Post-Graduate Physical Science Teachers' Knowledge of and Classroom Practice in the Nature of Science in KwaZulu-Natal

by

Kumarasen Kristnasamy Naidoo

Submitted in partial fulfilment
for the Degree of Master of Education
in the School of Science, Mathematics, and Technology Education,
Faculty of Education
University of KwaZulu-Natal

October 2008

ABSTRACT

The introduction of the new Physical Science curriculum in South Africa in 2006 has created challenges for physical science teachers and curriculum developers, including tertiary science educators. The curriculum recommends that the Nature of Science (NOS) has to be taught in an integrated manner in physical science lessons. In addition approximately one-third of all questions in class tests and examinations should be on NOS. Studies that were conducted nationally and internationally have shown that most science teachers' have inadequate views of NOS. This study, in particular, looks at post- graduate physical science teachers' knowledge and classroom practice of the Nature of Science in KwaZulu-Natal. Data was collected using a NOS questionnaire by a group of 38 FET physical science and life science teachers who had completed an honours module in NOS. Part of this module included the history and philosophy of science in classroom lessons, indigenous knowledge, and science and culture. Four physical science volunteers were then selected for in-depth classroom observations and interviews. This formed the main data for the study with fieldwork carried out in teachers' classrooms. Results indicated that postgraduate science teachers have an adequate understanding of NOS, mainly as a result of having completed modules covering NOS objectives, history of science and philosophy of science. Furthermore, evidence confirms that these teachers made positive attempts to plan and teach for the achievement of the NOS objectives during physical science class lessons and used materials and references from their post-graduate programmes.

PREFACE

The work described in this dissertation was carried out in the School of Science, Mathematics and Technology Education, University of KwaZulu-Natal, from **January 2006 to October 2008** under the supervision of **Dr. N. Govender** (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.

Kumarasen Kristnasamy Naidoo

October 2008

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

I would like to thank all my lecturers in the Masters Programme. You have imbued me with invaluable knowledge and research skills. A special thank-you and appreciation to Dr. Nadaraj Govender, for patiently guiding me through the writing of this dissertation. My appreciation to Dr Betty Govinden for editing this research.

Dedication

I dedicate this dissertation to my wife Pam, my daughter Marcene and my son Chazryn.

CHAPTER 1

INTRODUCTION

This classroom-based study was conducted over a six-week period in four different high schools. The research subjects were post-graduate physical science teachers who had completed a Nature of Science (NOS) module at the University of KwaZulu-Natal. The teachers in this study were expected to teach as part of their lesson NOS core concepts and activities as outlined by the National Curriculum Statement (Department of Education, 2003). Their NOS understandings and classroom practice formed the basis of the two research questions of this study. The schools involved were in the Durban region of the province of KwaZulu-Natal.

My aim in conducting the above research was to describe post-graduate honours science teachers' understanding and classroom practice of the nature of science. A Nature of Science (NOS) questionnaire was given to 38 post-graduate science teachers. I observed four volunteer male teachers in four different schools. Each of the teachers was observed for four one-hour science lessons. A structured observation schedule was used for the NOS concepts taught during the lesson. The teacher chose his best lesson and I interviewed the teacher using a structured interview schedule.

1.1 PURPOSE OF STUDY

Generally, most science teachers in South Africa do not teach NOS explicitly in the classroom (Dekkers & Mnisi, 2003a; Linneman, Lynch, Karup, Webb, & Bantwini, 2003). Their instructional strategies do not include the core components of NOS as outlined by the National

Curriculum Statement (Department of Education, 2003) and as described in the rich literature in this field as indicated here in Chapter Two. Briefly, the core components are the historical, social and religious aspects of science, creativity and the tentative nature of science knowledge, science as a human endeavour, science and technology, science and human development, and science and the environment. A review of the research (Aikenhead, 2000; Bell, 2001; Lederman, 1992; Lederman, 1998; Lumpe, 1998; McComas, 1998), with regards to nature of science, show a worldwide trend to explicitly address the issues of NOS in the classroom. The South African studies on the nature of science (Dekkers & Mnisi, 2003a; Linneman et al., 2003) only look at the teachers' perceptions and misconceptions with regards to the NOS, and not how these perceptions informs classroom practice. This study will add to the South African research with regards to the NOS views as understood by science teachers' and how these views reflect and inform science classroom practice. Hence, this study on post-graduate physical science teachers' knowledge and classroom practice of the nature of science fills a noticeable void in this field.

1.1.1 Focus of this study

The objective of this research was to engage with teachers who already have an informed and academic perspective on NOS (Abd-El-Khalick et al., 2001; Lederman, 1999). Teachers in the Bachelor of Education Honours Science programme study a module on NOS. Science teachers are the key agents of change to influence learners' views on the nature of science, society, and technology and the environment (Bryan, 2002; Collins, 2001; Dekkers, 2003; Lederman, 1999; McComas, 1998; Spector, 1998). Teacher's in this study would therefore be suitable participants to achieve the aims of this study in terms of classroom practice on the nature of science. This study focuses on curriculum reform and the findings of this research could be useful for PRESET science teacher education, INSET science programmes and workshops, science textbook writers, national and regional science education policy makers, and anyone interested in the improvement of classroom practice in science or the development of a scientifically-literate society.

1.2 RATIONALE FOR THE STUDY

For science educators the phrase “nature of science” is used to describe the intersection of issues addressed by the philosophy, history, sociology, and psychology of science as they apply to and potentially impact on science teaching and learning (McComas, 1998). Studies conducted internationally (Aikenhead & Ryan, 1992; Lederman, 1999) and locally (Dekkers & Mnisi, 2003a; Linneman et al., 2003) have given NOS the recognition it deserves in the science curriculum. In New Zealand (Bell et al., 1995), two of the six learning strands for students involve making sense of the nature of science and its relationship to technology. In the US the ‘benchmarks’ developed by the American Association of the Advancement of Science (AAAS, 1993) includes teaching students, the scientific worldview, scientific inquiry, and the scientific enterprise. In England and Wales, the National Curriculum requires all students to be taught about the nature of science as mandated by the school science curriculum (Taber, 2008, p.186). NOS teaching and learning improves scientific literacy in society, and it emphasizes the relevance of science education. It has been become pertinent in the S.A. science Outcomes Based Education (OBE) curriculum with the introduction of C2005. The OBE curriculum states specific and general outcomes to be achieved in the teaching and learning of Physical Science. The National Curriculum Statement for Physical Science, (Department of Education, 2003) states that nature of science, as learning outcome three, must be assessed at one–third of the total assessment for the year. Therefore, science teachers will have to explicitly teach NOS in the classroom. My focus is on how the teachers translate their knowledge and understanding of NOS into classroom practice.

Aikenhead and Ryan (1992) developed a questionnaire on the value of nature of science (VNOS) and this was used by local researchers (Dekkers & Mnisi, 2003b; Linneman et al., 2003). The study showed that teacher understandings and knowledge of NOS is inadequate. In that study the sample group interviewed by the researchers was in-service teachers. They completed a value of Science, Technology, Society (VOSTS) questionnaire and took part in a semi-structured interview. Ayayee and McCarthy, (1996) used Grade 12 pupils from former model C schools in Gauteng, pre-service teachers and practising science teachers to answer a VOSTS questionnaire. Analysis of the questionnaire data revealed that pre-service teachers had a better knowledge of NOS because they had done a methodology course in philosophy of science. Methodology courses in philosophy of science have known to enrich a science educators' knowledge of NOS (Eflin, Glennan, & Reish, 1999; Okasha, 2002). Lederman (1999), in examining pre-service teachers teaching of NOS, presented three pedagogic approaches to enhance learners' understandings of NOS. They are *the implicit approach*, which means that by doing science students will understand NOS, *the historical approach*, which implies presenting history of science in science teaching to present more informed views of the scientific endeavour and *the explicit approach,* which involves improving students understandings of NOS, through planned NOS lessons and not as a by product of science teaching. Furthermore, Lederman's (1999) research revealed that teachers who taught NOS explicitly were more successful in classroom discussions and inquiry learning, leading to constructivist learning and teaching. This view was also corroborated by Bell (2001), and Bianchini and Colburn (2000). As far as I am aware, South African research has not looked at how Bachelor of Education (Honours) science teachers NOS knowledge informs classroom practice. There is therefore a gap in the research, where our unique cultural context, with its legacy of apartheid, and our teachers, learners, schools are all factored in. Schools now have Black, Coloured, Indian, and White student populations and teachers can teach in any of these schools.

1.3 RESEARCH QUESTIONS

The two main research questions in this study are:

1. What are honours physical science teachers' understandings of the content knowledge of Nature of Science in terms of Outcomes Based-Education.

2. How do honours physical science teachers translate their Nature of Science understanding's into classroom pedagogical practice in terms of Outcomes Based-Education.

1.4 RESEARCH DESIGN AND METHODOLOGY

A brief review of the research design and methodology is given to locate the methods used in this study. The literature review indicates that most high school science teachers in South Africa have inadequate Nature of Science (NOS) views. In this study 38 teachers were given at the end of their study a Values of Nature of Science (VNOS) questionnaire to complete. A mixed method design was implemented. This included a quantitative and qualitative treatment of the

NOS questionnaire and a qualitative treatment of the observation schedule and interviews. The study was therefore to conduct in-depth classroom observations and interviews of how four Bachelor of Education (Honours) science teachers who enrolled at the University of KwaZulu-Natal (UKZN) translate their NOS views into classroom practice. The purpose of my study was explained in detail and four volunteers that teach physical sciences from four different schools were requested. This then became my core group for in-depth exploration. A series of observations for each teacher in a Grade 10-science class was conducted. Probing during the post-lesson interview was also conducted. Areas of the importance of NOS for classroom practice, resources used, and lesson- plan strategies were covered. The data collection techniques were as follows: Firstly, thirty-eight (38) post-graduate science teachers completed VNOS questionnaires. This was transcribed and analysed for common categories. Secondly, classroom observation and tape recordings was completed for each lesson, using an observation schedule. Thirdly, in depth post-lesson interviews were conducted, using an interview schedule and audio-tape. All the interviews were transcribed, to show teachers' commitment in teaching the Nature of Science.

The chapters to follow, describes and analyses the literature review of studies conducted nationally and internationally with regards to the Nature of Science, the theoretical and conceptual framework of this study, the mixed method design I have used, the research instruments, the data collection plan, the analysis of the data, the conclusion and the implications of this study.

Chapter Two introduces the literature review of studies conducted both nationally and internationally, with regards to the Nature of Science. It looks at the definitions of Nature of Science, core concepts of the Nature of Science, and the historical development of the Nature of Science. It reports on the teachers' conceptions of the nature of science. It suggests a teaching sequence for the Nature of Science, and looks at the importance of the nature of science for classroom practice. It concludes with the theoretical and conceptual framework of the Nature of Science.

