How the understanding of NOS may impact on teaching

According to Duschl (1987) teachers make the most critical decisions regarding the education of students. These decisions will be influenced by their understanding of the NOS, in turn influencing their attitude towards science. Hodson (1988) is of the view that the teachers'

attitudes towards science can be determined by their teaching styles. Shulman (1986) and Brickhouse (1990) have demonstrated that teachers' personal understanding of the subject matter they teach significantly influences their classroom instruction. The fundamental principles of shaping teachers' understandings of science are the conceptions they hold about the NOS (Hammrich, 1997). It can be concluded that a person's understanding of the NOS determines what their view of science is and subsequently how it should be taught.

Extensive research in the field of the NOS has demonstrated that both teachers and learners' beliefs of the NOS are inconsistent (Abd-El-Khalick & Lederman, 2000). This is due to the teachers' understanding of the NOS which determines their beliefs about what science is. These beliefs have an influence on the way they teach and consequently what learners learn about science. This is especially important when teaching a controversial topic such as evolution where misconceptions are easily formed. My study aims to determine what views the teachers participating in the research hold with regard to the NOS.

A similar study in the field of the NOS has revealed how teachers' understanding of the NOS influences their teaching in significant ways (Singh, 1998). The study reveals how teachers struggle to teach the NOS because their epistemologies are formed by their socialisation as teachers and how they were taught as learners, and therefore their identities have an effect on their understanding of the NOS. Textbooks, curriculum, teacher education, their own schooling experience and philosophies about science in the past (the old curriculum) shaped teachers' understandings about the NOS. For example, most teachers have a linear view of science. According to Shah (2008), teachers view science as a fixed body of knowledge that cannot be challenged. This linear view of science results in teachers viewing scientists as the only ones who can construct scientific knowledge, resulting in science lessons being presented as a body of facts that learners need to memorise. Hodson (1998) is of the view that this depersonalised image of science is a serious misrepresentation of the NOS and scientific practice. In a more recent study by Water-Adams (2006), "teachers acquired a confidence in their science practice only when there existed a resonance between their ideas about how to teach science, their understanding of the NOS, and their general beliefs about how they should be teaching children" (2006, p. 21). It may be concluded that the NOS may relate to different forms of practice, depending on the character of the teachers' understandings.

Lederman's research (1992) revealed that science curricula in all countries agree on the ''development of an adequate understanding of the NOS'' (1992, p. 331). This suggests that the NOS can be regarded as the cornerstone in the teaching of science. His findings also revealed that an individual's belief concerning whether or not scientific knowledge is amoral and empirically-based or tentative and a product of human development reflects that individual's conception of science. The study (Lederman, 1992) demonstrated that science teachers also agree that if science teaching is viewed as a purposeful and conscious act, then a teacher must possess an adequate knowledge of the NOS. Lederman (1992) concluded that teaching experience does not contribute to a teacher's understandings of the NOS. Bearing this in mind, my study involves participants with various years of teaching experience. Lederman (1992) also concluded that there could be some connections between teachers' views on the NOS and their conceptions of learning and teaching. Lederman's findings are relevant to my study in terms of how Life Sciences teachers' understand the NOS when teaching the theory of evolution.

Various studies conclude that teachers' understandings and beliefs about the NOS no doubt influence their classroom instruction. A common conclusion is that teachers cannot possibly teach what they do not understand (Abd-El-Khalick & Lederman, 2000; Abd-El- Khalick, Lederman & Zeidler, 1987). The naïve conception of science held by teachers strongly emphasises a rote type of learning of science content. This type of classroom instruction does not allow learners to develop an understanding of where the knowledge originates from (Shah, 2008). This makes it difficult for learners to understand the theory of evolution since they are unable to relate science to their daily lives.

The above literature signals an attempt to illustrate how teachers' understanding of the NOS may impact on their teaching of science. Inevitably, the quality of teaching rests with the teacher. Therefore Life Sciences teachers need a thorough understanding of the NOS to illustrate to learners that evolution is the organising principle of Life Sciences.

2.3 Conceptual framework

A number of concepts pertaining to the NOS served as a lens for this study as I explored teachers' understanding of the NOS and the influence of these understandings on the way they taught evolution. I have selected six aspects from Bell's (2008) framework as the

framework for my study. These aspects informed the construction of my instruments as well as the analysis of my data.

The diagram in Figure One represents six important statements with regards to NOS that served as a framework for the study.

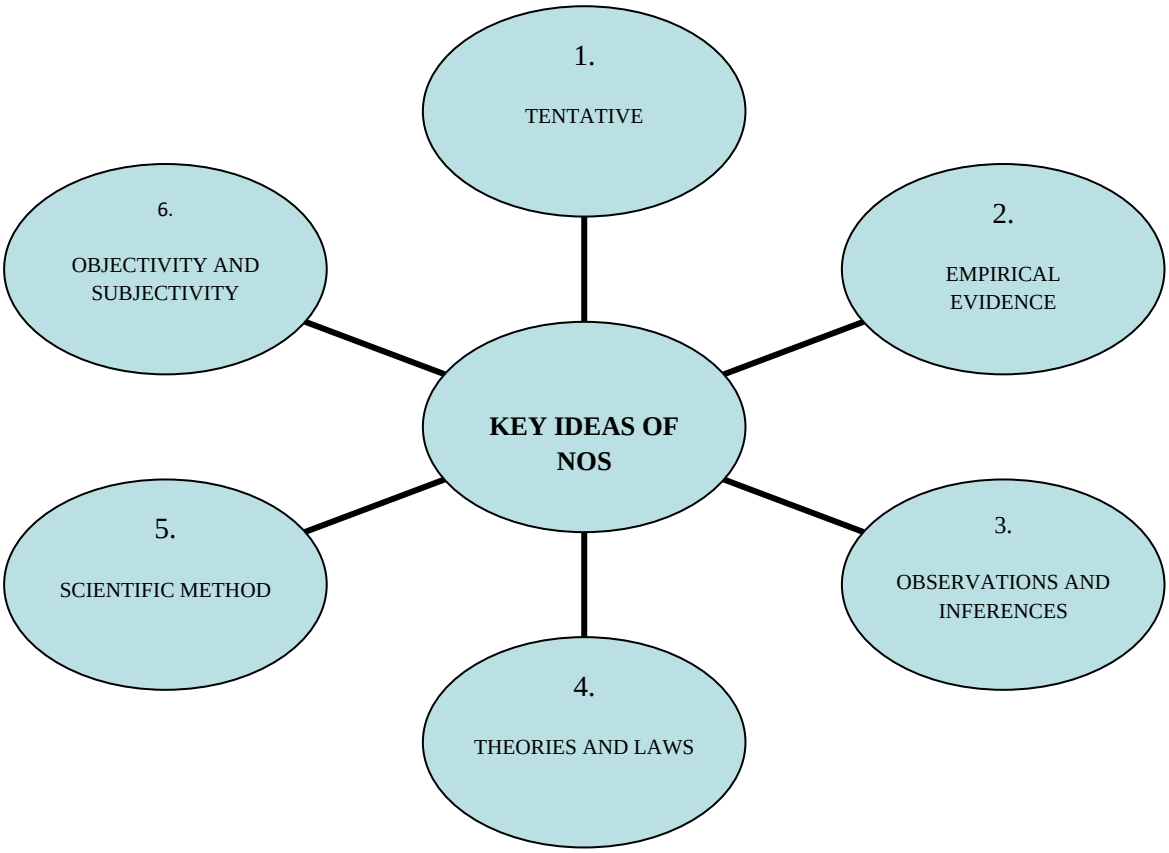

FIGURE 1: Six key ideas of NOS extracted from Bell (2008).

1. The tentative Nature of Science

The theory of evolution is a fact, but explanations for the way in which it may have occurred differ. Explanations for the manner in which evolution and natural selection may have occurred is tentative as every time new evidence emerges, understandings change. Research in the field of teaching evolution has revealed that teachers miss an opportunity to illustrate to learners the dynamic Nature of Science by using Darwin's theory of natural selection to explain how new ideas and interpretations emerge (Farber, 2003). Teachers teach natural selection but neglect to mention to learners that it took Darwin over twenty years to publish

his theory as he originally encountered many specific problems with his original theory of evolution, which eventually resulted in a new theory. Farber (2003) makes a valid point that it is important to dispel the myth that science is static, making the theory of evolution more acceptable. If teachers believe that science is tentative, then they are inclined to illustrate to learners that as new evidence emerges, explanations change.

2. Empirical evidence

Many teachers engage learners in routine laboratory work to teach the scientific method and this has created the misconception that an experimental approach is the essence of the NOS (Eick, 2000; Farber, 2003; Sanders, 2008). McComas, Clough and Almazoroa (1998) are of the opinion that there is no universal step-by-step scientific method and puts forward that science is a blend of logic and imagination. They argue that a variety of imagination and thought may be used when formulating hypotheses. Learners need to be made aware that scientists do not only work with data and well-developed theories. If teachers believe that scientific laws and theories are always produced through experimentation then they will be inclined to adhere to a 'recipe type' of scientific method to gather evidence. Similarly if teachers believe that scientific experiments are the only way of providing conclusive proof about phenomena, and then they may fail to illustrate that observations also provide proof about phenomena.

3. Observations and inferences

Learners need to be made aware that the theory of natural selection originated from many observations and inferences and is therefore reliable and valid. These two terms are often misunderstood by both teachers and learners. Observations involve the use of five senses to gather information and inferences involves developing explanations from observations (Bell, 2008). Teachers who believe that scientific laws and theories are only produced through experimentation are not likely to see the value of observation and inferences in scientific endeavours.

4. Theories and Laws

Studies have revealed that the use of terminology such as 'facts, laws, hypothesis and theories' are also often misused and undifferentiated by teachers when teaching evolution, creating uncertainty among learners (Eick, 2000; Farber, 2003; Sanders, 2008). The

misconceptions that have surfaced in the literature regarding the formulation of theories and laws reveal that these two concepts are not taken seriously by learners due to their general use in the English language.

5. Scientific method

Farber (2003) argues that learners need to be exposed to other forms of the scientific method, other than the experimental procedure. My observations in this regard would be to see if teachers are illustrating to learners that a variety of scientific methods were used to investigate the evidence for evolution. For example, Darwin spent many years testing his theory of natural selection through experiments and observations.

6. Objectivity and subjectivity

Teachers, who believe that scientists are objective and that science should always be objective, are unaware of the way in which socio-cultural factors influence scientific explanations. This mindset makes it more difficult for such teachers to accept the tentative NOS and different explanations for natural phenomena.

The above discussion illustrates how different constructs of the NOS may be linked to teachers understanding of scientific phenomena as well as their teaching. These six constructs guided the construction of my instruments. In reporting the findings I have attempted to show how the data was linked to the constructs discussed above. This was done by including the relevant number of the NOS construct represented in the diagram in brackets at the end of a stated finding e.g. NOS1, 2 etc.

2.4 Conclusion

In this chapter literature pertaining to the teaching of science within the framework of the NOS was discussed. This discussion provided a broad overview of how teachers' understanding of the NOS influences their teaching in different ways. A discussion of the NOS as my conceptual framework presented the key ideas which define the NOS.

In Chapter Three the methodological framework of the research will be discussed. This includes various issues related to conducting research. In this chapter I will also explain how I used the conceptual framework.