CHAPTER 2

LITERATURE REVIEW

The definitions' of the Nature of Science (NOS), were researched from national and international literature and they are outlined in this chapter. In particular, the core concepts of NOS and a Delphi study are examined in the context of NOS education. The historical development of NOS then follows. The pedagogical content knowledge of NOS is examined, with a focus on the sequence of NOS teaching. It was also important in this study to look at teachers' conceptions of NOS and explicit instruction with regards to NOS. The significance of NOS and classroom practice is explained from the 'experts' point of view. The chapter is then concluded with the theoretical framework of the study.

2.1 DEFINITIONS OF NATURE OF SCIENCE

I discuss some of the definitions of leading exponents of NOS both nationally and internationally below together with comments

> "The nature of science is a fertile hybrid arena which blends aspects of various social studies of science, including the history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology, into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavours." (McComas, 1998, p. 4)

Modern science has its roots in history and the philosophy of science. To make physical science meaningful to the learner, the teacher needs to explicitly teach the history and philosophy of science. It must then be linked with society's needs in terms of scientific literacy and scientific endeavours.

"The nature of science refers to the essence of scientific knowledge, i.e., (generation, characteristics, limitations) the values of science and how science is practised." (Ayayee & McCarthy, 1996, p. 2)

It follows from this definition that the physical science teacher should include in lessons, the construction of scientific knowledge, the tentative nature of science knowledge, and how this knowledge can be changed or modified when new and reliable evidence becomes available

"The nature of science refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge." (Lederman, 1992, p.331)

While it is necessary for physical science teachers' to teach the content knowledge of science in classroom lessons, it is also important for them to allow learners to debate the truth, and beliefs of how this knowledge became accepted in time.

"The questions, methods and claims of modern science are best described and deeply enmeshed in the historical, political, cultural, and technological fabric of society, phenomena no different in many respects from other social institutions and cultural practices." (Bianchini & Colburn, 2000, p. 179)

> This description of the Nature of Science is in agreement with (McComas, 1998, p. 4) and we again see the cultural and philosophical embedded-ness of scientific knowledge.

The famous philosopher Carl Popper said that scientific theory, and human knowledge generally, is irreducibly conjectural, and is generated by the creative imagination in order to solve problems that have arisen in specific historico-cultural settings. (Popper,1963). We see again in this description that scientific knowledge is culturally embedded. The famous history of science professor Thomas Kuhn said that science develops by the addition of new truths to the stock of old truths, or the increasing approximation of theories to the truth and the correction of past errors (Kuhn, 1963/1970). The historical development of scientific knowledge, the past errors, the subjectivity and the tentative nature of scientific knowledge should thus be part of everyday class lessons.

From these definitions one clearly sees that science teachers should include in their classroom practice, the history and philosophy of science. According to Matthews (1994, p. 68), teaching the history of science promotes better comprehension of scientific concepts and methods. In Lonsbury and Ellis (2002), 106 students were taught science history in Grade nine classes for a four-week period. Pre-tests and post-tests indicated that incorporating science history in class lessons increases students' knowledge related to NOS concepts. It connects the development of individual thinking with the development of scientific ideas. It also humanises the subject matter of science by exploring the life and times of individual scientists. I have outlined and described these definitions of nature of science to link it to the core concepts of the Nature of Science in the section that follows.

2.2 CORE CONCEPTS OF THE NATURE OF SCIENCE

It is important that all physical science teachers understand the core concepts of NOS instruction. This will assist the teachers' in the lesson and laboratory planning activities. According to McComas (2005, p. 6), the core NOS ideas appropriate for teacher education and classroom instruction are:

1. Science demands and relies on empirical evidence.
2. Knowledge production in science shares many common factors and shared habits of mind, norms, logical thinking and methods.
3. Scientific knowledge is tentative, durable and self-correcting.
4. Laws and theories are related but distinct kinds of scientific knowledge.
5. Science has a creative component.
6. Science has a subjective element.
7. There are historical, cultural and social influences on the practice and direction of science.
8. Science and technology impact each other, but they are not the same.
9. Science and its methods cannot answer all questions.

I have used these important criteria of Nature of Science to develop my questionnaire for the post-graduate science teachers to complete (Appendix D).

According to the National Curriculum Statement of the Department of Education (2003, p. 11) the nature of science must include the following aspects for classroom instruction:

1. The scientific enterprise and, in particular, how scientific knowledge develops.
2. That scientific knowledge is in principle tentative and subject to change as new evidence becomes available.
3. That knowledge is contested and accepted, and depends on social, religious and political factors.
4. That other systems of knowledge, such as indigenous knowledge systems, should also be considered.
5. That the other explanatory power and limitations of scientific models and theories need to be evaluated.
6. How science relates to students everyday lives, to the environment and to a sustainable future.
7. The importance of scientific and technological advancements and to evaluate their impact on human lives.

As can be seen, the core concepts of NOS of McComas (2005, p. 6) and the National Curriculum Statement (Department of Education, 2003) are very similar. I used these important concepts of the Nature of Science to develop my observation schedule for my classroom observation, of science teachers' nature of science understandings and their classroom practice. These core concepts of NOS are widely accepted by all other researchers in the study of NOS both nationally (Arnold, 2001; Dekkers, 2003; Linneman, 2003) and internationally (Abd-El-Khalick, 2001; Aikenhead, 2003; Aikenhead, 2005; Bell, 2001; Bianchini, 2000; Finley, 1997; Leach, 2002; Lederman, 1998; Lumpe, 1998; Mathews, 1998). Each of the above articles stresses the use of one or more core concepts of the NOS during classroom and laboratory activities. This study looked at how physical science teachers' used the core concepts explicitly during classroom lessons.

2.3 A DELPHI STUDY OF THE NATURE OF SCIENCE

It is important to look at a Dephi study of the nature of science because it gives a summary of the experts' opinions on the themes of NOS. A Delphi study invites selected individuals to take part in a study to generate ideas and consensus. These are highly intelligent individuals who have specific knowledge and expertise about a certain subject. Through a facilitator, the panel of individuals see and react to each others ideas through fax, phone or email. They then generate new ideas based on consensus.

This is a study of reliable research findings about the Nature of Science that I need to compare my research assertions with. The Delphi study I used, included participants like world-renowned scientists such as Professor Julia Higgins, Professor Frank Close, philosophers and sociologists such as Prof Harry Collins, Professor David Papineau, science educators such as Professor Joan Solomon, Professor Edgar Jenkins. To add, W.F McComas has written many articles (McComas, 2005) and an academic textbook (McComas, 1998) with regards to the Nature of Science. During the rounds, participants are encouraged to revise answers to converge towards the group consensus. A facilitator then summarizes the experts' views and opinions. In a Delphi study Collins, Osborne, Ratcliffe, Millar, and Duschl (2001) looked at how a range of 'experts' in science education, science, history, philosophy and sociology of science, answer the question. "*What should be taught to school students with regards to the nature of science*?"

The themes commonly agreed upon with a mode of 4-5 (5-point Likert scale) and standard deviation of less than 1 were as follows:

1. Science and certainty (Science taught in school is well-established and beyond reasonable doubt. It is subject to change when new evidence becomes available.)
2. Scientific method, and critical testing.
3. Creativity.
4. Historical development of scientific knowledge.
5. Diversity of scientific thinking.
6. Analysis and interpretation of data.
7. Science and questioning.
8. Cooperation and collaboration.

The Delphi study, the McComas' (2005) definitions, and the National Curriculum Statement (Department of Education, 2003) guidelines to NOS teaching informed my research attempts, to seek understanding between teachers' NOS understandings and their classroom practice. historical development of nature of science

A consensus view of the NOS objectives, as extracted from eight international science standards document in McComas, Clough, and Almazroa (1998, p.6), is:
1. Science explains natural phenomena.
2. There is no one way of doing science.
3. People from all cultures contribute to science.
[A complete list of the NOS objectives is in Appendix G]

The core concepts of the Nature of Science I used in this study are tentativeness of scientific knowledge, the creativity in the development of scientific knowledge, the subjectivity of scientific knowledge, the empirical evidence of scientific knowledge, the socio-cultural embedded-ness of scientific knowledge, the development of theories and laws and the importance of observations and inferences in developing scientific knowledge.

2.4 HISTORICAL DEVELOPMENT OF NATURE OF SCIENCE

From 1900 to 1930, physics and chemistry positivist research dominated the research front. The curriculum in school and universities reflected aspects of this, for example, practical investigations were imitated and simulated in classes. A time-line of the development of the history of Nature of Science from 1900-1990 is as follows:

1900-1960: rise of biology, general science, and scientific humanists.

1960-1970: The Nuffield Projects became popular. The Nuffield Projects looked at major science curriculum reforms in the UK and the rest of the world. The idea was to discover science and become a scientist for the day. This was achieved through “guided discovery” instead of “recipe investigations.” The aim was to get students to become active learners. These projects were done in independent schools and certain selected schools. This approach however ignored the social and the creative aspects of the NOS and was discontinued.

1970-1990: STS (Science, technology and society)

SISCON (science in a social context)

SATIS (science and technology in society)

SCIENCE IN SOCIETY

SALTERS PROJECT: This was a ‘context led’ basis to teach science. This led to relevance of science education and its links to NOS.

It is evident from the outline above that the Nature of Science is vital to science teaching and understanding, but how are South African science teachers coping with NOS learning and how is this examinable component (NOS) of their classroom instruction and teaching strategies to be implemented? There is a concern about teachers' views of NOS (Arnold, 2001; Dekkers, 2003; Linneman, 2003).

From 1989, onwards leading science education exponents like Aikenhead, Lederman, Mathews and McComas, campaigned for the Nature of Science to be included in the science curriculum. Collins, Osborne, Ratcliffe, Millar, and Duschl (2001) argue that questions such as "What is science? What is technology? How does society decide?" are worthy of revisiting if teachers want to prepare pupils for citizenship in a global society. South Africa is at the cutting edge of science and technology development, and we as science teachers need to bring science, technology and society into the classroom through discussions on history and philosophy of science, through project-based learning, through internet technology, through forum discussions and web-based logging (commonly understood as blogs). A blog is an online diary, where multiple users can log in and update information, exchange ideas, work on projects in a collaborative way to reach consensus on specific issues.

2.5 THE TEACHING SEQUENCE OF NATURE OF SCIENCE

To make NOS lessons meaningful, they have to be linked to the everyday social and cultural world of the learner. The science content that the student learns in classroom activities must be meaningfully linked to science contexts of society and technology and the environment.

The following diagram by Aikenhead (1994) looks at using a student-centred approach for the teaching of nature of science .

The figure that follows shows the inter-relationships of Science, Technology and Society (STS) student-centred approach for NOS classroom practice in detail.

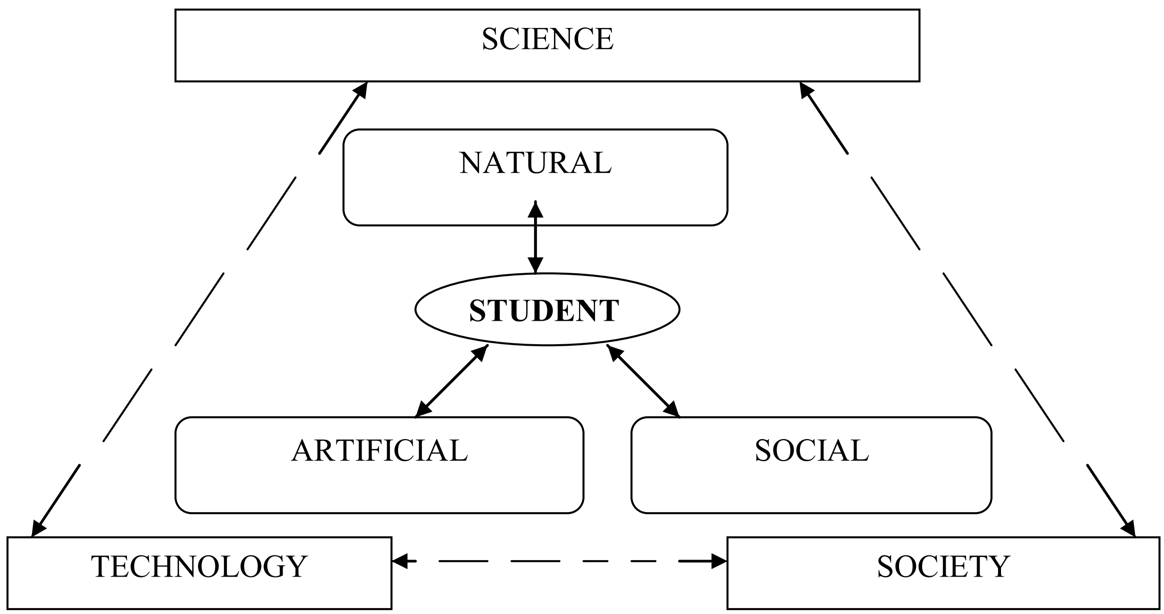

FIGURE 2.5.1: Student-centred approach for STS Teaching, Aikenhead (1994)

Aikenhead (1994) explains it as follows: In a science, technology and society (STS) science curriculum, the science content is connected and integrated with the students' everyday worlds, and in a manner that mirrors students natural efforts at making sense out of these worlds. Therefore STS science teaching must include the social responsibility in collective decision making on issues related to science and technology.

What would then help teachers to sequence their NOS lesson activities? The modified diagram Table 2.5.2. designed by Aikenhead (1994), suggests the following sequence for STS science teaching.

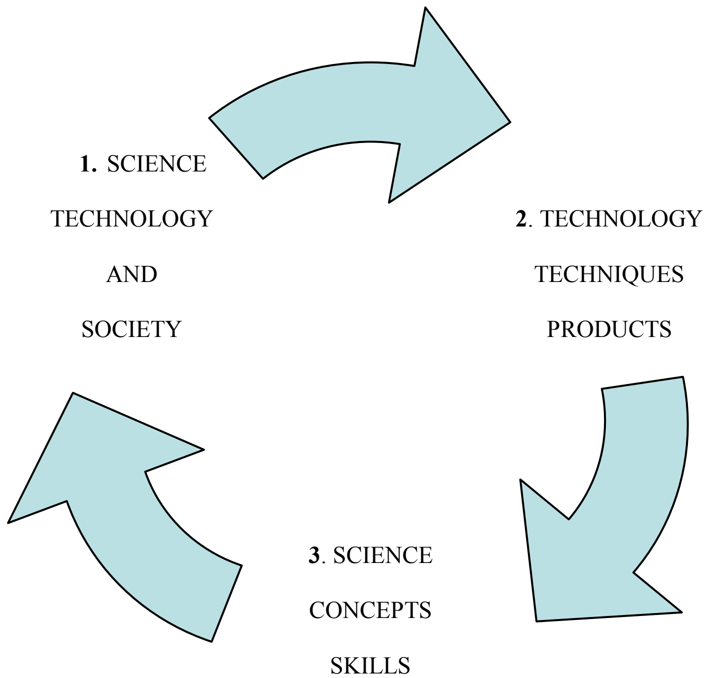

FIGURE 2.5.2: Sequence for STS Teaching, Aikenhead (1994)

Seeing that students are affected far more by the technological world than the scientific world, Aikenhead (1994) suggests that teachers start STS in the realm of society. This was also concluded by Schreiner and Sjoberg (2004) with regards to the relevance of science education in a social context. Aikenhead (1994) suggests that teachers start with a societal problem, and this will involve examining some technology. Hence societal issues are almost always related to technology. Examining both the societal world and the technology world creates needs to know some science content. The arrows suggest that we begin in the domain of society, move through the domain of technology and traditional science, and then out again to technology to understand the deeper meaning of science and technology. Hence traditional science is not watered down but is embedded in a social–technological context. The link to the nature of science is that new science principles are used in technology and that new technology develops new science principles.

Lemke (2005) encourages the following in science lessons: teaching students to talk science, the harmful and beneficial issues in science, helping all students use science in their own interests etc.. For secondary schools, Lemke (2005) suggests the following approach: open the potential career path to science and technology for all, provide information about the scientific view of the world that is of proven usefulness for most citizens, give some sense of the role of science and technology in social life, help develop skills of complex logical reasoning and use of multiple representations, and for those who wish it: (a) a less intensive path that keeps open the option for a science or technology specialization, (b) a more intensive path for those who have already decided they wish to follow this path in university or advanced technical education.

2.6 TEACHERS' CONCEPTIONS OF THE NATURE OF SCIENCE

The teachers' conception of the Nature of Science (NOS), are very important for classroom practice. This study also compared and reported some of the national studies in NOS and the international studies.

Many studies were conducted nationally (Ayayee & McCarthy, 1996; Dekkers & Mnisi, 2003a; Linneman, Lynch, Karup, Webb, & Bantwini, 2003; Ogunniyi, 2006; Webb, Cross, Linneman, & Malone, 2005) and internationally (Abd-El-Khalick, Bell, & Lederman, 2001; Aikenhead & Ryan, 1992; Akerson & Volrich, 2006a; Bell, 2001; Bianchini & Solomon, 2003; Botton & Brown, 1998; Clough, 1998; Lederman, 1999) to elicit teachers' views on the nature of science. These studies worked with pre-service as well as in-service teachers. The studies showed that most science teachers have inadequate NOS views. Can science teachers change their views of the nature of science? In a study by Finley and Palmquist (1997) the following issues with regards to pre-service teachers' nature of science (NOS) views were investigated and they are:

1. What were pre-service teachers' nature of science views prior to two methods courses and associated practicals?
2. How did pre-service teachers' nature of science views change after taking the two methods courses?
3. What aspects of the nature of science are portrayed in the classroom actions during pre-service teachers' practical experience?

The NOS questionnaire was given prior, and post the two methods courses and compared for changes in views. Mid-methods course data were obtained by analysing lesson plans, curricular materials and journal entries. The study found that most of the traditional views of science were replaced with contemporary views of science after the methods course.

This also concurred with other studies (Akerson & Volrich, 2006a; Duveen, Solomon, & Scot, 1992; Eflin, Glennan, & Reish, 1999; Lederman, 1999; Linneman, Lynch, Karup, Webb, & Bantwini, 2003). This important study by Finley and Palmquist (1997) concluded that teachers could make better curricular decisions with respect to the nature of science if they knew how different classroom activities portray the nature of science.

Lederman (1992) reviewed the research on the nature of science, in terms of teachers' conceptions and concluded the following:

1. Science curricula in all countries agree on the 'development of an adequate understanding of the nature of science.'

2. An individual's belief concerning whether or not scientific knowledge is amoral, tentative, empirically-based, a product of human development, reflects that individual's conception of the nature of science.

3. If science teaching is viewed as a purposeful and conscious act, then a teacher must possess an adequate knowledge of the nature of science.

4. Science methods courses improve teachers' understandings of the nature of science.

5. Inclusion of philosophy and history of science courses improves science teachers' understandings of the nature of science.

6. Teaching experience does not contribute to a teacher's understandings of the nature of science.

7. There could be some connections between teachers' views on the nature of science and their conceptions of learning and teaching.

The statements 3-5 above are pertinent to this study. The national South African studies by Dekkers (2003) and Linneman (2003) indicated that science teachers had inadequate knowledge and views on NOS.

Abd-El-Khalick, Bell and Lederman (2001) looked at pre-service teachers' understanding and teaching of the nature of science. Deductions from the study are as follows:

1. Participants with strong intentions, well-developed NOS views, and an extensive knowledge of science content were most successful in their instruction.

2. It was found that even though pre-service teachers held informed views of several aspects of NOS, only a small minority attempted to incorporate NOS in their teaching.

3. Pre-service teachers had not internalised the importance of teaching NOS and were thus unlikely to afford any instructional importance.

Locally, important studies (Linneman, Lynch, Karup, Webb, & Bantwini, 2003) researched South African science teachers' perceptions of the nature of science. Linneman et al., studied responses to a questionnaire and subsequent focus group interviews of 135 Eastern Cape science teachers from Grades 4-9. Two important research questions were addressed, namely, "What do science teachers view as the place for the nature of science in the school science curriculum?" and "What do these teachers' view as the role of technology education in the broader effort of science education?" Many of the teachers admitted to never having thought about focussing their science teaching towards the nature of science as a goal. Linneman et al., concluded that although the survey subjects strongly disagreed with the notion of separating science, technology and society, evidence in the questionnaire and group interviews suggest that they have little, if any formal exposure to the nature of science.

Dekkers and Mnisi (2003a) conducted another important South African study and examined whether science teachers have the understandings of the nature of science that they are expected to teach. Pre-service and in-service teachers in Limpopo province in South Africa completed a Values of Nature of Science (VNOS) questionnaire and participated in a semi-structured interview. Results suggest that the teachers believe that science relies solely on experiments. They believe that experiments prove rather than support scientific claims. They see laws as certain and that experiments provide proof. The true understanding of the tentative nature of science was scarce amongst science teachers. Dekkers and Mnisi (2003a) concluded that the majority of participants did not exhibit a fully adequate understanding of the nature of science. Their findings indicate a need for in-service programmes to develop teachers' understandings of the NOS and for appropriate pedagogy.

The view that science teachers' have an inadequate knowledge of NOS and a need for in-service professional development programmes is not unique to South Africa. International studies (Aikenhead, 2000; Bryan, 2002; Lederman, 1998; Lumpe, 1998; Macdonald, 1996) have always campaigned for in-service and pre-service programmes to make the nature of science a daily way of science teaching.