CHAPTER THREE
METHODOLOGY

3.1 Introduction

A review of the literature in the previous chapter revealed that teachers generally do not implement the curriculum with regards to the theory of evolution due to the many issues associated with the topic. Gaps in the literature reveal that limited research exists with regards to teachers' understanding of the NOS in relation to the way in which they teach evolution.

In this chapter the methodological framework and research design selected to generate data for the study will be described and explained in detail. I will indicate how the paradigm in which my research is located determined my research approach, as well as the research design. My choice of an interpretive study within a qualitative research paradigm will also be justified. I also discuss my choice of a case study inquiry and the data collection methods, namely the questionnaires, classroom observations and post-lesson interviews. The sampling procedures and the data analysis strategy are subsequently discussed, as well as the presentation of the findings. The chapter concludes with a discussion on the validity, trustworthiness and ethical concerns and limitations of the study.

3.2 Methodological framework

Paradigmatic assumptions and perspectives impact significantly on methodological choices and demand a consideration of different research methods (Cohen, Manion & Morrison, 2007). My study is located within an interpretive paradigm and I have applied a qualitative approach. My choice of a case study inquiry favoured the use of unobtrusive data collection techniques which minimises any disturbance to the natural setting. This allowed me to understand the participants from within their natural contexts (Maree, 2007).

3.2.1 Research paradigm

Maree (2007) refers to a paradigm as being the "lens or organising principles by which reality is interpreted," (2007, p. 48). Terre Blanche, Durrheim and Painter (2006) describe

paradigms as “acting as perspectives that provide a rationale for the research and commit the researcher to particular methods of data collection, observation and interpretation,” (2006, p. 40).

My study is located within an interpretive paradigm as the three participants in the study were observed in their day-to-day contexts. “The purpose of interpretive explanation is to foster understanding by providing a theoretical explanation about why events occur and how things work within a specific social context and setting” (Neuman, 2011, p. 84). Working within an interpretive framework, I was allowed to gain insight and form a clear understanding of how the three participants used the NOS in their lessons by observing them in practice. However, Henning, Van Rensburg & Smit (2004) is of the opinion that “observation is fallible and has error and that all theory is revisable,” (2004, p. 19). In order to ensure credibility in my study, I further attempted to make sense of the participants’ teaching strategies thereafter by interacting with them and clarifying their meanings in the form of post-lesson interviews.

3.2.2 Methodological approach - The qualitative approach

My study was conducted using a qualitative research approach. The purpose of my study is to understand how individual teachers teach evolution based on their understandings of the NOS. Wimmer and Dominick (2000) describe qualitative research as an approach which strives to comprehend how individuals in everyday settings construct meaning and explain the events of their worlds.

Denzin and Lincoln (2000) in turn, view qualitative research as an approach which “involves an interpretive, naturalistic approach to viewing the world,” (2005, p. 3). Maree (2007) further describes qualitative research as describing and understanding phenomena within their naturally occurring contexts with the intention of developing an understanding of the meanings imparted by the participants. This research approach can also be best described as “seeing through the eyes of the participants,” (Maree 2007, p. 51).

My choice of a qualitative approach allowed me to gain insight for understanding why life sciences teachers teach evolution the way they do. Henning et al., (2004) refers to this approach as a “quest for understanding and for in-depth inquiry,” (p. 3). Borrowing from Thomas’ (1928) famous dictum that if people define their situations as real then they are real

in their consequences (cited in Cohen, Manion & Morrison, 2007). In terms of my study, life sciences teachers' understanding of the NOS may influence the way they teach evolution. The research approach allows me to obtain thick descriptions of life sciences teachers' understandings of the NOS by the use of the appropriate instruments characteristic of qualitative research. "Thick descriptions represent the complexity of situations and are preferable to simplistic ones," (Cohen et al., 2007, p. 21). The literature in the previous chapter highlighted the complexity of teaching a controversial topic such as evolution and therefore gathering data from the participants cannot be reduced to a simplistic analysis.

3.2.3 Case study

According to Merriam (1998), a case study design is employed to gain an in-depth understanding of the situation and meaning for those involved. Due to the qualitative nature of the study, an instrumental case study has been selected as it is useful in providing theoretical insight into why teachers teach the way they do. It also assisted me in gaining a clearer understanding and acquiring knowledge regarding teachers' understandings about the NOS and how this understanding influences the way they teach evolution.

The case study design is advantageous to research as it provides a large amount of information and detail about the research topic and allows the researcher to deal with a variety of raw data (Wimmer & Dominick, 2000). According to Leedy and Ormrod (2001), case studies are very useful for learning about situations which might be poorly understood or about which not much is known, as in the case of teaching evolution. A criticism of the case study methodology is that the results may not be generalisable due to its dependence on a single case. However, according to Maree (2007) the purpose of case study research is not to generalise but instead to gain more insight and understanding of a specific phenomenon. Other limitations of case study methodologies may include that they are not easily open to cross-checking and therefore prone to bias (Nisbet & Watt, 1984 as cited in Cohen et al., 2007).

My study aimed to understand the relationship between the teachers' views of the NOS and how they taught evolution. In doing so, I needed to acquire an in-depth understanding of the teachers' understanding of NOS. According to Denzin and Lincoln (2000) "an instrumental case study is used to provide insight into an issue or to redraw a generalisation," (p. 445). My

intentions were to inquire about what the teachers' understandings of the NOS were and how these understandings influenced their everyday teaching of evolution. The case study approach was suitable for this study as it allowed me to gain an in-depth understanding of the various teaching strategies employed by the participants when teaching evolution and provided rich descriptions of the participants' perceptions of the NOS and the theory of evolution.

3.3 Sample and setting

According to Cohen et al. (2007) convenience sampling can also be referred to as opportunity sampling. It involves choosing the nearest individuals to serve as participants because they happen to be available and accessible. However, the participants selected for my study do not represent a sample of a larger cohort but is a case study of three teachers who teach Grade 12 Life Sciences were selected due to the convenience of being accessible.

The research was conducted in a Durban suburb where I reside and teach. The three teachers were selected as they were in close proximity. Having taught in the same area for the past eleven years, I had developed an excellent rapport with the Life Science teachers in the neighbouring schools which made accessing the participants easier. The three participants in the study are referred to as Owen, Dolly and Shirley (pseudonyms). All the participants teach at public schools and have an average of forty five learners in their life sciences classes. Owen and Dolly have Junior Secondary Education Diplomas (J.S.E.D) and furthered their qualifications with Bachelor of Arts degrees (B. A). They majored in Biology in their JSED qualification. Shirley has a National Higher Diploma in Education (N.H.D.E) with a major in Biology. Dolly and Owen have been teaching Life Sciences (previously called Biology) for more than thirty years while Shirley, being the youngest participant, has been teaching Life Sciences for twelve years.

3.4 Data collection

Multiple data collection methods were used in the study to enable me to answer my research questions. Data was collected from the three Grade 12 Life Science teachers who taught evolution. The three instruments were used as follows to answer the three research questions:

1) *What are Life Science teachers' understanding of the Nature of Science within the context of teaching evolution?*

The questionnaire (Appendix 1) in this study was used to obtain background information relating to the teachers' understanding of the NOS within the context of evolution. The questionnaires were self-administered by the participants in their spare time and were aimed at achieving honest responses to a sensitive topic such as evolution.

2) *How do Life Sciences teachers' understanding of the Nature of Science influence their pedagogic practice (teaching strategies) when teaching evolution?*

A structured classroom observation schedule (Appendix 2) was prepared to focus on key aspects of the lesson by observing the participants teaching, in order to understand their pedagogic practices, while taking into account their views of the NOS obtained from the questionnaire. Each participant was observed for a total of three hours. The data were recorded on the observation schedules while observing the participants in practice. The classroom observation schedule together with the questionnaire was used to obtain answers to the second research question.

3) *Why do Life Sciences teachers teach evolution the way they do?*

A structured interview schedule (Appendix 3) was prepared to generate more data by clarifying responses from the questionnaires and to probe further into the teaching strategies observed during the classroom observations. The interview method allowed me to personally interact with the participants to gain detailed explanations on their understandings of the NOS. An interpretation of the data obtained from the first two research questions contributed to answering the third research question.

3.5 Methods and instruments

"A key strength of the case study design is the use of multiple sources and techniques in the data gathering process (Maree, 2007, p. 76)". Given the nature of my inquiry, a case study of three teachers, my methods included a questionnaire, followed by classroom observations and lastly post-lesson interviews in order to focus on the NOS and evolution. These methods are explained in more detail in the following section.

3.5.1 Questionnaire

"A questionnaire is a widely used and useful instrument for collecting survey information, providing structured data and being able to be administered without the presence of the

researcher" (Wilson & McLean, 1994, p. 3). A questionnaire was used in the study as it was convenient and could be completed in a short time without my presence. The questionnaire was used to ascertain the extent of the participants' understandings and personal views of the NOS and evolution as well as their teaching strategies.

"The wording of the questionnaire is of paramount importance and pretesting is crucial to their success," (Cohen et al., p. 341). It is for this reason that I chose to use questions from pre-existing questionnaires which had been used in previous studies. The questionnaire was only piloted to gain feedback on the suitability of the questions, the length of the questionnaire and feedback on the open-ended response categories. The pilot involved three colleagues who were not involved in the study. All three colleagues have been teaching life sciences for many years. All three teachers reported the questionnaire to be long and time consuming. However, they did not experience any difficulty in answering the questionnaire and expressed the view that the questions were very relevant for the study.

The questionnaires were administered to the three teachers in an attempt to find out what their understanding of the NOS is within the context of teaching evolution. In addition, it attempted to obtain information on how this understanding influences their pedagogic practice when teaching evolution. The data aimed to seek response to the first two research questions.

Section A of the questionnaire required the participants to complete their biographical details including their teaching experience of Biology/Life Sciences, as well as their experiences with any issues related to the life sciences curriculum that were important for teaching the theory of evolution. This information was significant to ascertain the participants' confidence with the subject matter.

Section B was adapted from two sources. The first part of Section B (Table B.1) contains twelve questions relating to the NOS and was adapted and modified from a questionnaire designed by Singh (1998). Questions six to twelve were related to evolution and was adapted and modified from an online evolution survey developed by the ENSI (Evolution and the Nature of Science Institute), University of Indiana, USA. Reliability and validity of the questions were established by their original sources. An attempt was made to ensure the

trustworthiness of the data by including contradictory statements, for example questions two and five of Table B.1. The second part of Section B (Table B.2) contains questions relating to the teaching of evolution. The final questionnaires were handed directly to the participants in the different schools. The questionnaires were self-administered by the participants during their spare time. All three participants were given sufficient time to think about their responses and to complete the questionnaires. The questionnaire assisted me in obtaining personal information from the various participants in the three schools and allowed me to focus on the principles of the NOS.

Section B made use of a likert-type scale to answer a number of questions related to the NOS and their teaching practices. The scale included response categories, namely agree, strongly agree, disagree, strongly disagree and uncertain. According to Bell (2005) "scales are intended to help researchers discover strength of feeling or attitude," (2005, p. 167). The typical likert scale as described in detail by Maree (2007) forces the participant to either agree or disagree with no possibility of being neutral. However, my design differs by allowing an 'uncertain' category on the scale, thereby eliminating bias and encouraging honest responses. Furthermore, I did not distinguish between the categories 'agree' and 'strongly agree', but took both responses as an 'agree' response. The same applies to 'strongly disagree' and 'disagree'.