Ogunniyi (2006), an education researcher in Western Cape, South Africa, studied the views of NOS of two science teachers, and the methodological approach to NOS teaching, in a Masters programme before and after taking a semester-long Nature of Science course. The study points to the use of historical, philosophical and social perspectives of the NOS for the process of classroom argumentation. The data looked at the responses to a questionnaire before and after taking the NOS course and follow up interviews to clarify responses. The content of the course was based mainly on the *History of Science*: works of Cline, Kuhn, Toulmin, and Goodfield; *Philosophy of Science*: works of Carnap, Frank, Gilje, Harre, Hempel, Hull, Nagel, Popper, Rosh, Rosenberg, and Skirbekk; *Sociology of Science*: drew on the works of sociologists of science, anthropologists, linguists, scientists and science educators such as Aikenhead, Barad, Bybee, Carlton, Chomsky, Cobern, Driver, Halliday, Lemke, Merton and Ziman. It is important as science educators that we understand how to include and teach the history of science, the philosophy of science and the sociology of science in our everyday lessons. It will show our learners that scientific knowledge is not developed in a linear fashion but is a dynamic process as described below.

In *The Structure of Scientific Revolutions* (SSR), Kuhn (1963/1970) argued

> “ science does not progress via a linear accumulation of new knowledge, but undergoes periodic revolutions, also called "paradigm shifts", in which the nature of scientific inquiry within a particular field is abruptly transformed. In general, science is broken up into three distinct stages. Prescience, which lacks a central paradigm, comes first. This is followed by "normal science", when scientists attempt to enlarge the central paradigm by "puzzle-solving". As anomalous results build up, science reaches a crisis, at which point a new paradigm, which subsumes the old results along with the anomalous results into one framework, is accepted. This is termed revolutionary science”. (Kuhn, 1963/1970)

Karl Popper very strongly advocated “that scientific theories, and any other claims to knowledge, can and should be rationally criticized, and (if they have empirical content) can and should be subjected to tests which may falsify them” (Popper, 1963).

This seldom happens in a science classroom. As science teachers, we are more eager to prove rather than disprove theories. The least we should try to do is to engage our students in constructive debates, with regards to socially-accepted scientific theories.

2.7 EXPLICIT INSTRUCTIONS WITH REGARDS TO THE NATURE OF SCIENCE

Teachers' need to include in their lesson plans their NOS concepts that they will be using in the lesson. Nature of science is not a by-product of science teaching. NOS concepts are useful to include in science lessons because it enhances context-based teaching.

Macdonald (1996) investigated how science teachers' convey explicit messages about the nature of science. He investigated both novice as well as experienced science teachers in terms of: teaching (in the generic sense), science subject matter and the nature of science. He analysed teachers' lesson plans in terms of explicit NOS instruction. He found that" novice science teachers were only concerned with science subject matter and ignored the NOS aspect". (p. 184). The experienced teacher explicitly taught aspects of NOS in terms of predictions, hypothesising, observations, falsification, subjectivity and creativity. This statement is important because it contradicts Lederman (1992) in his reviewed research on NOS that teaching experience does not contribute to a teacher's understanding of the nature of science.

Lederman and Lederman (2004) investigated Project ICAN (Inquiry, Context and the Nature of Science). This project was an attempt to couple teachers' professional development relative to NOS, and scientific inquiry with an extended focus on teachers' classroom practice and student achievement. The emphasis was on 'constructivist' teaching for this project. Teachers attended a three-week summer institute followed by monthly workshops. Supervisors conducted on-site classroom observations to provide individualised feedback. Lederman and Lederman (2004) emphasised an explicit/reflective approach to teaching of NOS and Scientific Inquiry (SI).

Science teachers should include in their lesson plans NOS teachings. NOS and SI understandings should be intentionally planned for, taught and assessed rather than be expected to emerge from teaching science content or process skills. This view was also expressed by Akerson and Volrich (2006b), Holbrook & Rannikmae (2007), Khishfe and Lederman (2006), Lederman, (1999), Macdonald, (1996), Spector et al., (1998) and Schwartz et al., (2002).

2.8 THE IMPORTANCE OF NATURE OF SCIENCE AND CLASSROOM PRACTICE

According to Collins, Osborne, Ratcliffe, Millar, and Duschl (2001) the nature of science for explicit classroom instruction is important for the following reasons as summarised. Pupils will be given an opportunity to use scientific inquiry and develop the ability to think. Pupils will understand the growing dominance of science and technology in our society. Pupils will be well-equipped to respond to socio-scientific issues.

From South African newspaper reports and television broadcasts, there is a dire shortage of science teachers in schools especially in rural schools. For our pupils to understand and engage in science and technology that involves their daily lives, the Nature of Science has to be classroom reality. The responsibility therefore falls on teachers to engage students in issues of science, technology and society.

Internationally, as quoted by McComas, Clough, and Almazroa (1998), there is a movement from “what do scientists know” to “ how do scientists know”. Science teachers must include in their classroom practice, how knowledge was constructed. The misconceptions that teachers have about NOS are an important reason for NOS modules to be included in pre-service and in-service programmes for science educators.

McComas, Clough, and Almazroa (1998) furnish five reasons why NOS should be part of everyday classroom practice. These are:

1. “NOS enhance the learning of science content”. McComas, Clough, and Almazroa (1998, p.11).This will allow students to develop a dynamic and not a static view of science. It will also allow for an integrated understanding of science concepts. Their conceptual understanding of science and technology is enhanced.

2. “NOS knowledge enhances understanding of science”. McComas, Clough, and Almazroa (1998, p.12) Teachers who do not have a good understanding of the history and philosophy of science have difficulty in teaching discovery and relevance in their science instruction. This emphasises the need for pre-service and in-service courses in history and philosophy of science.

3. “NOS enhances interest in science”. McComas, Clough, and Almazroa (1998, p.13). Teachers need to make pupils aware of the development of scientific knowledge to sustain their interest in science. Teachers should engage students in the lives of scientists through assignments, role-playing and debates. Pupils will then understand how scientists used experimentation and available technology to construct scientific theories and principles.

4. “NOS enhance decision-making”. McComas, Clough, and Almazroa (1998, p.13) Teachers who teach NOS explicitly are inculcating in pupils, how science functions. Pupils can therefore make more informed decisions. When pupils’ scientific literacy is improved through NOS teaching, they are more likely to engage in scientific decision-making.

5. “NOS Knowledge enhances Instructional Delivery”. McComas, Clough, and Almazroa (1998, p.14). Matthews (1998) argues for the inclusion of NOS courses in science teacher education programmes. He believes that this will help teachers to implement conceptual change models of instruction. The construction of scientific knowledge has much in common with conceptual change. Teachers who undertake professional development courses in conceptual change are more comfortable in teaching NOS and the scientific construction of knowledge.

According to McComas, Clough, and Almazroa (1998), " because a teacher has an understanding of NOS does not mean that they know how to integrate NOS in the classroom" (p. 14). Given this assertion it was important for me to observe NOS integration and practice in classroom lessons.

2.9 THEORETICAL AND CONCEPTUAL FRAMEWORK

The Nature of Science (NOS) is embedded in the social reality and the cultural practices of different communities. Social constructivists in general, and theorists such as Bruner and Vygotsky (1978, 1996), believe learning is an active process that takes place in social contexts. Learners construct new ideas or concepts based on prior-learning experiences. NOS will therefore be positioned along the following frames of inquiry: The first will be the *Historical, Social and Philosophical considerations of the nature of science,* and the second *will be the Constructivist theory and the development of knowledge.*

2.9.1 Historical, Social and Philosophical considerations of Nature of Science

I feel that the history of science is fundamental to the NOS principles because it adds a 'human face' to science. Scientists like Copernicus, Kepler, Galileo, Newton, and Einstein were ordinary citizens of the world. They had families as well as jobs as scientists. When teachers set historical projects or assignments with regards to scientists' lives, their families, their beliefs, their communities and their philosophies it gives students a greater insight into the construction of knowledge. Historical studies create curiosity in the learner (Eflin et al., 1999).

Ravetz (1971) explains that the social and ethical problems caused by the industrialisation of science are the deepest problems in the understanding of science in our period. This still holds true for the modern day because of advancement in technology, space exploration, the medical field, communications, transportation etc. Teaching NOS needs to consider real world social and ethical contexts through discussions, models, charts, reflective journals, role-play etc. Okasha (2002) adds that the philosophy of science questions assumptions that scientists take for granted. Philosophers of science, such as Karl Popper and Thomas Kuhn, should be introduced at high school level for students to gain a deeper insight into NOS (Eflin et al., 1999).

As early as 1935, Popper (1983) believed that scientific knowledge consists of guesses or hypothesis. Hypothesis he believed solved that which we want to solve, but there may be another known hypothesis, which may solve the problem better. For example, Einstein searched for almost forty years for a better approximation of his theory on general relativity. Students will then appreciate that the science knowledge they study had taken many years of painstaking research and investigations.

Teachers need to teach children of the chance discoveries of the past, for example Roentgen and the discovery of X-rays or Pasteur and the immunization of chickens against chicken cholera. This will show students that science knowledge construction does not have a set A-to-Z way of doing things.

Newton was one of three scientists of modern history (the other two were Darwin & Freud) who changed the way of thinking of ordinary people. Kuhn (2000) asks questions with regards to the teaching of Newtonian mechanics especially the inter-related concepts force, mass and weight. Students need to think about how Newton looked at these concepts. Teaching the history of science will therefore allow our learners to appreciate the scientific construction of knowledge. History of science according to Kuhn (1963/1970) helps the children get an understanding of the scientific enterprise.

According to the Association of Science Education (1981), religion, politics, economics and the arts all worked within concepts that drew inspiration or support from the implications of Newtonianism, This is congruent with Kuhn's paradigm era. Duveen, Solomon, and Scot (1992) who state that the most common benefits of teaching the history of science are as follows: "Better learning of the concepts of science, increased interest and motivation, an introduction to the philosophy of science, better attitude of the public towards science and an understanding of the social relevance of science." (p. 418)

Matthews (1998), Lonsbury and Ellis (2002) and Ziman (1988) emphasise that when history and philosophy are considered in the nature of science, epistemological considerations follow. For example, "What is human knowledge? What is distinctive about scientific knowledge? Is there a scientific method? In what sense is science objective? Is science value-free?"

Science teachers seldom ask these types of philosophical questions. According to Fensham (1992) schools are established by societies that have various social groups. These social groups are interested in what happens in schools, more especially in science and technology education.

Industries of today need to know that our students are scientifically literate to contribute to the economy.

Ladyman (2002) also concurs with Mathews (1998) with regards to epistemology. He states that the area of philosophy that overlaps considerably with philosophy of science is epistemology. He also states that teachers need to consider in classroom discussion, questions with regards evidence and theory, theory change, the truth behind scientific theories, and the scope of scientific knowledge. Post-graduate science teachers that consider questions like these are therefore more comfortable dealing with discussions and issues of epistemology.

Students must be provided with various contexts for studying science, society, technology and the environment; for example, astronomy, machines, communication, medical technology, architecture, engineering, applied research, global science issues, etc. This will help to integrate the elements of NOS of tentativeness, creativity, subjectivity, empiricism, social and cultural factors, theories and models, and observations and inferences. The historical, social and philosophical considerations of the Nature of Science links to the theoretical framework of social constructivism.

2.9.2 Constructivist theory and the development of knowledge

According to Bodner (1986), we can teach well without having the students learn. To incorporate NOS in the classroom, teachers need to evaluate the child's prior learning experiences and in which social or cultural context his or her knowledge is based.

Does the child's indigenous knowledge system clash with the western knowledge discussed in classrooms? We need to cater for the African worldview of science versus the Western worldview (Jegede, 1999, Govender, 2009 in press). Problem-based learning allows for real life experiences and promotes NOS in a social setting.

Problem based learning is in line with the social constructivist theorists such as Bruner, Vygotsky and Piaget. Vygotsky's theories (1978, 1996) stress the fundamental role of social interaction in the development of cognition. He also stresses that social learning precedes development. Compared to Piaget, Vygotsky places more emphasis on culture, social factors and the role of language in cognitive learning. This thinking is in line with NOS education researchers like Aikenhead, Lederman and McComas.

Science must be taught as a process-based curriculum. Making sense of the world we live in is directly linked to NOS and science as a human endeavour and science for human development. Constructivist classrooms must motivate the students' curiosity of real life experiences, through role-play, games, timelines, charts, maps, reflective journals and open-ended investigations.

Constructivism is having a major impact on science teachers' instructional strategies (Fosnot, 1996; Taylor, 1998; Glasersfeld, 1996). Although constructivism is a theory about learning, Fosnot, (1996) outlines the following general principles for the science educators to rethink and reform their educational practices. The principles are as follows: "Learning is not the result of development. Learning is development". "Errors need to be perceived as a result of learners' conceptions and therefore not minimized or avoided". "Reflective abstraction is the driving force of learning". "Dialogue in classrooms engenders further student and teacher thinking". "Learning proceeds to the development of cognitive structures". Construction of scientific knowledge is therefore dependent on the theory of social constructivism, and how knowledge is contested and accepted, links to the nature of science, the social, political and religious factors.

The principles of constructivism must help the South African physical science teacher to engage students in science dialogue. They need to understand, that when students have misconceptions, they must to be guided to correct conceptions via dialogue and debates and not merely instructed to change their way of thinking.

According to Taylor (1998), constructivist theory was elaborated to take into account the social context of knowledge construction. This has become even more relevant to the teaching and learning of the nature of science. Taylor (1998) goes on to say that if science education is to benefit from constructivism, then science educators need an explicit moral framework for helping students to judge the worth of competing knowledge claims. He concludes by saying that constructivism is providing teachers with a powerful perspective of understanding pupils experiences of the natural world.

Some of the benefits of constructivism are that children learn more when they are actively involved, rather than as passive learners. They think and understand real world contexts. Constructivism promotes social and communication skills. It helps students transfer skills to the real world. It promotes intrinsic motivation to learn.

It therefore means that physical science teachers are not only preparing a scientifically-literate community of learners but, more importantly, are preparing these learners for life-long learning through context-based learning.

2.10 SUMMARY OF THE LITERATURE REVIEW

The literature review began with a discussion and comments on some of the leading exponents of the Nature of Science (NOS) for example, McComas, Lederman, Bianchini, and included philosophy of science (Carl Popper) and history of science (Thomas Kuhn). This is important because it clarifies all the core concepts of the nature of science that I discuss thereafter. The core concepts of Nature of Science as suggested by the National Curriculum Statement (Department of Education, 2003) which I have outlined on page 19 suggests that all physical science teachers' should include the historical, cultural and social influences of the construction of scientific knowledge during classroom lessons and activities. I have used these important concepts in my NOS questionnaire and my observation schedule. The core concepts of the Nature of Science I used in this study are: tentativeness of scientific knowledge, the creativity in the development of scientific knowledge, the subjectivity of scientific knowledge, the empirical evidence of scientific knowledge, the socio-cultural embedded-ness of scientific knowledge, the development of theories and laws and the importance of observations and inferences in developing scientific knowledge. The Delphi Study (Collins et al, 2001) looked at what should be taught to school students with regards to NOS. The science educators and philosophers in the Delphi Study also reach consensus that creativity, tentativeness, and the historical and cultural influences of the construction of scientific knowledge should be part of science lessons. I then traced the historical development of NOS from the 1960 and the Nuffield science initiatives of the 1970’s, to promote NOS in classrooms. This was outlined to show that NOS was very much part of classroom lessons in the past and it should again be part of all science teachers’ future lessons. I then discussed the teaching sequence of NOS as suggested by Aikenhead (1994). He suggested a student centred approach for the teaching and learning of NOS in the classroom to emphasise the social –technological context of NOS.

The next important issue I discussed was the different national and international studies, of NOS with regards to science teachers’ conceptions of the NOS. It was evident from a discussion of these studies that those science teachers that were not exposed to modules in NOS had inadequate views of NOS. This study therefore looks at postgraduate students who have been exposed to NOS modules.

This is followed by a discussion on the importance of NOS for classroom practice (McComas, 1998). NOS enhances the learning of science content, decision making, promotes interest in science, enhances understanding of science and instructional delivery of science lessons.

Lastly I discussed the historical, cultural and social influences in the construction of scientific knowledge and how this will be linked to the theoretical framework of social constructivism.

The next chapter is the methodology chapter that focuses on the research design, the data collection, the case study, the research instruments, the limitations and the ethical considerations of this study.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

The focus in this study was on post-graduate honours physical science teachers' understandings of the Nature of Science (NOS) and how their views are translated into classroom practice. A mixed method design was implemented and research instruments were used to gather data. The mixed method designed included a qualitative and quantitative treatment of the NOS questionnaire and a qualitative treatment of the NOS classroom observations. The design focused on how individual physical science teachers implement the NOS aspects of teaching. A detailed observational schedule was completed for each physical science teacher. The research instruments, included, a NOS questionnaire, a classroom observation schedule, audio recordings of each teacher's lessons and a structured post-lesson interview schedule.

3.1 RESEARCH DESIGN

According to the literature review in Chapter 2, most science teachers in South Africa have inadequate NOS views (Dekkers & Mnisi, 2003). The research design was therefore to engage in a study of how four Bachelor of Education (B.Ed) Honours Physical Science teachers' translate their NOS views into classroom practice. These teachers were enrolled at the UKZN in modules that covered science education issues including curriculum planning and NOS. They were in their final year of a two-year part-time study degree.

3.1.1 Setting the scene for the design of the study

Initially, the teachers were given a Value of the Nature of Science (VNOS) questionnaire to complete, prior to the university exposure of NOS. Teachers were accessed at the beginning of module covering NOS on the university campus. Permission was sought from teachers and university staff to conduct the research. The honours programme at UKZN is offered on a part-time contact-mode basis, where teachers attend coursework during their vacations. Hence during the July vacation, the module *Issues in Science Education* was taught. The lectures, seminars and interactive discussion sessions ran for two weeks followed by a 3-day session in September. The coursework assessment is based on teachers' participation in different tasks and on a major assignment.

The two lecturers of the modules introduced me to the teachers and briefly explained the research I was conducting. Thereafter, I explained the purpose of my study and asked for four volunteers from four different schools in the Durban area. I requested teachers' from the Durban area because this is where I reside. The research only started in 2006 when the teachers, had completed their studies.

3.1.2 The Case study

This research was designed as a case study. The 'case' in question was four physical science teachers' NOS views and how these teachers were translating their NOS views into classroom practice. Denzin and Lincoln (1994, p. 440) argue that a case is essentially "a phenomenon of some sort occurring in a bounded context." The phenomenon is the teaching of NOS and the bounded context is the science classroom, the teacher and the students.

The study was descriptive and exploratory in nature as “coming to understand a case usually requires extensive examining of how things get done, but the prime referent in case study is the case, not the methods by which cases operate” (Denzin & Lincoln, 1994, p. 245). A case according to Cohen, Manion, and Morrison (2000) “investigate and report the complex dynamic and unfolding interactions of events, human relationships and other factors in a unique instance” (p. 181).

I wanted to observe the NOS aspects of tentativeness, creativity, subjectivity, empirical basis, social and cultural embedded-ness, theories and laws, observations and inferences. Thus, this study focuses on how physical science teachers’ are engaging with NOS in classroom interactions as part of their instructional strategies.

As a case study, the researcher also needs to sample a range of “nested activities” (Denzin & Lincoln, 2004, p. 441). These include participant and non-participant observation. Non-participant observation was employed for this case study. For data collection the researcher sat at the back of the classroom and observed the teaching and learning of NOS categories, namely, tentativeness, creativity, subjectivity, empirical basis, social and cultural embedded-ness, theories and laws, observations and inferences. These observations were recorded in the NOS-structured observation schedule (Appendix E). The intention was to describe and interpret the classroom dynamics and human relationships with regard to NOS teaching.

3. 1.3 Sampling

The four teachers from four different schools represent a sample of all post-graduate science teachers in KwaZulu-Natal. This was a sample of convenience. It was easy to travel to these schools. Two teachers taught at former all-white schools in a white suburb and two teachers taught at state schools in an Indian suburb. The students came from different social backgrounds representing a good proportion of all the different population groups of South Africa. I made an appointment with all the principals of these schools and explained my research to them. I then sought their consent to carry out my research through a consent form for principals and a different consent form for the four teachers' (Appendix B and C)

3.1.4. Data Collection

Thirty-eight post-graduate science teachers' completed a Value of Nature Science (VNOS) questionnaire. Classroom observation schedules were used for each of the four teachers to record the NOS teachings (Appendix E). Each lesson was recorded with audiotapes. Each teacher took part in a structured post-lesson interview on one of the four, lessons he felt were successful in terms of Nature of Science and classroom practice. I used a structured interview so I could make a comparison of the responses of the four teachers.

3.1.5 Data collection plan

The general question plan for data collection was guided by a Masters Proposal writing Handbook by Jansen and Vithal (1997) and widely used by postgraduate education university students in their research modules. The plan assisted the researcher in gaining an overview of the data collection process. It is represented in table 3.1 below.

Table 3.1. Data Collection Plan

Questions	Data collection plan	Justification
Why is the data being collected?	To examine the relationship between science teacher's views of NOS and knowledge and their classroom teaching.	The teachers' NOS beliefs and knowledge does not always translate into practice
What is the research design?	Observation of classroom lessons and interviews	It will show the teachers intention and planning to teach NOS.
Who will be the sources of data?	B.Ed. (Hons) science teachers registered at the University of KwaZulu- Natal.	B.Ed. (Hons) science teachers have been exposed to a module covering the NOS.
How many of the data sources will be accessed?	Four teachers will be observed in class and a post-lesson interview will be conducted with each teacher. The interview will be approximately 30 minutes.	It will represent a sample of B.Ed.(Hons) science teachers registered at UKZN for the programme.
Where will the data be collected?	At the schools where the teachers teach.	The school science classrooms are the sites where NOS is taught and teachers will be in authentic teaching and learning situations, thus making the research valid.
How often will data be collected?	Over a six-week period in the four schools in the Durban, KZN	A variety of topics and lessons will be taught in these periods

	area.	allowing teachers to integrate NOS in their lessons.
How will the data be collected?	Observation schedules and a post-lesson interview	To probe the variety of instructional strategies used for NOS teaching and learning. Also to probe the extent to which NOS is focussed in classroom practice.