The statements were linked to the research questions with the intention of providing insight into the participants' understandings of the NOS as it relates to the teaching of evolution. This section of the questionnaire consisted of closed-ended questions with the intention of providing me with insight into the participants' understanding of the NOS, evolution and their classroom practices. The extensive use of closed questions was appropriate for this study as they were quick to answer and allowed for any sensitive questions to be easily answered. This type of questioning was most suitable for the school context as the educators involved were restricted by time. Oppenheim (1992) suggests that closed questions do not enable participants to add any remarks or explanations to the categories, creating the risk that the categories might not be exhausted and may be biased. In order to overcome this limitation, some open-questions were included in the last category (Section C) of the questionnaire. The statements in Section B focused on the following:

3.5.1.1 The Nature of Science (NOS)

In an attempt to assess the extent of the participants' understandings of the NOS, twelve statements regarding the NOS and their links to evolution were asked (refer to Table B.1). Statement one was aimed at gauging the extent to which teachers accept that scientific facts are obtained by empirical evidence which helps us to understand the world (NOS 2). Statements two and five and six were linked to the tentative Nature of Science (NOS 1). If teachers believe that scientific knowledge is always true then they do not understand that all scientific knowledge is subject to change when new evidence becomes available. These two contradictory statements ensured trustworthiness of the data. Statement three speaks to the objective Nature of Science (NOS 6). Statements four and six attempts to gauge teachers' understanding that more than one scientific method is used by scientists (NOS 5), while statement eleven points to the fact that evidence may be obtained through observations and inferences and not only through experiments conducted in laboratories (NOS 3). Although statements seven to twelve are about evolution, they are intended to gauge teachers' understanding of NOS with regard to the nature of laws and theories in science (NOS 4). If teachers believe that theories are well-supported explanations then they are more likely to treat the theory of evolution as a valid scientific theory. The answers to these statements formed an important source of data in assisting me to gauge their level of understanding of the NOS.

3.5.1.2 Teaching and the curriculum

The statements in this category were related to the participants' teaching of evolution (Table B. 2). The statements were designed to determine how the participants' understanding of the NOS influenced the way they taught evolution by focusing on the strategies they employed. Important aspects such as lesson approaches, learner interactions, the use of resources and presenting evolution as a belief system or scientific phenomenon were raised. This category of nine statements provided further insight into the participants' thinking processes regarding the teaching of evolution in the curriculum. Statement one speaks to the fact that the curriculum advises that alternative belief systems to evolution should be taught. Teaching alternative belief systems may influence teachers' understanding of the significance of theories and laws as fundamental tools of the scientific community (NOS 4). Statement two pertains to the scientific method as it attempts to determine if teachers are aware that the scientific method can encompass a variety of approaches (NOS 5). Teachers who engage in

inquiry-based lessons attempt to stimulate learners' thinking so they would ask questions in the lesson and attempt to discover information for themselves from different sources and in different ways. Statement three is also linked to this aspect in that learner participation is an essential aspect of inquiry-based learning. Statements four, five, six and seven and refer to the nature of scientific laws and theories (NOS 4). The questions are intended to find out if teachers understand the power of a scientific theory and if they are presenting the theory of evolution as a valid scientific theory or as a belief system. Statement eight is linked to the empirical evidence aspect of the NOS (2). If teachers understand that empirical evidence can be obtained in various ways, then they are inclined to present this in their lessons. Statement nine speaks to the acceptance of evolution as a scientific phenomenon. Teachers who present evolution as a scientific phenomenon (NOS 2) may be more inclined to integrate evolution in other themes in the curriculum.

Section C of the questionnaire does not directly relate to the NOS but instead relates to the teaching of evolution as my study is about teachers' understanding of the NOS in the context of evolution. Section C comprised a few open-ended questions related to the teaching of evolution. This enabled the participants to write a free account and explain their responses in Section A and B, thereby eliminating any bias that may have emanated from the closed-ended questions. The questions in this category focused on the participants' opinions and attitudes regarding the teaching of evolution. The responses obtained in this section allowed me to gain insight into the participants' understandings of the NOS and allowed me to compare the various responses from the three participants.

3.5.2 Classroom observations

"What people may do differs from what they say they do, and observation provides a reality check; it also enables the researcher to look afresh at everyday behaviour that otherwise might be taken for granted, expected or go unnoticed," (Robson, 2002, p. 310). The classroom observation schedules in this study were aimed at answering the second research question by observing the participants teaching in order to document their teaching so that I could later analyse my observations. Evidence of how the principles of the NOS such as empirical evidence, theories, facts and tentativeness were engaged with, was obtained during the classroom observations. This was accomplished by observing the three teachers in practice, teaching evolution. The case-study method allowed me to be unobtrusive by

blending into the classroom environments and listening to the various teachers and learners talking about evolution and the NOS. This also gave me the opportunity to directly experience the different teaching environments the teachers operated in. My role as a 'complete observer' in the study allowed me initially to adopt a passive role with the purpose of gathering the data with ease. Maree (2007) suggests that data should never be obtained aggressively but instead the events should be observed in their natural settings. According to Morrison (1993) "observations enable the researcher to gather data on the physical setting, the human setting, the interactional setting and the programme setting," (1993, p. 18). Being in the classroom gave me first- hand experience and information about the classroom environment, the kind of teaching strategies employed by the participants, the classroom dynamics and other techniques and resources that were used to teach a sensitive topic such as evolution. The classroom observation schedule (Sections B and C) contained pre-determined categories of teaching in order to determine if the participants' pedagogy demonstrates their understanding of the NOS as revealed by their responses in the questionnaires. The categories were aimed at establishing evidence of addressing the NOS, teaching strategies and the teachers' knowledge of the subject matter. Each teacher's lesson is discussed within the context of two categories.

3.5.2.1 Delivery of the lesson

My interest here was to inquire if the teachers presented evolution to the learners as a belief system or a scientific phenomenon. Careful attention was paid to the educators' use of specific words, for e.g. 'theories, the NOS and any other words relating to the NOS. By doing so, this allowed me to determine if the educators' understanding of the NOS influenced the way they taught evolution. The first five questions in the observation schedule were aimed at viewing how the teacher uses her understanding of theories and laws to explain the theory of evolution to the learners. I also paid attention to the aspect of the presentation of the evidence for evolution as this also indicated the extent of the teachers' understanding of the NOS in the context of teaching evolution. A good understanding of the NOS would ultimately enable the educators to successfully integrate evolution into other topics of the life sciences curriculum. My observations therefore also focused on the educators' ability to link evolution to other topics in curriculum such as *meiosis and genetics*.

3.5.2.2. Teaching strategies

This category of the observation schedule focused on the pedagogic practices of the educators when they presented the topic to the learners. My observations focused on the creativity of the teachers in terms of their ability to make the lessons interactive and interesting and whether they employed an inquiry-based approach. If teachers allowed the learners to discuss other belief systems, they are therefore implying that the theory of evolution is just a 'theory' and that there are other explanations which learners may accept. Most importantly, my focus was on the ability of the teachers to integrate evolution to other topics in the syllabus as this would be a good indication of their understanding of evolution. This would enable learners to see evolution as the main idea connecting all the topics covered in the curriculum. The data were recorded on a structured observation schedule (Appendix 2). My choice of a structured observation schedule ensured pre-determined observations and maximum use of the time by focusing on the use of the NOS in the lessons. However, due to time constraints, each participant could only be observed for a duration of three hours.

3.5.3 Interviews

The aim of qualitative interviews is to "see the world through the eyes of the participants," (Maree, 2007, p. 87). The observation schedule was a very useful tool to gain deeper insight into the participants' teaching strategies; however observations may be selective and biased. To overcome this limitation, all three participants were requested to participate in post-lesson interviews to obtain clarification where necessary of the data collected.

According to Lincoln and Guba (1985), "the structured interview is useful when researchers are aware of what they do not know and therefore are in a position to frame questions that will supply the knowledge required," (1985, p. 354). Taking Lincoln and Guba's (1985) suggestion into account, a semi-structured interview schedule (Appendix 3) was prepared to save time and most importantly to obtain additional clarity with regard to the data and additional input from the teachers.

Since an interview is a social relationship between the participant and the researcher with the aim of exchanging information, it was necessary to remind each of the participants about the three critical questions pertinent to the research to encourage honest responses (De Vos, Strydom, Fouche and Delport, (2011). A nine-question interview schedule was prepared and

the participants were asked the questions in the same order. The use of the three probing strategies during the interview process assisted in obtaining maximum data. These probes as outlined by Maree (2007, p. 88) included the *detailed-oriented probes* which assisted in understanding the "what" and "why" of the answers given by the participants. The *elaboration probes* allowed me to obtain more details about certain questions. Lastly, the *clarification probes* were used to check my understanding of what was being said. The responses were recorded on paper to later assist with the analysis. According to Leedy and Ormrod (2001) face-to-face interviews enables the researcher to gain the participants' co-operation by establishing a relationship with them. Within this study, establishing such relationships allowed me to gain more information by the participants providing explanations for the strategies used in the delivery of the lessons and their elaborations on their responses in the questionnaires regarding the NOS. The first two interview questions pertained to the scientific method. The aim was to establish if the teachers had a linear view of science and believed in the recipe type of scientific method as being the only approach to gathering data. Question three confirmed the teachers' understanding of a 'theory' by observing how the teacher presented the lesson. Questions four and five were included to confirm the teachers' response to question three. Teachers were given the opportunity to explain their understanding of a 'theory'. Questions six and seven aimed to confirm if teachers had a good understanding of the NOS. A good understanding of the NOS would enable teachers to engage in inquiry-based lessons and teach without complete reliance on textbooks. Questions eight and nine confirm the teachers' understanding of the NOS in the context of teaching evolution. These two questions confirm the teachers understanding of NOS and the theory of evolution. Teachers that understand the NOS and its role in evolution will view the theory of evolution as the underlying principle of Biology and integrate it in their teaching throughout the curriculum.

3.6 Data analysis

There is no single or correct way of data analysis and the strategy should be chosen according to 'fitness for purpose' (Cohen, et al., 2007, p. 501). In terms of my study, the key ideas of the NOS were used as a framework for data analysis. By using these key ideas I was able to analyse perceptions, attitudes and understanding of the participants to determine how they used the NOS in the teaching of evolution.

The closed-ended questions were analysed using a deductive approach to determine the level of the participants' understanding of the NOS and evolution as well as how they used the NOS in their teachings. The open-ended questions were analysed using an inductive approach by reading the responses from the three teachers and placing them into common categories. The initial step in the analysis of qualitative data is the immersion of the researcher within the data in order to become familiar with the information. During this process the researcher will take all the collected data and begin to form clearer understandings of the information (Terre Blanche & Kelly, 2002). The observation schedules were analysed qualitatively by studying each participant's response in detail in order to ascertain how their understanding of the NOS influenced their teaching strategies. Similarly, the semi-structured interview schedule was analysed in order to obtain clarity on the reasons for the participants' teaching strategies.

3.7. Reporting the findings

I chose to report the findings through narrative inquiry. Narrative inquiry refers to a subset of qualitative research designs in which stories are used to describe human action. Polkinghorne (1995) distinguishes between two types of narrative inquiry, namely 'analysis of narratives' and 'narrative analysis'. The 'analysis of narratives' approach gathers stories for its data and analyses these stories to produce categories out of common elements. The 'narrative analysis' approach, on the other hand, analyses gathered data to produce explanatory stories. My study follows the 'narrative analysis' approach as described by Polkinghorne (1995). This type of narrative is better suited to analyse the data in my study as I have studied three particular teachers (life sciences teachers) and produced storied accounts of their understanding, thoughts and experiences about the NOS and teaching evolution. The storied account of each teacher renders meanings to assist in answering the research questions.

3.8 Validity and reliability

Validity and reliability are normally associated with quantitative research. These two terms are suitable for quantitative research as this type of research usually entails replication, a degree of control and manipulation of phenomena (Cohen et al., 2007). The terms 'validity and reliability' are unsuitable for qualitative research as the criteria for reliability differs. "In qualitative methodologies reliability includes fidelity to real life, context-and situation-specificity, authenticity, comprehensiveness, detail, honesty, depth of response and meaningfulness to the respondents" (Cohen et al., 2007, p. 148). Lincoln and Guba (1985)

prefer to replace 'reliability' with terms such as credibility, trustworthiness and dependability. The term 'trustworthiness' refers to the way in which the inquirer is able to persuade the audience that the findings in the study are worth paying attention to and that the research is of high quality (Lincoln and Guba in Johnson and Turner, 2003).

I have set out to ensure truthfulness in the study by the appropriate use of instruments. The questionnaire has been designed with structured, pre-determined and mostly closed-ended questions. The questionnaire incorporated (Sections A and B) the participants' understanding of the NOS and evolution in five ways: *agree, strongly agree, disagree, strongly disagree and uncertain*. The questionnaire is structured as such to encourage honest responses. The inclusion of some open-questions in the last category of the questionnaire enabled the participants to write a free account and explain their responses, thereby eliminating any bias that may have emanated from the closed-ended questions. The few open-ended questions further ensured authenticity as it encouraged the participants to express their thoughts that may not have been covered by the structured questions. I have also considered that the participants may not have been well versed in answering questionnaires and therefore overcame this by keeping the questions simple and straightforward. Trustworthiness was further ensured by having structured interview questions so that each participant was subjected to the same questions. According to Oppenheim (1992) "wording is an important factor in attitudinal questions," (p. 147). Triangulation of the findings from the questionnaire, the classroom observation schedule and the interviews ensured greater trustworthiness of the findings. I have also strived to eliminate any further bias that might be brought to the study by constantly reflecting on the research process.

The questionnaire was piloted to refine the contents to ensure it was appropriate for the targeted participants. I have strived to produce findings that are believable and convincing by presenting inconsistent findings as well in order to provide credibility to the study. The questionnaire was ultimately assessed by both my supervisors, as well as the University of KwaZulu-Natal's ethical clearance department to ensure that it was appropriate for measuring what it was supposed to measure. As this questionnaire was not constructed by me, but adapted from other sources, I accept that the questions produce credible answers.

3.9 Ethics

Due to the sensitive nature of the topic, I proceeded with caution. An ethical clearance form was first submitted to receive ethical clearance from the university (Appendix 4, HSS/0641/012M). Permission was then obtained from the Department of Education (DoE) (Appendix 5) to conduct research in selected schools. Once the permission was granted from both the university and the DoE, permission was then sought in writing from the respective school principals (Appendix 6). Appointments were made with the respective principals where the research was explained and permission was obtained. The principals were most obliging and encouraged the research. The next step entailed obtaining consent from the teachers at the respective schools to participate in the study (Appendix 7). Anyone involved in research needed to be aware of the general agreements about what is proper and improper (Babbie, 2007).

Due to the sensitive nature of the study, I have ensured that informed consent to participate, promise of anonymity, confidentiality of participants and respondent validation were strictly adhered to. According to Cohen et al. (2007, p. 52) "informed consent is the procedure in which individuals choose whether to participate in an investigation after being informed of facts that would be likely to influence their decisions." The purpose of the research was explained to the respective teachers, emphasising that they may choose to withdraw at any time. Written consent was obtained from the three teachers. While all three teachers agreed to the classroom observations and post-lesson interviews, all three were not keen on me tape-recording their lessons and interviews.

3.10 Limitations of the study

Due to the duration of the national teachers strike and the World Cup Soccer event in 2010, the academic year was greatly affected, especially the Grade 12 classes which were part of my study. Each participant could only be observed for a total of three hours each. Due to the completion of the matric syllabus and time constraints, each participant was observed over three hour lessons which were held on Saturdays by the various schools in the area.

3.11 Conclusion

In this chapter, I discussed in detail the research methodology that was selected and justified my choices. The next chapter presents the findings of my study based on the analysis of all the data collected through the research instruments.

CHAPTER FOUR
DATA AND DISCUSSION

4.1 Introduction

The previous chapter covered the methodology applied in this study. I explained my research approach as well as my research design. Furthermore I gave a full account of the instruments used and justified the reasons for choices made with regard to the methodology. I indicated how my conceptual framework was used to shape the instruments. This chapter discusses the findings that emerge from this data. According to Maree (2007), "Interpretive studies generally attempt to understand phenomena through the meanings that people assign to them", (2007, p. 59). The three different instruments produced qualitative data from three life Sciences teachers, Owen, Dolly and Shirley which allowed me to determine how teachers' understanding of the NOS influenced their teaching of evolution.

4.2 The teachers

The findings are reported as a narrative of each teacher within the context of their understanding of the NOS and the way this understanding influences their teaching of evolution. A narrative inquiry was suitable for this study as it was a way of understanding the teachers' experiences. As stated earlier, the narrative approach applied here is that of a 'narrative analysis'. While the narrative follows the findings obtained from the questionnaire, classroom observation and interview (in this sequence), findings from one data source may be integrated in another to substantiate evidence.

4.2.1 Owen's narrative

Owen has been teaching Biology/Life Sciences for 34 years. The biology laboratory is sufficiently equipped with apparatus and resources for learners to work in groups. Owen does not belong to any science education professional organisation. He is of the opinion that the Life Sciences syllabus is too long and yet many aspects of the syllabus are not tested in the National Senior Certificate (NSC) examination. He also feels that certain sections in the syllabus need to be simplified in order to match the capacity of the learners.

Owen believes that science alone cannot provide an understanding of the world. He therefore interprets the 'world' as being more than just the natural word. This is supported by his view that scientific experiments do not provide conclusive proof about phenomena in the world where phenomena appear to mean more than natural phenomena. His agreement that laws and theories are *always* produced through experimentation indicates that he does not believe that other methods produce laws and theories (NOS 5). This implies that he may have a poor understanding of how scientific evidence is obtained. However, he accepts that evidence for evolution may be obtained by methods other than experimentation (NOS 3). While some evidence for micro-evolution may be obtained through experimentation, most evidence for evolution is obtained through observation and inference. Owen believes scientific knowledge is tentative and explained that new discoveries are being made regularly during his lesson (NOS 1). His disagreement that scientific knowledge is always true supports his understanding of the tentative NOS. If teachers regard scientific knowledge as true and static, then they may possibly have a poor understanding of science. Owen's response is an indication that he does understand the tentative NOS. He also views scientists as being subjective people. This suggests that he understands that human influence on scientific practices and science can therefore not be as objective as we may wish (NOS 6). Science is a social construct and not a fixed body of knowledge that exists out there.

Owen accepts evolution as a valid scientific theory and this seems to suggest that he has understanding of the NOS (NOS 4). However, he disagrees that evolution is a fact, which is a contradiction. This may possibly point to a misunderstanding of what a scientific theory is. This interpretation is re-inforced by his uncertainty of what is meant by 'only a theory'. He appears to understand the term theory as it is used outside scientific contexts. If this is the case, it is understandable that he may not view evolution as a fact. However, the fact that Owen believes that evidence for evolution exists, makes it difficult to understand his view that evolution is not a fact. My interpretation is that the term 'theory of evolution' is embedded in his consciousness as the non-scientific meaning of the concept 'theory' making it difficult for him to view evolution as a fact. On the other hand, Owen's responses suggest that he has a fair understanding of some aspects of the NOS and a poor understanding of others. He appears to have a better understanding of evolution despite his confusion between a fact and a theory.

Owen believes his lessons are learner-centered as his lessons are inquiry-based with learner participation. This suggests that he attempts to give learners the opportunity to think, inquire and make discoveries for themselves. He regards evolution as a scientific phenomenon that cannot be debated as if other alternatives exist. However, his positive response to the teaching of alternative views (question 6) appears to contradict his viewpoints discussed above. My view is that while Owen mentions alternatives when he teaches evolution, he points out that scientific evidence exists for various phenomena (as supported during his interview).While he believes that evolution is a valid scientific theory; he does not teach it as a valid scientific theory (NOS 4). It may well be that he is responding to the suggestions made in the curriculum documents (NCS, 2008) where discussions of different belief systems are suggested, but one would think that a teacher who has a good understanding of the NOS would apply a different strategy.

As stated earlier, Owen accepts evolution as a scientific phenomenon and therefore integrates the topic in other themes that he teaches (NOS 2). It is apparent that Owen is aware of the usual statements made about the NOS, namely its 'tentative nature'. This applies to much research about the mechanisms of evolution, as views change as more evidence becomes available (NOS 1). However, Owen seems to misunderstand this, hence the contradiction in his responses. Owen presents the evidence for evolution in his lessons which suggest that he understands that empirical evidence can be in the form of both observational and experimental data (NOS 2 and 3). However, this is in contrast to his responses in the first section of the questionnaire where he agrees that theories are developed by experimentation. These contradictions suggest that Owen's knowledge of NOS does not inform his understanding of evolution.

Owen's responses to the three questions on the curriculum provided some insight into his views of integrating evolution as well as his attitude towards teaching evolution. Although Owen views evolution as a scientific phenomenon his response to *Question 1* suggests that he does not view evolution as the unifying theme in Biology. This is because he suggested that evolution should be one of the two topics removed from the curriculum, should it require shortening. His view that diseases and disorders should also be removed, suggests to me that he does not see the relationship between evolution and this topic which lends itself to exploring variation as the basis for evolution when dealing with human disease and disorders,

as well as antibiotics and its effect on bacterial evolution. There are many other topics where the link with evolution is less clear that Owen could have suggested be removed.

Question 2 and 3 measured Owen's *attitude* towards teaching evolution. He felt that evolution should be taught but with an open-mind so as not to offend any religion- *teachers must be careful in not criticising any religion'*. Owen believed that evolution should always be taught in a comparative way. He allows learners to discuss other viewpoints whilst explaining the difference between religious beliefs and scientific facts. His view that most life sciences teachers would avoid teaching evolution if given the opportunity as it was in conflict with religious beliefs indicates his view that most teachers are unable to teach evolution as he does.

Owen has made contradictory statements. However, he does have some understanding of the NOS in that he believes that science is tentative and objective (NOS 1 and 6). It is difficult to determine if his misunderstanding of a number of concepts related to evolution are as a result of his lack of understanding of the NOS. His poor understanding of the nature of 'laws and theories', as well as his misunderstanding of the 'scientific method' may contribute to his misconceptions regarding evolution. His positive responses regarding evolution gives the impression that he is presenting a view that is regarded as the 'correct view'. His view of the curriculum suggests a poor understanding of evolution as the underlying principle of Biology.