3.2. CASE STUDY

My study was best suited for a case study because it describes the cases of four physical science teachers in their attempts at NOS classroom practice. I wanted to observe how teachers are translating their NOS views into classroom practice. According to Cohen, Manion, and Morrison (2000) “case studies investigate and report the complex dynamic and unfolding interactions of events, human relationships and other factors in a unique instance” (p. 181). I wanted to observe to what extent these teachers are implementing NOS in the classroom and what are some of the successes and challenges for them in this implementation.

As Neuman (2000) suggests, “the interpretative approach is the systematic analysis of socially-meaningful action through the direct detailed observation of people in natural settings, in order to arrive at understandings and interpretations of how people create and maintain their social worlds” (p. 68). The teachers’ natural setting is his or her classroom and his or her teaching of

NOS is very much part of our social world. I needed to understand and interpret the four cases I have used.

In my case study, I was especially interested to see how science teachers are engaging with NOS as part of their instructional strategies. I used non-participant observation for my case study. I sat at the back of the classroom and ticked my NOS-structured observation schedule (Appendix E). My intention was to describe and interpret the classroom environment in terms of NOS teaching.

3.2.1 Sample

My case study belongs to the category aptly called by Denzin and Lincoln (2000) "the teaching case study" (p. 238). This implies that individual teachers will be observed in the classroom and interpretations and observations from the lessons will be described as a case. All the teachers in my sample have completed a module on NOS in their B.Ed Honours Science degree. They have informed views on the Nature of Science, and are suitable participants for my case study. The four teachers from four different schools represent my sample of all post-graduate science teachers in KwaZulu-Natal.

3.2.2. Limitations of my sample

This is a small-scale study of how four physical science post-graduate teachers translate their NOS views into classroom practice. It is the very first time, due to the new FET syllabus, that they are compelled to teach and examine NOS. The first year would definitely be a 'trial run' with its many challenges of getting to know the new syllabus as well as teach NOS in the classroom. These teachers would be the 'trailblazers' for the NOS inclusion in the South African science curriculum and the South African context. This study is important to identify all these challenges. A follow-up study in a year's time should see how these teachers have developed in terms of their NOS teaching.

3.2.3. Ethical issues involved

My focus in this research was teacher observations of classroom practice of NOS. I therefore obtained ethical clearance from the University of KwaZulu-Natal. I obtained permission to conduct research in schools from the Department of Education of KwaZulu-Natal. The principals of each of the four schools signed informed consent letters. (Appendix B). The four physical science teachers signed informed consent letters (Appendix C). I also explained to the teachers in my sample that they were free to read my analysis of the data collected.

3.3. RESEARCH INSTRUMENTS

I used the following research instruments: A Value of the Nature of Science (VNOS) questionnaire (Appendix D) adapted from international and national literature (Aikenhead, Ryan, & Fleming, 1989; Linneman, Lynch, Karup, Webb, & Bantwini, 2003). A structured observation schedule (Appendix E) adapted from international literature (Abd-El-Khalick, Bell, & Lederman, 2001). This was followed by a structured interview schedule (Appendix F) adapted from international literature (Clough, 1998b).

3.3.1 The purpose of the questionnaire

A questionnaire was employed because I could get a good population of thirty-eight post-graduate science teachers to complete it in a short time. I wanted confirm if they had adequate understandings of NOS with regards to the tentativeness of scientific knowledge, the creativity in the development of scientific knowledge, the subjectivity of scientific knowledge, the empirical evidence of scientific knowledge, the socio-cultural embedded-ness of scientific knowledge, the development of theories and laws, the link between science and technology and the importance of observations and inferences in developing scientific knowledge. I used both closed questions and open questions. According to Neuman (2000), with closed questions, "it is easier to code and statistically analyse" and with open questions, "it permits creativity, self-expression and richness of detail" (p. 241). Open-ended questions were used in the questionnaire because it "invites an honest, personal comment from the respondents, in addition to ticking boxes" (Cohen, Manion, & Morrison, 2000, p. 255). I wanted the science teachers' to write their personal views so that I could gauge their understandings of the Nature of Science. I then piloted the questionnaire with 5 post-graduate physical science teachers but it did not lead to any change in the original questionnaire.

I analysed the closed-ended questions using the SPSS programme because this part was subjected to quantitative analysis for the percentage of correct responses. I analysed the open-ended questions using codes, categories and then formed assertions. This enabled me to get a balanced understanding of post-graduate science teachers' understandings of the Nature of Science.

Aikenhead, Ryan, and Fleming's (1989) Value of Nature of Science (VNOS) questionnaire was used to understand 1000 Canadian Grade twelve learners' views on Nature of the Science. They supplied a question with eight to ten alternatives to choose from. The questionnaire was a hundred and sixteen pages long. Linneman, Lynch, Karup, Webb, and Bantwini (2003) used a three-point Likert scale with ten NOS questions. I used questions from both (Aikenhead, Ryan, & Fleming, 1989; Linneman, Lynch, Karup, Webb, & Bantwini, 2003) but used a five-point Likert scale. I designed the questionnaire to keep up to date with international research, and also to ground it in a South African context. The 15 closed ended questions came from both,local and international contexts (Aikenhead, Ryan, & Fleming, 1989; Linneman, Lynch, Karup, Webb, & Bantwini, 2003). The questions I chose is in keeping with the South African National Curriculum Statement (Department of Education, 2003) core NOS concepts. The 5 point Likert scale gave participants a chance to see how strongly they agree or disagree with the 15 statements.

3.3.2. Observation

According to Krishnaswami and Ranganathan (2005), "observation is selective". A researcher does not observe anything and everything but "selects the range of things to be observed on the basis of the nature, scope and objectives of his study." (p. 170). This is very pertinent to my study. I had a structured observation schedule. I used this schedule to observe the science teacher in the classroom practice of NOS. My observation schedule had a specific purpose of noting only the NOS aspect of the lesson. I was a non- participant direct observer. My observation schedule was adapted from a study by (Abd-El-Khalick, Bell, & Lederman, 2001) of pre-service science teachers' knowledge and classroom practice of NOS (Appendix E).

The observation schedule was used for the following reasons: "It makes it possible to study the behaviour as it happens. The observation is less demanding on the subjects. It improves the opportunities for analysing the contextual background of the behaviour" (Krishnaswami & Ranganathan, 2005, p.173).

I used "event sampling" (Cohen, Manion, & Morrison, 2000) to record my observations in the observation schedule. Each time a teacher used one or more aspects of NOS with explanations, descriptions and supporting examples I recorded the relevant aspect.

For example:

1. If the teacher gave a definition of indigenous knowledge I used one # in the column on social and cultural embeddedness.
2. If the teacher provided a description in his own words of indigenous knowledge and accepted examples of indigenous knowledge from the class I used two # # in the column on social embeddedness.
3. If the teacher provided a description in his or her own words and gave additional supporting examples I used three # # # in the column on social embeddedness.

3.3.3. Interviews

According to Cohen, Manion, and Morrison (2000) "the information must have a direct bearing on the research objectives" (p. 268), thus interviews are important for gathering information. I used a structured interview schedule because I was only interested to hear about the teachers' views on teaching Nature of Science in the classroom. I adapted some of the questions from (Clough, 1998) and drew up a ten-question interview schedule. All the respondents were asked the same questions in the same order. Their responses were recorded on paper and audio-taped.

The interview allowed the respondent to be able to express himself in terms of how he views NOS teaching, his lesson plans and future lesson plans to facilitate his classroom practice of NOS. My interview data was qualitative and my aim was to interpret the data in the context of the teachers' lesson plan and the actual delivery of the lesson.

3.4. TEACHERS' BACKGROUND

The four teachers in my study will henceforth be described as Alan, Ben, Carl, and Dan (pseudonyms). I have outlined the teacher's teaching experience, then subject taught, qualifications, his school context and his teaching style (as I have seen it for the four lessons.)

3.4.1. Alan

Alan has twenty years of experience teaching Physical Science at Senior Secondary phase (Grades 10-12). He has majored in Chemistry and has completed the B.Ed Honours Science degree through the University of KwaZulu-Natal. He teaches in large school of 1100 students. The student population is about 60% Indian students and 40 % Black students. Students pay school fees of R1200 per annum. It is situated in a middle class suburb. My observations show that his instructional strategy is teacher-centred although his questioning techniques allow for some discussion and debates.

3.4.2. Ben

Ben has fourteen years of experience teaching Physical Science at Senior Secondary phase. He has majored in Chemistry. He has one module left to complete his B. Ed Honours Science degree through the University of KwaZulu-Natal. He has however completed the module on the Nature of Science and was eligible to be a participant in this research. He teaches in a small school with a student population of about 650 students. The student population is about 50% Indian students and 50% black students. School fees per student are R500 per annum. The school is situated in a lower class suburb with a fair percentage of unemployment, poverty and crime. My observations show that his instructional strategy is teacher-centred, but his enthusiastic students like to debate and argue a lot. He has to constantly redirect the discussion at hand.

3.4.3. Carl

Carl has nineteen years of experience teaching Physical Science at Senior Secondary phase. He has majored in Physics and has completed the B. Ed Honours Science degree through the University of KwaZulu-Natal. He teaches in large school of about 900 students. The student population is about 60% White students, 20 % Black students and 20% Indian students. It is situated in an upper class suburb and students pay school fees of R16 000 per annum. My observations show that his instructional strategy is largely teacher-centred, but he allows for group work at the conclusion of each lesson.

3.4.4. Dan

Dan has eight years of experience teaching Physical Science at Senior Secondary phase. He has majored in Physics and has completed the B. Ed Honours Science degree through the University of KwaZulu-Natal. He teaches in large school of about 1000 students. The student population is about 75% White students, 15 % Black students and 10% Indian students. It is situated in an upper class suburb and students pay school fees of R13 000 per annum. From my observations, his instructional strategy is student-centred. From the outset of each lesson he divides the class into new groups for each lesson which involved debates, group discussions, practical work, and, investigations.

The next chapter analyses the data collected through the research instruments, that is, the questionnaire, the observation schedule and the interview schedule.

CHAPTER FOUR

DATA ANALYSIS

This chapter will focus on the analysis, of the research instruments used, that is, the NOS questionnaire, the observation schedule and the interview schedule. The NOS questionnaire is analysed both qualitatively to form assertions held by the majority of postgraduate science teachers and quantitatively to check for the percentage of acceptable NOS views held by post graduate science teachers. I also compared the assertions from this study to a Delphi Study. I then analysed the observation schedule for the four cases I observed followed by comments and a discussion. Lastly I analysed the structured interview schedule to ascertain the teachers' commitment to teaching NOS in the classroom.