Owen taught the topic 'evidence for evolution'. Two categories were used in the analysis of Owen's lessons: *Teaching evolution within the context of the NOS and Teaching strategies.* Owen commenced the lesson by briefly recapping his last lesson. He introduced the topic by stating that 'scientific ideas are accepted or rejected on the basis of evidence' (NOS 2). He emphasised that nothing in science required any belief or conviction and proceeded with his lesson. This suggests that he considers evolution to be a scientific phenomenon (NOS 2). During his lesson, he made brief reference to the word 'theory' when he spoke about evidence. He made mention of the 'cell theory' and 'atomic theory' to indicate the importance of the word 'theory'. This confirms Owen's belief that evolution is a scientific phenomenon. Evidence of understanding the NOS was apparent in his lesson (the explanation of the origin of cells and atoms). He presented evolution as scientific phenomenon and illustrated to learners the tentative NOS by explaining the contributions to science made by

Lamarck and then Darwin (NOS 1). He illustrated the point of how ideas (genetic) originated from Lamarck but later changed once more evidence became available from Darwin. He also stressed that evolution was a valid scientific theory by presenting all the evidence. Owen was able to integrate the theory of evolution with that of 'genetics' and 'meiosis'. The way Owen presented his lesson supports a better understanding of the NOS than his responses given in the questionnaire.

Owen did not rely on any textbooks in the lesson but used an overhead projector to illustrate pictures of embryology and fossil evidence for evolution. He used known evidence to capture the learners' attention initially. As the lesson progressed, he did not encourage learners to discuss their beliefs, however learners kept on interrupting the lesson to express their views and beliefs. The lesson was interactive in the sense that Owen engaged the learners by asking questions and considering their responses. Owen focused on evidence from paleontology and comparative anatomy. The lesson appeared to be exam driven as he made reference to the exams numerous times. His lessons were basic and lacked an inquiry approach as declared in the questionnaire. The syllabus and examinations dictated how he taught. Owen presented himself as a progressive teacher in the questionnaire, however this is not a true reflection as his pedagogy was more teacher-centered than implied in the questionnaire. Owen's teaching approach suggests that he is very confident with the subject matter as he did not rely on textbooks to guide him. The way in which he presented the evidence for evolution did not reveal his misconception as to how evidence may be obtained.

While the findings suggest that Owen does not have a very good understanding of what a scientific theory is, this was not evident during his lesson. While Owen indicated that he uses an inquiry approach, this was not evident either.

During the interview, Owen had a strong view of presenting evolution as a scientific theory as was also evident in his teaching. His misconceptions with regard to theories and laws therefore do not seem to affect his teaching of evolution.

> *Owen: … It should be taught as a scientific phenomenon and not as a controversial topic. The evidence for evolution is real and scientific and therefore should not be open for debate.*

He appears to understand the link between meiosis and genetics, which is quite obvious, although not with other topics as indicated in the questionnaire. He places much emphasis on presenting the evidence for evolution.

> *Owen: … Learners should be made aware of the scientific evidence and be left to make their own decisions. It is important to use known evidence for evolution, not to create doubt or misconceptions. Start with the evidence for evolution and then proceed with the syllabus requirements.*

Owen strongly feels evolution should be taught in a comparative way by allowing learners to discuss the creationist view. He believes that it is the ideal platform for the teacher to relate the learner's views to the scientific evidence.

> *Learners must be allowed to give their views and the teacher must be able to relate their views to the scientific evidence of evolution.*

Although his teaching is influenced to a certain extent by his knowledge of the NOS, it is also strongly influenced by the pressure of the examination and this pressure appears to override the possible desire to teach it differently.

> *Owen: … We do not have the time to teach that way as the syllabus will never be completed before the exams.*

Owen teaches to the examinations. This is his main focus and what he teaches about evolution is what he knows or what he suspects is bound to come up in the examination.

Owen's narrative is one of a teacher who has some understanding of the NOS but holds certain misconceptions that cloud his understanding of evolution. However, while these misunderstandings are evident in his responses in the questionnaire and interviews, they are not evident in his lessons.

4.2.2 Dolly's narrative

Dolly has been teaching Biology/Life Sciences for 30 years. Her school has a dilapidated laboratory with very little apparatus, most of which is old and deemed unsafe. Dolly does not belong to any science education professional organisation. She is of the opinion that the Life Sciences syllabus is too vast for her learners who have poor capabilities. Dolly's understanding of the NOS in the context of teaching evolution is reported as a narrative based on data from all the data sources (questionnaire, classroom observation and interview).

Dolly believes that science alone cannot provide an understanding of the world. Like Owen, she interprets the 'world' as being more than just the natural world. She believes that

scientific knowledge is always true which indicates a possible lack of understanding what is meant by the tentative NOS. This suggests that she does not understand that science changes as new evidence becomes available (NOS 1). The fact that she agrees that science is tentative supports my interpretation of Dolly's misunderstanding of the meaning of the tentative NOS. This could be a classic example of giving the 'expected' response as this statement is used very often in the discussion of the NOS and evolution. Dolly views scientists as being subjective people which suggests that she understands the human influence on science. Dolly believes that laws and theories are always products of experimentation, which, in my view demonstrates poor understanding of the scientific method (NOS 5). Dolly disagrees that scientific experiments provide conclusive proof about phenomena in the world. Like Owen this could mean that she views phenomena as more than natural phenomena.

Dolly's view of a theory is based on the popular concept of a theory, rather than the scientific meaning (NOS 4). "A theory is a set of principles devised to explain a group of facts or phenomena, especially one that has been tested or is widely accepted and can be used to make predictions about the natural phenomena, " (The American Heritage Dictionary, 2012). The National Academies Press (2012) defines a scientific theory as being "explanations of natural phenomena built up logically from testable observations and hypotheses." Dolly believes that evolution is not a valid scientific theory but instead 'only a theory.' Based on the definitions above, it appears that Dolly does not view evolution as a scientific fact and this is confirmed by her response that she disagrees that evolution is a scientific fact. Dolly's disagreement that there is little evidence for evolution, confirms her misunderstanding of what is meant by facts and theories in the context of evolution (NOS 2). These responses suggest misconceptions with regard to the NOS as well as evolution.

Dolly's believes that her teaching approach is not exam-driven. She believes her lessons are inquiry-based and she encourages learner-participation. Her responses suggest that she understands the variety of approaches that are used to gauge the learners' understanding. She uses debating as a teaching strategy to teach evolution and allows learners to discuss their belief systems (NOS 2). This confirms Dolly's earlier response of evolution being only a theory. She offers alternative explanations to Darwin's explanation which confirms her earlier response that she does not agree that evolution is a scientific fact. Therefore she does not teach evolution as a valid scientific theory. Dolly however believes that scientific

evidence can explain the past and presents it in her lessons (NOS 2). She integrates evolution into other concepts in the syllabus which suggests that she views evolution as a scientific phenomenon. However this response contradicts her earlier response of teaching evolution as a belief system.

Dolly's contradictory responses suggest that she has misconceptions about evolution. While she appears to understand certain NOS concepts (NOS 2 and 4), she does not apply this to evolution. These misconceptions appear to have led to her to not accept evolution as the underlying principle of Biology, in spite of the fact that she integrates evolution in others themes.

Dolly responded to the three open-ended questions as follows: She strongly felt that environmental issues should be removed from the syllabus as they were given sufficient coverage in the media and other subjects as well as in the Grade 10 and Grade 11 life sciences curriculum. She did not recommend evolution for exclusion to shorten the syllabus. However, she did not make the connection between biodiversity, an important environmental issue, and evolution. Dolly regarded teaching evolution as a *bit daunting*. She complained about the topic causing confusion among the learners which supports her negative response to the inclusion of evolution in the curriculum- *the vocabulary is tongue-twisting; different theories put forward do not really portray evolution as one believes it to be.* She did however indicate that the topic made learners aware of the importance of meiosis, genetics and natural selection. Dolly believed that most life sciences teachers would avoid teaching evolution if given the opportunity as it was in conflict with religious beliefs. Dolly noted that teaching evolution involved too much detail- *too much detail to disseminate to the learners.*

Dolly holds some misconceptions of the NOS. In my view she misunderstands the meaning of the tentative nature of science. Her misunderstanding of evolution pertains to the notion of theories and facts. She presents her pedagogy as progressive although her strategies do suggest that evolution is treated as one of a number of alternative explanations for natural phenomena.

Dolly taught the topic: *Natural Selection*. The two categories used in the analysis of Dolly's lessons were also *Teaching evolution within the context of the NOS and Teaching strategies.*

Dolly commenced her lesson by presenting evolution as a belief system and asking learners to discuss their beliefs with regards to evolution with their peers (NOS 4). She then listened to a few of the responses and proceeded to present evolution as a scientific phenomenon. This confirms her earlier response of presenting evolution as a belief system but perhaps due to the syllabus requirements, later presents evolution as a scientific phenomenon. It was clear from the learners' responses that most of them referred to a 'theory' as a 'scientific fact' yet believed that 'theories' were handed down by the elders by listening to indigenous stories. Learners were confused about what a theory meant. The learners held two contradictory views. Dolly then revised the concepts of *theories, facts, experiments and deductions* by using Lamarck's idea as an example to explain a 'theory'. She explained the concepts by using a giraffe to explain why Lamarck's observations were regarded as a theory, and from that point proceeded to explain the other concepts (NOS 3 and NOS 4). She encouraged learner participation by requesting learners to explain the concepts of camouflage and heights of giraffes. She made no attempt to correct the learners' two contradictory viewpoints as her own understanding of a theory is misleading. She regarded Lamarck's observations as a theory and used it to explain the concept of natural selection. Dolly's teaching did not demonstrate evidence of understanding of the NOS as she equated Lamarck's idea to that of a 'scientific theory', adding to the confusion of her learners.

Dolly referred to the textbook on her table intermittently and requested learners to complete an activity from their textbooks. The only evidence she presented for evolution was that from the textbook and she also spoke briefly about the Sterkfontein Caves (NOS 2). She relied on the question and answer method to capture her learners' attention. She did allow the learners early in the lesson to express their views but only received minimal responses. The lesson was teacher-centered with Dolly answering most of her own questions that were posed to the learners. Her teaching appeared to be exam-driven as she focused on exam-type questions. It was interesting to note that her learners were neither enthusiastic nor curious about the topic of evolution. The lesson was geared at passing the exams by simplifying the work so learners could cope (in spite of the fact that she mentioned that her lessons were not exam driven). Dolly did mention to the learners that she was omitting some activities in the textbook and making them complete only those necessary for the exams so that they could cope with the workload. Her teaching strategy was in accordance with her responses indicated on the questionnaire. Dolly's learners similarly, had a poor understanding of science as they queried

science concepts found in the activities. She tried to engage her learners in the lesson with the 'question and answer method'. There was no evidence of an inquiry approach whereby learners were posed with challenges and encouraged to think. She did make mention of topics such as *genetics, DNA, meiosis and crossing over* and its relevance for variation in offspring (NOS 2).

Dolly's reference to the textbook during the lesson could be an indication of her lack of confidence in teaching this topic. Her use of Lamarck's idea to illustrate a scientific theory suggests her poor understanding of the meaning of theory in science. Dolly portrayed herself as a progressive teacher in terms of her pedagogy in the questionnaire; however this is not a true reflection. Her poor understanding of evolution is reflected in her teaching.

During the interview Dolly's responses confirmed her misconceptions. She seems to misunderstand what a 'theory' in science means as she does not regard evolution as a valid scientific theory. Her notion of a theory is confusing as she refers to it as not being valid but yet defines it as having scientific facts.

> *Dolly: … I referred to evolution as a theory because facts are present and conclusive unlike theories*.

This demonstrates a gap in her understanding of the NOS and confirms her misconception of what a theory means in science, as evolution talks about ideas and concepts and only one theory, Darwin's Theory of Natural Selection. As a result, Dolly does not present evolution as the underlying principle of Biology and this view is transferred to her learners. She understands the link to genetics and meiosis but does not integrate evolution in her teaching of the other topics in the syllabus. This is apparent as her learners fail to see the relevance of evolution in science.

> *Dolly: … Learners find the topic too far-fetched. They don't seem to understand why it needs to be studied or its relevance to life.*

Although Dolly does not accept evolution as a fact, she presents it as a theory to 'save time'.

> *Dolly: … Yes I present evolution as a theory or else too much time will be spent on debating religion.*

Dolly believes that she could approach the topic in a better way if she had more resources available at school. She blames her learners' lack of enthusiasm on their academic weakness and social backgrounds.

> *Dolly*: *…There is a lack of resources at school. Learners are generally passive and also very weak.*

She would prefer learners to research the topic instead of her having to give them all the details as she believes it is too much content for them to absorb in lessons. She also wishes that it possible for them to see the evidence for evolution first-hand to make it more believable and generate interest.

> *Dolly: … I believe that learners should research the topic. In this way they are formulating their own theories. They should start at the very beginning when 'life began (originated) on earth'. If time and money was available, the learners could have visited relevant sites of interest to view fossils etc.*

The above statement confirms Dolly's misconception with regard to theories as well as an understanding of evolution when she refers to the origin of life as an example of evolution.

Dolly was unable to explain concepts clearly as she herself has misconceptions. This has an influence on the way she teaches, adhering closely to what is in the textbook. Her confusion with 'theories' influences the way she teaches as she teaches two belief systems.

4.2.3 Shirley's narrative

Shirley has been teaching Biology/Life Sciences for 12 years. She has a laboratory with limited equipment. Shirley does not belong to any science education professional organisations. Her understanding of the NOS in the context of teaching is similarly reported as a narrative based on data obtained from all the data sources (questionnaire, classroom observation and interview).

Like Owen and Dolly, Shirley believes that science alone cannot provide an understanding of the world, indicating that she also interprets the 'world' as being more than just the natural world. Shirley believes that laws and theories are not only produced by experimentation but that experiments do provide conclusive proof about phenomena in the world (NOS 2). This suggests that she has some understanding of the different ways in which empirical evidence may be obtained and theories and laws developed (NOS 2 and 4). Her uncertainty with regard to the statement that 'scientific knowledge is always true' does raise doubts as to whether she has a good understanding of what is meant by the statement and this speaks to her understanding of what is meant by the tentative Nature of Science (NOS 1), although she indicates that she thinks science is tentative. This however could be an example of giving the 'expected' response as literature abounds with statements with regard to the tentative Nature of Science. Shirley views scientists as being subjective people indicating an understanding that scientific activities are influenced by the human beings that conduct them. Shirley

indicates clearly that she does not accept evolution as a valid scientific theory, nor does she view evolution as a scientific fact (NOS 4). Her uncertainty of whether evolution is 'only a theory' does point to some uncertainty as to the use of the concept 'theory' in science. This is confirmed by her disagreement that theories should not be given much focus, which is a contradictory response to her earlier responses. Furthermore, her disagreement that there is little evidence for evolution implies that she believes that there sufficient evidence and this contradicts her belief that evolution is not a scientific fact. Shirley's responses show that she has a good understanding of the NOS, but a poor understanding of evolution.

As with previous participants, the second part of the questionnaire served to provide some clarity with regard to the degree to which Shirley's pedagogy is informed by her understanding of the NOS. The data that emanated from this part of the questionnaire enabled me to get a better understanding of her understanding of the NOS and how Shirley's view impacted on her pedagogical practices.

Shirley claims to use an inquiry approach to teaching, as well as presenting evolution as a scientific phenomenon (NOS 4). She presents her pedagogy as learner-centered. While she claims not to teach evolution as a belief system, she uses debating as a strategy to teach the topic and allows learners to discuss their different beliefs. Shirley does not offer alternatives to Darwin's explanation of evolution. She teaches evolution as a valid scientific theory contrary to her earlier response of not regarding evolution as being a valid scientific theory (NOS 4). This implies that she teaches what she does not accept. Shirley's responses suggest that she holds misconceptions with regard to the NOS. She also indicated that the examination does not determine how she teaches.

Like Dolly, Shirley strongly feels that environmental issues and reproduction should be removed from the syllabus as they were given sufficient coverage in lower grades. Shirley did not make the connection between biodiversity, an important environmental issue, and evolution either. The connection between reproduction (human systems) and evolution is less clear. Shirley believed that the introduction of evolution into the FET curriculum was a good idea as it challenges the belief systems of the learners. She believes that teaching evolution would encourage learners to think critically. However, she was also of the opinion that most

life sciences teachers would avoid teaching evolution if given the opportunity as it was in conflict with religious beliefs.

Shirley taught the topic: *Speciation - including natural selection.* The two categories used in the analysis of Shirley's lessons were also: *Teaching evolution within the context of the NOS and Teaching strategies.* Shirley presented the topic as a scientific phenomenon by recapping on the concept of 'theory' in her review of *Lamark's theory* and *Charles Darwin's theory.* She also taught the *theory of natural selection* to the learners (Darwin's theory) (NOS 4). The fact that she reviewed Lamarck's theory in terms of an 'idea' indicates some understanding of what is meant by a scientific theory, but does not indicate her personal views as presented in her previous responses. Shirley briefly mentioned the link between evolution and genetics. The concept of *genotype* in genetics was used to assist in understanding the concept of *natural selection*. She started her lesson by introducing evolution as a scientific phenomenon (NOS 2) but as the lesson progressed, she taught evolution as a belief system. This suggests that Shirley, while not accepting evolution as a scientific phenomenon attempted to teach to the syllabus requirements.

Shirley showed a few pictures of *speciation* on the overhead projector and divided the class into small groups. The groups were requested to discuss the phenomena illustrated. The group report-backs initiated many questions. Shirley encouraged learners to explore various ideas and philosophies on human evolution. Learners were told to make informed decisions on what they chose to believe. This suggests to learners that an alternative belief system does exist. Her teaching style was scenario-based. Questions were posed and learners probed to solve the questions. Learners were allowed to discuss their viewpoints during the lesson. She created an interactive atmosphere emphasising the concept of *natural selection* which results in *speciation.* She used ultrasound pictures of pregnant women and pictures of foetuses' of animals to illustrate *comparative embryology*. She wanted learners to note the similarities in the developing embryos to understand the concept of 'sharing a common ancestor'. She presented evidence of evolution by showcasing newspaper articles on *Australopethicus sediba* and fossils found in Africa, for example Lucy and the Taung Child. Learners were engrossed with the evidence and requested an excursion to the Sterkfontein Caves (NOS 2).

Shirley's lesson was very interactive, possibly due to the nature of the topic which provides more resources which are easily accessible and also because of the many pictures that appeared in the newspaper. The lesson was exam-driven as exam-type questions were discussed orally and on the worksheet she issued. Shirley had rushed through a large amount of work in the session due to time constraints.

Shirley portrayed herself as a progressive teacher in terms of her pedagogy; however her lesson was interactive but not inquiry-based. An inquiry-based lesson would be more 'minds-on' to facilitate a deeper understanding of the topic instead of the teacher telling the story. Teaching the theory of evolution is complex as learners do not easily understand words such as 'hypothesis' and 'inference'. Shirley's focus was on the empirical evidence in the form of observations and inferences (NOS 2 and 3). Shirley appears to teach what the syllabus requires, while setting her own beliefs aside.

Shirley's responses during the interview confirmed her belief that her lessons are interactive. She has an understanding of the concepts related to the topic.

> *Shirley: … Discuss comparative embryology as an introduction, thus opening the idea of evolution.*

She does not have an adequate understanding of what a theory is.

> *Shirley: … Evolution is a theory as certain aspects cannot be scientifically proven due to mass extinction. The scientific evidence should be the guide as there are too many misconceptions about what evolution entails.*

She prefers debating as a method of teaching in hope of clarifying the learners' viewpoints.

> *Shirley: … Evolution is not in conflict with religion. The Book of Genesis explains the time of creation. The idea of evolution must be brought in during conversation. Each viewpoint should be examined and debated. Learners are well aware of the topic being controversial. At least this way I get to hear their viewpoints and correct them rather than them leaving my classroom with doubts.*

The interview suggests that Shirley encourages discussion of topics and not formal debates as her response in the questionnaire suggested. Her lessons on evolution are interactive due to the availability of resources on the topic. She also considers the textbook to be an important teaching tool.

> *Shirley: … The use of many textbooks is important as each author focuses on his/her viewpoint*.

Shirley also teaches to the examination as the other teachers do. Despite her negative beliefs of evidence to explain the past, she is able to focus on the scientific evidence for evolution as required by the syllabus.

Shirley: … Expose learners to as much scientific evidence as possible.

Shirley presented the NOS concepts accurately in her lesson, in spite of her own personal beliefs. She was able to present an interactive lesson in which she presented evolution as a scientific phenomenon. Shirley teaches evolution the way she does in order to dispel any myths and misconceptions associated with topic. Her teaching approach is also determined by time-constraints and the pressure of the examination.

4.3 Conclusion

This chapter presented the findings of the study based on the data collected from the questionnaires, classroom observation schedules and the post-lesson interviews. The findings were presented as narratives of the three teachers. In the final chapter I will use the findings presented in the narratives to answer my research questions. Furthermore I will present recommendations based on the findings of the study.

CHAPTER FIVE

FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

In the previous chapter the findings of the study were presented. Data produced by the various instruments were synthesised to produce a narrative account of each of the three teachers' knowledge, views, accounts and experiences. In this chapter I draw the findings together in an attempt to demonstrate how the research questions were answered and I relate my findings to the existing literature.

5.2 Overview of findings

The intention of my study was to explore three life sciences teachers' understanding of the NOS and how it informs their teaching of evolution. The focus of my study was directed by the critical research questions as mentioned above.

5.2.1 Teachers' understanding of the NOS

In answering *question one*, "What are life sciences teachers' understandings of the NOS within the context of teaching evolution?" the study analysed a questionnaire related to the NOS and the teaching of evolution. The findings revealed that the three teachers presented different levels of understanding of the NOS.