4.1. ANALYSIS OF THE OPEN-ENDED QUESTIONS IN THE QUESTIONNAIRE

The Nature of Science (NOS) statements (Appendix D) were analysed using the inductive approach. Inductive reasoning, according to Babbie (2004, p. 25), "moves from a set of specific observations to the discovery of a pattern that represents some degree of order among all the given events".

I used the inductive approach because I wanted to read what each science teacher has to say about the Nature of Science concepts. I was then able to place them into common categories. I finally made assertions for each of the 5 open-ended questions based on common categories.

For each of the five open-ended questions in the questionnaire the following inductive approach was used:

I typed the 38 responses to each question on Microsoft Word Document. I assigned the numerical codes one to thirty-eight for the responses. After four readings of the 38 responses, I assigned the categories A, B, C, D, E to those numerical codes that were saying more or less the same thing.

As an example: numerical codes 1, 5, and 6, had the following similar response to the question: Is science and technology related? What is your viewpoint?

Numerical Code1: “Science in its pure form is related to laws, enquiries and methods. Technologies are systems in place to assist humankind.”

Numerical Code 5: “Technological changes are always based on scientific research and break-throughs.”

Numerical Code 6: “Many of the technological advancements are based on certain scientific principles.”

These numerical codes, as well as others, that were saying more or less the same thing about science and technology were given the category A. Likewise I assigned similar numerical codes to Categories B, C, D, E. I made assertions from the categories, according to what the majority of science teachers were saying about the question.

To ensure the *reliability* of my categories, I asked two science colleagues in my school to read the 38 responses and see if my categories and assertions were in line with what the respondents were saying in their statements. They agreed with me and I was now confident to type my data analysis.

My assertion was a specific statement derived from what the majority of teachers were saying about the NOS question. “two characteristics of science that are used to handle the problem of validity in analysis of existing statistics are, logical reasoning and replication” (Babbie, 2004, p. 327). My assertions were valid because 60% of the respondents repeatedly answered it in the same way, while 20% had alternative views and 20% were not sure. A science education professor familiar with NOS research then checked the data analysis and assertions. He also agreed with my assertions.

4.1.Table of categories from the open ended response questions

I have typed in the different categories and indicated the number of related responses in each category.

Question number one: *Is science and technology related? What is your viewpoint?*

Table 4.1.1. Categories of related responses for question 1

Categories of related responses	Number
A. Science involves laws and methods and technology is the practical application of scientific	15

principles.	
B. Science has helped technology and vice-versa.	8
C. Science lays foundations for technological developments.	10
D. Technology solves everyday problems	2
E. No response	3

Fifteen people have answered according to category A, eight people have answered according to category B, and ten people have answered according to category C. I then combined these three categories for my assertion with regards to Science and Technology.

Assertion

The majority of teachers' viewed science as involving laws and methods, while technology as involving practical applications. They are linked as science is seen to lay the foundation for technology and vice versa.

Question number two: *"Explain the component of subjectivity as it relates to science and scientific knowledge."*

Table 4.1.2. Categories of related responses for question 2

Categories of related responses	Number
A. Subjectivity involves your values,	10

experiences and attitudes.	
B. Subjectivity involves previous knowledge.	4
C. Subjectivity is affected by environments and religious backgrounds.	3
D. Scientists support a theory that they believe in.	4
E. Science is objective because of facts.	8
F. No response or unrelated response	9

ASSERTION: COMBINED A, B, C, D (21 RESPONSES)

The assertion is that there are many interpretations of subjectivity. It also shows that 20% of science teachers are unsure of what subjectivity is, and 20% are saying that science is objective because it has facts.

Question number three**:** *"Explain the component, creativity as it relates to science and scientific knowledge."*

Table 4.1.3 Categories of related responses for question 3

Categories of related responses	Number
A. Creativity involves going beyond laws.	5

B. Creativity involves new and dynamic ways.	5
C. Creativity involves designing experiments to prove or disprove.	4
D. Creativity involves looking for patterns.	8
E. Creativity involves imagination.	4
F. No response or unrelated response.	12

ASSERTION: COMBINED A, B, C, D, E (26 RESPONSES)

The assertion is that there are many different views of creativity held by teachers. This augurs well for NOS teaching as each teacher will be creative in his or her own way.

Question number four: *If observations are made carefully, two different skilled observers should see the same thing."*

Table 4.1.4. Categories of related responses for question 4

Categories of related responses	Number
A. Observations are affected by different personal, religious and cultural experiences.	12
B. Prior knowledge affects observations and experiences.	4
C. Preconceived ideas influence	8

observations.	
D. Observations should not differ.	9
E. No response or unrelated response.	5

Assertion: Combined A, B, C. (24 responses)

While the majority of teachers are saying that observations are affected by prior knowledge, preconceived ideas, personal, religious and cultural backgrounds, 20 % are saying that observations should not differ and 10% are not sure.

Question number five: *"The mass media (T.V., newspapers, magazines, movies) give a more accurate picture of science, than science classes."*

Categories of related responses from the 38 respondents

Table 4.1.5. Categories of related responses for question 5

Categories of related responses	Number
A. Media relies on sensationalism when presenting science issues.	7
B. Media has an inherent bias.	10
C. Science in classrooms is more interactive than media presentations.	10
D. Some forms of media will not substitute the science in classrooms because they do not teach of scientific principles.	6
E. No response or unrelated response.	5

<u>Assertion: Combined A, B, C, D (33 responses)</u>

The majority of teachers are saying that media are private enterprises that seek a profit. Media therefore has an inherent bias through sensationalism. It lacks scientific principles and is not interactive like science lessons in the classroom.

To see if teachers' have an adequate understanding of NOS, I compared the assertions to the experts in the field of NOS (Collins, Osborne, Ratcliffe, Millar, & Duschl, 2001; McComas,1998). Collins et al., reported on a Delphi study.

If my research assertions compared favourably with the experts' statements from the Delphi study or from McComas then I could deduce that post-graduate science teachers' have an adequate knowledge of NOS.

<u>Table 4.1.6 Comparisons of assertions of this study and experts' views</u>

Assertion from this study	Experts' statement including the reference
<u>Science & Technology</u>: The teachers view science as involving laws and methods, while technology involves the practical application. They are linked, as science is seen as laying the foundation for technology and vice versa.	"New scientific discoveries are reliant on new technology and new science enables new technology" (Collins, Osborne, Ratcliffe, Millar, & Duschl, 2001)

<u>SUBJECTIVITY</u>: The assertion is that there are many interpretations of subjectivity. It also shows that 20% of science teachers are unsure of what subjectivity is, and 20% are saying that science is objective because it has facts.	"Scientists like all observers, hold myriad preconceptions and biases about the way the world operates." (McComas, 1998)
<u>Creativity</u>: The assertion is that there are many different views of creativity held by teachers. This is good for NOS teaching for each teacher will be creative in his or her own way.	"Scientists, as much as any other profession , are passionate and involved humans whose work relies on inspiration and imagination." (Collins, Osborne, Ratcliffe, Millar, & Duschl, 2001)
<u>Observations</u>: While the majority of teachers are saying that observations are affected by prior knowledge, preconceived ideas, personal, religious and cultural backgrounds, 20 % are saying that observations should not differ and 10% are not sure.	"No two individuals with the same expertise could review the same facts and likely reach identical conclusions." (McComas, 1998)
<u>Media</u>: Media has an inherent bias because of sensationalism, lacks scientific principles and is not interactive like science lessons in the classroom.	The science that is encountered by adults, whether through the media or through work contexts, typically presents questions, decisions and the need for prioritization. In order to respond to these questions people need to know something about the functioning of science itself. (Collins, Osborne, Ratcliffe, Millar, & Duschl, 2001)

It is evident from the comparison above and the tables of responses, that of the 38 post-graduate science teachers' NOS views analysed, only 60% have acceptable views, 30% have alternative views and 10 % are unsure.

4.2. ANALYSIS OF THE CLOSED ENDED QUESTIONS

The fifteen NOS statements were analysed using the deductive approach. Babbie notes that "deductive reasoning moves from a pattern that might be logically or theoretically expected to observations that test whether the expected pattern actually occurs" (Babbie, 2004, p. 25).

Deductive reasoning works from the more general to the more specific. This is informally called a "top-down" approach. The starting point in deductive reasoning is thinking up a *theory* about the topic of interest. We then narrow that down into more specific *hypotheses* that we can test. We must narrow down even further when we collect *observations* to address the hypotheses. This ultimately enables us to test the hypotheses with specific data - a *confirmation* (or not) of our original theories. (www.social researchmethods.net)

Codes for the bibliographic data and the fifteen NOS statements were used. I decided to use numeric coding (Krishnaswami & Ranganathan, 2005) because I wanted to subject them to descriptive statistics. I assigned the codes to the bibliographic data and the Likert scale responses, ensuring that the codes were mutually exclusive, that is, no two codes can both be true (Tripathi, 2005). I recorded all the codes in a code book. I then entered all the codes and the data onto the SPSS programme. The group of 38 postgraduate science teachers consisted of about 70% Biology teachers and 30% Physical Science teachers for there are about 3 biology teachers but only 1 Physical Science teacher per school. About 90% of the teachers had 10-14 years teaching experience. Of the 38 postgraduate science teachers 21 were female and 17 were male.

<u>Table 4.2.1.Codes for Bibliographic Data</u>

Labels	Values
Gender	1= male 2= female
Teaching Experience: I wanted to compare novice teachers' NOS views with experienced teachers' views.	1= 0 to 4 years 2= 5 to 9 years 3= 10 to 14 years 4= 15 to 19 years 5 = 20 years or more
Teaching Qualification	1= H.E.D 2= B.Ed 3= PGCE 4= M.Ed
Major Subjects	1= Physics 2= Chemistry 3= Biology 4= Mathematics 5= Botany 6= Zoology
Teaching subject	1= Physical Sciences 2= Life sciences
15 V NOS statements	1= strongly disagree 2= disagree 3= not sure 4= agree 5= strongly agree

To determine whether the teachers' had an <u>adequate understanding of the NOS statements</u>, I checked the correct responses using the SPSS programme, descriptive analysis (frequency table). The <u>correct percentage response</u> is revealed in the table below. I used the frequency table to get the number of correct responses with acceptable NOS views. 10% of postgraduate teachers recorded under ‘not sure’ for a few questions, and I did not comment on this, because my focus was on classroom observation of the four cases. If the 4 cases indicated unsure then I commented on those responses. I was merely recording those correct responses.