The findings suggest that Own has a fair understanding of the NOS, however he holds some misconceptions. He believes that science is tentative and accepts that the evidence for evolution exists. He regards evolution as a valid scientific theory. However, Owen misunderstands how scientific evidence is obtained. He believes that evidence can only be obtained through experimentation. He is unable to differentiate between a 'theory' and 'fact' and believes that evolution is not a fact. He also viewed the curriculum as being relevant to the learners, suggesting that he believed the science he taught had a purpose, although he did not believe that evolution should be included in the curriculum. This finding is in partial support of Lederman's (1992) research which found that teachers who possess an adequate understanding of the NOS, view teaching science as a purposeful and conscious act. In spite

of certain misconceptions pertaining to the NOS, Owen has a better understanding of evolution. He was able to teach evolution as a valid scientific theory and present it as a scientific phenomenon by concentrating on the evidence for evolution.

Dolly's understanding of the NOS is poorer than Owen's as she holds many misconceptions. She does not understand the tentative NOS as well as important science concepts such as 'theories' and 'facts'. However, Dolly interprets the 'world' as being more than just the natural world and views scientists as being subjective people. Her misconception has led her to believe that evolution is not the underlying principle of Biology as she believes that evolution is not a scientific fact.

Shirley has a better understanding of the NOS but a poor understanding of evolution. She does not accept evolution as a valid scientific theory, nor does she view evolution as a fact. She appears to be confused with the term 'theory' and also holds misconceptions with regards to the manner in which scientific evidence is gathered. These misconceptions have contributed to her poor understanding of evolution. The misconception that scientific evidence can only be obtained by experimentation has resulted in the belief that there is no scientific basis for evolution and it should therefore be taught alongside other belief systems.

The findings revealed that all three teachers had gaps in their knowledge of the NOS. The notion of the 'scientific method' suggests the teachers' poor understanding of science. Lederman's (1992) view that teaching experience does not contribute to a teacher's understanding of the NOS is particularly relevant here as all three teachers have been teaching for many years. The findings also confirm Abd-El-Khalick and Lederman's (2000) study of teachers and learners having inconsistent beliefs of the NOS. The study revealed it is the teachers' understanding of the NOS which determines their beliefs about what science is. While the three teachers hold misconceptions to various degrees, these misconceptions do influence their understanding and acceptance of evolution. This view is corroborated by other studies of teachers' understanding of evolution (Eick 2000, Rutledge & Warden, 2000).

5.2.2 Teachers' understanding of the NOS and their pedagogic practice

In answering *question 2*, "How do life sciences teachers' understandings of the Nature of Science influence their pedagogic practice (teaching strategies) when teaching evolution?"

teachers' classroom practices were analysed and interpreted. The findings revealed that the three teachers' pedagogy was quite different.

Owen's teaching was informed by his understanding of the NOS to a certain degree. He was able to relate the topic to just two other topics in the curriculum, genetics and meiosis. These two topics are the most obvious to see their links to evolution. Owen's failure to integrate evolution into other topics suggests that he does not view evolution as the underlying principle of evolution. Owen taught with confidence and did not rely on textbooks for knowledge. His misconception with regard to theories and laws did not affect his teaching as he presented the evidence for evolution accurately and with confidence. Gaps in his knowledge of the NOS did not affect his teaching of evolution. The strong focus on the examination and awareness of limited time does influence his pedagogy and may contribute to the fact that he does not raise issues that he is unsure of or does not believe.

Dolly's teaching approach was informed by her limited understanding of the NOS. It was evident that her lack of confidence and enthusiasm for the topic was transferred to her passive learners. She was dispassionate about the topic and therefore her teaching did not generate any interest with the learners. Her misuse of the word 'theory' added to the confusion of the learners. This lack of sound understanding of the topic was further evident in her reliance on the textbook. Her lessons were exam-driven to a large extent. In Dolly's case, her limited understanding of the NOS was evident in the content she taught as well as in her pedagogy. Dolly was not able to put her personal beliefs aside when teaching evolution.

Shirley's teaching approach was very interactive and her misconceptions with regard to the NOS were not evident in her teaching, neither was her personal beliefs regarding evolution. She presented the evidence for evolution in her lessons and taught evolution as a scientific phenomenon, despite her using debating as a strategy to discuss different beliefs. Shirley believes that evolution is not a valid scientific theory, nor does she view evolution as a scientific fact. Her confusion with the tentative NOS is further apparent as she is uncertain whether scientific knowledge is always true. However, Shirley was able to shelve her personal beliefs and teach evolution the way the syllabus requires the topic to be taught (as a scientific phenomenon). Shirley's lessons were also exam driven.

Two of the three lessons (Owen and Shirley) presented were different to the teachers' understanding of the NOS. Whilst Owen and Shirley had misconceptions regarding the NOS, it was not evident in their teaching of evolution. However, Dolly's misconceptions regarding the NOS were evident during her teaching of evolution. This is in accordance with the findings of similar studies. While the work of authors such as Irez & Cakir, (2006); Lederman, (1999); Rutledge & Mitchell, (2002); and Water-Adams (2006) suggest that the misconceptions with regard to the NOS have a direct effect on the way teachers teach science, it was not that clear-cut in the teaching of evolution in this study.

5.2.3 Why teachers teach evolution the way they do?

The previous two research questions focused on the NOS within the context of teaching evolution. The findings suggest that the way the NOS is understood does have an influence on teachers' understanding of evolution, but not necessarily on the way they teach evolution. The *third question*, "Why do life sciences teachers teach evolution the way they do?" can only be answered by considering a number of factors pertaining to teaching that emerged from the study. To enable me to answer this question, data from post-lessons interviews as well as the data obtained from the first two research questions were interpreted to develop some understanding of why teachers teach evolution the way they do.

5.2.3.1 Understanding of the NOS

The findings suggest that while all three teachers held misconceptions with regard to the NOS this does not impact significantly on their teaching. They are able to teach evolution concepts and present evidence for evolution as the curriculum prescribes. Their misconceptions about NOS was evident in their inability to realise that evolution should be integrated across the curriculum, suggesting ignorance with regard to understanding that evolution is the underlying principle in Biology. They were all able to tell the 'evolutionary story' by concentrating on the evidence for evolution as discussed by Farber (2003) in spite of their different understandings of the NOS. Water-Adams (2006) is of the view that understanding of the NOS has an effect on the way teachers teach and the lack of inquiry-based pedagogy in all three teachers' lessons may be due to their incomplete understanding of the NOS.

5.2.3.2 Exam-driven approaches

All three teachers commented on the lack of time to complete the syllabus before the exams and therefore focused on the basic aspects of evolution and this impacted negatively on the learners' understanding of evolution. Their lessons focused on equipping learners with the possible exam-type questions and therefore the teachers presented the lessons the way they did. Lack of time may also be the reason why Dolly and Shirley did not engage in discussions about different belief systems which would have revealed their own views about evolution.

5.2.3.3 Teacher identity

An interview with the three teachers revealed how they were taught science (question one). Owen and Dolly were exposed to theoretical lessons when they were taught science which may explain their current practice in the classroom. Their lessons were teacher-centered and did not cater for learner creativity. Shirley, on the other hand, was exposed to some practical work when she learnt science which may explain her interactive lesson.

5.2.3.4 Controversy

Teachers fear the controversy (Moore et al., 2003) and teach in a manner that does not offend learners' beliefs. The teachers in my study appear to be no different in this regard. Owen believed that evolution should be taught along with creation to avoid conflict in the classroom. Shirley believed that debating should be used to teach evolution as it gives learners a chance to discuss their creationist views. Dolly believed that the learners should formulate their own opinions about how life began on earth. This is not evolution and is further evidence of her lack of understanding of evolution. However, none of the teachers addressed this controversy in their lessons. Whether this was due to my presence is not clear.

5.2.3.5 Lack of resources

Owen and Dolly regarded the textbook as an important teaching tool due to the lack of resources to teach evolution. The lack of resources were evident in their lessons as Owen confined his lesson to the use of the overhead projector to present pictures while Dolly relied on her textbook as her resource.

5.3 Recommendations

The study confirms that teachers do have gaps in their knowledge of science and are not equipped with the necessary skills to engage learners in inquiry-based lessons for various reasons, as discussed above. The DoE is aware of the many problems associated with the teaching of evolution and has offered short professional development courses and workshops. However, the literature has indicated that the workshops provided by the DoE have been unhelpful and facilitated by education departmental officials who themselves did not understand the issues concerning evolution (Ngxola & Sanders, 2008). The poor coverage of evolution in the 'new' FET textbooks has also added to the confusion of many teachers (Decker, Summers & Barrow, 2007). Teachers have to consult multiple resources which are sometimes not feasible as many schools in South Africa are under-resourced.

From the findings of my study and the literature reviewed on teachers' understanding of the NOS and its influence on their teaching strategies, I offer the following recommendations as strategies to improve life sciences teachers' understanding of the NOS and by extension, understanding of evolution.

Recommendation 1: The NOS needs to be taught so that learners come to understand the key ideas that characterise the natural sciences. This requires teachers who are knowledgeable with regard to the NOS. The DoE needs to host workshops that actively engage teachers with the NOS. A recent study by Naidoo (2008) has confirmed that teachers who were actively involved in the NOS workshops improved their teaching strategies. Teachers need support from the DoE in terms of how to plan lessons informed by the NOS.

Recommendation 2: The life sciences curriculum needs to foreground evolution in all topics. This means that macro-evolution should be an integral part of each topic taught. Including the principles and mechanisms of evolution towards the end of the curriculum is not helpful as learners find the topic too unfamiliar. This approach would allow teachers and learners to see the relevance of evolution in context.

Recommendation 3: Textbooks that include the NOS activities need to be provided to teachers given the current state of schools being under-resourced. These activities may be

difficult to enact without resources but may encourage teacher-improvisation and creativity instead as well as research opportunities for learners.

Recommendation 4: Life sciences curriculum developers need to review the number of topics covered in each grade as the content-laden curriculum puts too much pressure on teachers which results in lessons that are exam-driven.

5.4 Suggested areas for further research

The findings of my study have highlighted the following areas for further research in a South African context:

- How the NOS may be included in all science teacher education programmes.
- The type of in-service courses that would enable the understanding of the NOS.
- Ways in which school textbooks should approach the NOS.

5.5 Conclusion

An outline of my study was presented in Chapter 1, where I discussed the purpose of my study, which was to explore life sciences teachers' understanding of the NOS in the context of teaching evolution. I explained the reasons for undertaking this research study, and this was discussed under the rationale for the study. My interest lies in the teaching approaches that life sciences teachers engage in to teach the theory of evolution and whether they teach evolution as yet another topic and not as an organising principle. Chapter 2 presented the literature review and conceptual framework. The key issues that emerged from the literature review were issues concerning the teaching of evolution and the influence of the NOS on pedagogy. The main issue that emerged from a review of the literature was that the effective teaching of evolution was dependent on the teachers' knowledge of the NOS. The literature revealed that teachers generally do not implement the curriculum in accordance with the NOS due to many issues surrounding the teaching of evolution. The key concept, the NOS, formed the framework of the study. My study contradicts the literature to some extent. Lederman (1999) suggests that teachers need a thorough understanding of the NOS if they are to teach science topics accurately. However, this was not the case with Owen and Shirley. Owen and Shirley have misconceptions with regards to the NOS but are able to present evolution the way the syllabus requires them to do so. Owen and Shirley are also able to shelve their

personal beliefs and teach evolution as a scientific phenomenon, contrary to the findings of Rutledge & Mitchell, (2002) who suggested that a poor understanding of the NOS (due to religious beliefs) leads to evolution being taught poorly.

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APPENDIX 1

QUESTIONNAIRE

The purpose of this research is to explore teachers' beliefs about the nature of science and its influence on their pedagogic strategies within the context of teaching evolution.
All responses to the questionnaire are strictly confidential and are for research purposes only.

Should you experience any difficulties with the questionnaire, please contact

Fadeela Kirsten
083 775 4328 / fadeela@mweb.co.za

THANK YOU

SECTION A: TEACHER BIOGRAPHY

1) Name : _____

2) Name of school : _____

3) Gender : _____

4) How long have you been teaching life sciences? _____

5) What are your teaching academic and teaching qualifications?

_____

6) Do you belong to any professional organisations related to the teaching of science? If yes, please provide details:

_____

_____

_____

_____

_____

7) Identify some important issues related to the content of the life Sciences curriculum discussed at science meetings with regards to the Grade 12 life sciences curriculum:

_____

_____

_____

_____

_____

S ECTION B:

The following tables concern issues around the nature of science and teaching. Please indicate the degree to which you agree or disagree with each statement in the tables by placing an X in the appropriate column. The following key applies to the tables:

SA : STRONGLY AGREE

A : AGREE

UN : UNCERTAIN

D : DISAGREE

SD : STRONGLY DISAGREE

TABLE B.1: Nature of Science

NO.	STATEMENTS	SA	A	UN	D	SD
1.	Only science can help me to understand the world around us.					
2.	Scientific knowledge is always true.					
3.	Scientists are objective people.					
4.	Scientific laws and theories are always produced through experimentation.					
5.	Science is tentative (changeable).					
6.	Scientific experiments provide conclusive proof about phenomena in the world.					
7.	Evolution is a valid scientific theory.					
8.	Evolution is only a theory.					
9.	Evolution is a scientific fact.					
10.	There is little evidence for evolution.					
11.	Science can infer what happened in the past, based on evidence.					
12.	Theories are undeveloped ideas and therefore should not be given that much focus.					

TABLE B.2: Teaching and Curriculum

NO	Statements	SA	A	U	D	SD
1	The syllabus and examinations dictates how I teach evolution.					
2	My lessons are inquiry-based when I teach evolution.					
3	I encourage learners to participate in classroom discussions when I teach evolution.					
4	I use debating as a teaching strategy when I teach evolution.					
5	I present evolution as a scientific phenomenon, not as a belief system.					
6	I offer alternatives to Darwin's explanation of evolution.					
7	I teach evolution as a valid scientific theory.					
8	I present the evidence for evolution in my lessons.					
9	I integrate evolution in other themes that I teach that I teach in Life Sciences.					

SECTION C: OPEN-ENDED QUESTIONS

ANSWER THE QUESTIONS BELOW:

1) From the 7 topics below, which 2 do you believe should be left out if the syllabus needed shortening? Give a reason for your answer.

   DNA and protein synthesis, Chromosomes and meiosis, Genetics, Diseases and disorders, Reproduction, Environmental issues, Evolution

_____

_____

_____

_____

_____

_____

_____

2) Evolution is new in the life sciences curriculum. What is your attitude regarding the teaching of evolution?

_____

_____

_____

3) Why would teachers avoid teaching evolution?

_____

_____

_____

THANK YOU FOR YOUR INVALUABLE CONTRIBUTION AND TIME.

APPENDIX 2

CLASSROOM OBSERVATION SCHEDULE

A) GENERAL DETAILS

TEACHER: A_____ B_____ C_____

DATE OF OBSERVATION:

_____

GRADE 12 _____

TOPIC TAUGHT:

_____

B) LESSON

1) Does the teacher appear to present evolution as a belief system or a scientific phenomenon?

_____

_____

2) How did the teacher use the word 'theory' in the lesson?

_____

_____

_____

3) Did the teacher teach any other theories?

_____

_____

4) How did the teacher encourage learner participation and discussion?

_____

_____

5) Were the learners allowed to express their views? How did the teacher respond?

_____

_____

_____

6) Did the teacher rely on any textbooks for the lesson? If yes, how often and for what purpose?

_____

_____

7) Did the teacher present any evidence for evolution?

_____

_____

_____

_____

8) Was evolution integrated or linked to other topics in the life sciences curriculum?

_____

_____

_____

_____

C) TEACHING STRATEGIES

1) What strategies were employed by the teacher?

_____

_____

_____

_____

2) Did the teacher allow the learners to discuss other belief systems as part of his/her teaching strategy?

_____

_____

_____

_____

3) Was the lesson interactive, inquiry-based or teacher-centered?

_____

_____

_____

_____

4) Did the teaching appear to be exam-driven or did the teacher allow for creativity beyond the syllabus?

_____

_____

_____

_____

D) OTHER OBSERVATIONS

_____

_____

_____

_____

APPENDIX 3

TEACHER INTERVIEW SCHEDULE

Thank you for participating in my study. May I record the interview to help me with my data analysis?

1) Were you exposed to a particular way of doing science? Explain
2) Do you think evolution should be taught in a particular way? Why?
3) Explain why you referred to evolution as a theory / scientific fact.
4) Was there any particular reason for your choice of teaching strategy?
5) What would you regard as the best way to present evolution to the learners?
6) Do you think only certain topics in the life sciences curriculum can lend itself to scientific inquiry? Please elaborate.
7) Do you regard the textbook as an important teaching tool for an evolution lesson? Explain.
8) Why do you think that the Grade 12 Learning Programme Guidelines for Life Sciences requires that the theory of evolution be taught last? Do you agree with its placing?
9) Do you agree that evolution should be integrated or linked to other topics in the Grade 12 curriculum or do you believe it should be taught separately? If yes, which ones?

APPENDIX 4

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

8 August 2012

Ms Fadeela Kirsten 9500176
School of Science, Mathematics, and Technology Education

Dear Ms Kirsten

Protocol reference number: HSS/0641/012M
Project title: Life Sciences teachers' understanding of the Nature of Science within the context of teaching Evolution.

EXPEDITED APPROVAL

This letter serves to notify you that your application in connection with the above has now been granted full approval following your response to queries raised by the Humanities and Social Sciences Research Ethics Committee.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach/Methods must be reviewed and approved through an amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years

Best wishes for the successful completion of your research protocol.

Yours faithfully

.....
Professor Steven Collings (Chair)

/px

cc Supervisor Dr M Stears
cc co Supervisor Dr J Coleman
cc Academic Leader Dr D Davids
cc School Admin. Mrs S Naicker

Professor S Collings (Chair)
Humanities & Social SC Research Ethics Committee
Westville Campus, Govan Mbheki Building
Postal Address: Private Bag X54001, Durban, 4000, South Africa
Telephone: +27 (0)31 260 3587/8350 **Facsimile:** +27 (0)31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za

APPENDIX 5

16. Aug. 2010 23:19 No. 6101 P. 3

kzn education
Department:
Education
KWAZULU-NATAL

FADEELA KIRSTEN
152 SPENCER ROAD
CLARE ESTATE
DURBAN
4091

Enquiries: Sibusiso Alwar
Date: 23/07/2010
Reference: 0058/2010

PERMISSION TO INTERVIEW LEARNERS AND EDUCATORS

The above matter refers.

Permission is hereby granted to interview Departmental Officials, learners and educators in selected schools of the Province of KwaZulu-Natal subject to the following conditions:

1. **You make all the arrangements concerning your interviews.**
2. **Educators' programmes are not interrupted.**
3. **Interviews are not conducted during the time of writing examinations in schools.**
4. **Learners, educators and schools are not identifiable in any way from the results of the interviews.**
5. **Your interviews are limited only to targeted schools.**
6. **A brief summary of the interview content, findings and recommendations is provided to my office.**
7. **A copy of this letter is submitted to District Managers and principals of schools where the intended interviews are to be conducted.**

The KZN Department of education fully supports your commitment to research: **Life sciences teachers' understanding of the nature of science within the context of teaching evolution**

It is hoped that you will find the above in order.

Best Wishes

R Casslus Lubisi, (PhD)
Superintendent-General

...dedicated to service and performance beyond the call of duty.

KWAZULU-NATAL DEPARTMENT OF EDUCATION
POSTAL : Private Bag X9137, Pietermaritzburg, 3200, KwaZulu-Natal, Republic of South Africa
PHYSICAL: Office G25; 188 Pietermaritz Street; Metropolitan Building; PIETERMARITZBURG 3201
TEL: Tel: +27 33 341 8610/8611 | Fax: +27 33 341 8612 | E-mail

APPENDIX 6

152 Spencer Road
Clare Estate
Durban
4091

The Principal

Dear Sir/ Madam

PERMISSION TO CONDUCT RESEARCH AT THE SCHOOL

I am a Masters student in the School of Science, Mathematics and Technology Education at the University of KwaZulu-Natal. My study is entitled: *Life Sciences teachers' understanding of the Nature of Science within the context of teaching Evolution*.

The purpose of this research is to explore the relationship between the teachers' understanding of the nature of science and the teaching strategies they engage in with regards to teaching the theory of evolution.

The KZN Department of Education has granted me permission to conduct research in schools (refer to attached letter). I wish to request your permission to distribute questionnaires among Grade 12 life sciences teachers and thereafter conduct interviews and observe a selected sample of teachers in practice.

The teachers' participation in this study is voluntary. Teachers may refuse to participate or withdraw from the study at any time with no negative consequences. There will be no monetary gain from participating in the survey. Confidentiality and anonymity of records will be maintained by the School of Science, Mathematics and Technology Education, UKZN.

The study may benefit curriculum developers in teacher-education institutions, by critically evaluating the preparatory programmes for life sciences teachers aimed at improving the teaching of evolution in schools.

Should you have any concerns about the study, you may contact me or my supervisors at the contact details listed below.

Thanking You

Researcher: Ms Fadeela Kirsten (083 775 4328)

Supervisors: Dr M. Stears (031 260 3444) and Dr J. Coleman (031 260 3594)

APPENDIX 7

152 Spencer Road

Clare Estate

Durban

4091

Dear Colleague

PERMISSION TO PARTICIPATE IN RESEARCH

I am a Masters student in the School of Science, Mathematics and Technology Education at the University of KwaZulu-Natal. My study is entitled: *Life Sciences teachers' understanding of the Nature of Science within the context of teaching Evolution*.

The purpose of this research is to explore the relationship between the teachers' understanding of the nature of science and the teaching strategies they engage in with regards to the theory of evolution.

I wish to obtain your consent to complete a questionnaire and observe a lesson in practice and thereafter conduct a brief interview to consolidate the study.

Your participation in this study is voluntary. You may refuse to participate or withdraw from the study at any time with no negative consequences. There will be no monetary gain from participating in the survey. Confidentiality and anonymity of records will be maintained by the School of Science, Mathematics and Technology Education, UKZN.

The study may benefit curriculum developers in teacher-education institutions, by critically evaluating the preparatory programs for Life Science teachers aimed at improving the teaching of evolution in schools.

Should you have any concerns about the study, you may contact me or my supervisors at the contact details listed below.

Please complete the declaration below if you wish to participate in the study.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

……

……..

SIGNATURE OF PARTICIPANT DATE

Thanking You

Researcher: Ms Fadeela Kirsten (083 775 4328)

Supervisors: Dr M. Stears (031 260 3444) and Dr J. Coleman (031 260 3594)