Table 4.2.2.Percentage of correct responses from questionnaire

NOS Statement	% response
If observations are made carefully, two different skilled observers should see the same thing.	53% disagreed
It makes no sense to talk about ‘African Science’ because there is only one science and it is universal.	45% disagreed
Two technological societies could have very different but valid theories about the same idea (e.g., state of matter).	71% agreed
A theory such as atomic theory describes substances as they really are.	45% disagreed
Scientists always do things in the same order. First they collect data and then generate theories by looking for patterns in the data.	53% disagreed
The status of ‘facts and theories’ depend on the values that scientists hold.	71% agreed
Technologists have their own body of knowledge to build on.	29 % disagreed
Co-operations e.g., mining, forestry, pharmaceuticals should control scientific research.	66% disagreed
Scientists are not isolated from their society.	71% agreed
Religious or ethical views do not influence scientific research.	84% disagreed
Science and technology can help in the social problems, of poverty, crime and unemployment.	89% agreed
The mass media, (T.V., newspapers, magazines, movies), give a more accurate picture of science, than science classes.	71% disagreed
Scientific discoveries made by women will tend to be different from those made by men.	74% disagreed
Scientific knowledge is tentative knowledge	40% agreed

Science should be treated as a separate discipline largely unrelated to the nature of science.	76% disagreed

Claims from the data

The assertions from the open-ended questions are very favourably similar to the experts' views on NOS. The SPSS frequency table revealed that most teachers answered the Likert scale's NOS statements correctly with acceptable NOS views.

Although most teachers had difficulty in expressing themselves in the open-ended questions, especially the principle of tentativeness and subjectivity, the combined categories to form the assertion, suggests that the majority 60% of teachers' do understand the NOS principles. This understanding is more evident in the closed-ended NOS statements where only four statements had a below 50% correct response. These alternative views falls into the indigenous knowledge (55%), science theories (55%), technology body of knowledge (71%), and tentative nature of science knowledge (60%). These alternative responses could be probed and analysed in another study or paper.

I then proceeded to do the analysis of variance to check the influence of independent variables (gender, teaching experience) on the NOS views of the teachers' (dependent variable). This is important because I wanted to see if male and female science teachers have differing NOS views seeing that there were 21 female teachers and 17 male teachers of the 38 postgraduate science teachers who completed the NOS questionnaire.

Example: Anova for Gender and Observations of Observers (Q1)

ANOVA

Gender of teacher

Table 4.2.3.Anova for Gender

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.200	4	.050	.180	.947
Within Groups	9.194	33	.279		
Total	9.395	37			

The significance level indicates that there was no significant difference in the way male and female post graduate teachers answered the question on observation of observers, that is, "If observations are made carefully, two different skilled observers should see the same thing."

Lastly, I used the SPSS programme to do a Chi-Square test to understand how the different groups of post-graduate teachers understand the nature of science.
(e.g., between novice teachers and experienced teachers, between Physical Science teachers and Life Science teachers, between male teachers and female teachers). This is important, because all science teachers' need to teach the Nature of Science in class, and not only the Physical Science teachers'. I reported only the Chi-Square for gender for consistency in my data reporting. I did not report on Chi-Square between novice teachers and experienced teachers, or between life science teachers and physical science teachers because of the uneven distribution such as 90%

experienced teachers and 10% novice teachers, and 70% Life Science teachers and 30% Physical Science teachers. The closest percentage was about 55% female teachers (21) and the 45% male teachers (17) and I have therefore computed the Annova and Chi-Square for gender.

<u>Example</u> How do the male and female teachers answer with regards to observation of observers? (Q1)

Test Statistics

Chi-Square Test

Gender of teacher

<u>Table 4.2.4. Chi-Square for Gender</u>

	Observed N	Expected N	Residual
Male	17	19.0	-2.0
Female	21	19.0	2.0
Total	38		

	Gender of teacher
Chi-Square(a)	.421
df	1
Asymp. Sig.	.516

a 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 19.0.

Discussion:

The result is statistically significant at 0.516 which indicates that there is no significant difference in the way male and female postgraduate science teachers' will answer this particular aspect of the nature of science.

The data from my questionnaire was analysed qualitatively and quantitatively and I can now conclude that any random selection of post-graduate science teachers will have an adequate understanding of the Nature of Science as a group. However some science teachers in the group will have alternate views and will be unsure on some aspects of NOS.

I also needed to record the responses of the sample group of teachers for the VNOS questionnaire. This will indicate their NOS understandings.

4.3 VNOS questionnaire answered by the sample group.

The following responses were recorded for the sample group of physical science teachers. I used the first letter of their names to identify these teachers. Alan is A, Ben is B, Carl is C and Dan is D.

Table 4.3.1 : Responses to questionnaire of sample group

No	STATEMENT	Strongly disagree	disagree	Not sure	agree	Strongly agree
1.	If observations are made carefully, two different skilled observers should see the same thing.		A, B, C, D.			
2.	It makes no sense to talk about 'African Science' because there is only one science and it is universal.	A, B, D.		C		

3.	Two technological societies could have very different but valid theories about the same idea (e.g., state of matter).				B	A, C, D.
4.	A theory such as atomic theory describes substances as they really are.	A, B.	C, D			
5.	Scientists always do things in the same order. First, they collect data and then generate theories by looking for patterns in the data.	A, D.	B, C			
6.	The status of 'facts and theories' depends on the values that scientists hold.				B, D	A, C
7.	Technologists have their own body of knowledge to build on.	A	B, C, D			
8.	Co-operations eg mining, forestry, pharmaceuticals should control scientific research.	A, B	C, D			
9.	Scientists are not isolated from their society.				B	A, C, D
10.	Religious or ethical views do not influence scientific research.	A, C, D		B		
11.	Science and technology can help in the social problems of poverty, crime and unemployment.				B	A, C, D
12.	The mass media, (T.V., newspapers, magazines, movies), give a more accurate picture of science , than science classes.	A	B, C		D	
13.	Scientific discoveries made by women will tend to be different from those made by men.	A, B, C	D			
14.	Scientific knowledge is tentative knowledge		C		B, D	A
15.	Science should be treated as a separate discipline largely unrelated to the nature of science.	A, B, C, D				

(Modified from Aikenhead et al., 1989 & Linneman et al., 2003)

Comment: It is very interesting to note that Alan, Ben, Carl and Dan have a better understanding of NOS views than the group of 38 respondents who completed the VNOS questionnaire. They have given the same correct responses in all but three questions, and I telephoned those teachers whose responses varied from the rest of the four cases.

Responses: telephone conservations with teachers with regards to their choice of response for the VNOS questionnaire.

Researcher: Why did you choose "not sure" for question 10?

Ben: *Religion should not affect scientific research and decisions, but I am not sure if it does. I suppose cultural backgrounds and bias will influence research.*

Researcher: Why did you choose "not sure" for question 2?

Carl: *We teach universal science in school and pupils and teachers do not know much about indigenous knowledge, because there is insufficient documentation.*

Researcher: Why did you choose "disagree" for question 14?

Carl: *Once a person has a clear understanding of the science knowledge it is not tentative to him or her. They can use this knowledge to solve scientific issues.*

4.4. Analysis from the Observation Schedule.

Although participants had a good understanding of the Nature of Science (NOS), they experienced difficulty in teaching the aspects of tentativeness, creativity and subjectivity. They were at ease with explanations and examples of empirical basis, indigenous knowledge, theories and laws, observations and inferences. Only the aspects of NOS that were observed in the classroom are discussed below so that the research question on classroom practice of NOS could be answered.

The following NOS views were recorded for Alan during his four lessons.

Table 4.4.1. Alan's NOS views addressed in the lessons

NOS views	Lesson 1	Lesson 2	Lesson 3	Lesson 4
Tentative				
Creative			# #	
Subjective				
Empirical basis	# # #			# # #
Social/Cultural	# # #		# # #	
Theories/laws	#	# #		
Observations/inferences	# #			

 # provides a definition or affirmative response. # # provides a description in own words, examples from class.

 # # # provides a description in own words and additional supporting examples.

Discussion of the four lessons of Alan's in terms of Nature of Science

It is important to see how each of the teachers addressed the NOS aspects in their classroom activities. This is important for this study because it will show the teachers intention to explicitly teach NOS aspects in everyday physical science lessons.

Lesson 1: Thermal conductors

Empirical basis

The teacher explained the working of a vacuum flask. He questions the children on their understanding of thermal insulators. He then gives them examples of divers' 'wet' suits, polar fleece, etc.

Social/Cultural

The teacher looked at how people dress differently in different countries. He gives examples of cold and hot countries and asks pupils to comment on the appropriateness of their dress in terms of thermal conductors and insulators.

Theories

The teacher explains to the class what a theory is. He then uses the idea of a theory to explain the Domain Theory of magnets.

Observations/Inferences

The teacher asks the pupils for the understanding of why some modern houses still prefer thatched roofs. Why do some pizza outlets prefer clay ovens?

Lesson Two: The Atom

Theories/laws

The teacher explains to the pupils the size of an atom and the sub-atomic particles that an atom has. He explains this in terms of a definition of the model he has given them. He then moves to the periodic table, and the number of protons, neutrons, and electrons in the atoms of the different elements.

Theories and Models

The teacher gives the class a definition of what a theory is and what a model is. He then explains the reason why the atom is taught in terms of a model. He also explains the existence of protons, neutrons, and electrons.

Lesson Three: Historical development of the atom

Creative

The teacher introduces the idea of a black box with five items in the box. He then asks pupils for scientific ways of identify "what is in the box."

Social/Cultural

The teacher explains to the students the history of the development of understanding the atom, beginning with the Greeks' understanding. He then moves to Dalton, Thomson, Rutherford, and Bohr. He also explains the creative and the subjective issues of how scientists conduct research.

Lesson Four: Characteristics of the atom / Periodic Table

Theories/ laws

The teacher explains to the class the size of the nucleus of an atom, protons, neutrons, electrons, the charges that they have. The pupils are asked to read extracts with regards to the orbitals and of shapes of molecules. The teacher continues with the formation of compounds using the periodic table, and the concept of valency.

Summary of Alan's classroom practice of the Nature of Science

Alan always follows the same plan for each lesson. He introduces the topic, asks a lot questions, explains in detail, the aspects of Nature of Science he will cover for the lesson, he develops notes for the students on the chalkboard, and then sets them class work and homework. His instructional strategy is teacher-centred. For lesson one, he covers adequately the NOS aspects of empirical basis, social and cultural influences, theories and laws, and observations and inferences as outlined in discussion of Alan's lesson one. He talks about theories and models in lesson two, and in lesson three introduces the NOS aspect of creativity. In lesson four he discusses the atomic theory shapes of molecules using models and the formation of compounds. Although he does not cover tentativeness and subjectivity in his lessons, from my observations, he has integrated the teaching NOS as part of the new curriculum reform.

The following NOS views were recorded for Ben during his four lessons:

Table 4.4.2 : Ben's NOS views addressed in lessons

NOS views	**Lesson 1**	**Lesson 2**	**Lesson 3**	**Lesson 4**
Tentative				
Creative	#			
Subjective				
Empirical basis				# #
Social/Cultural		# # #	# #	# #
Theories/laws	# #	#	# #	
Observations/inference				

 # provides a definition or affirmative response. # # provides a description in own words, examples from class. # # # provides a description in own words and additional supporting examples.

Lesson One: Earth's Magnetic Field

Theories/ laws

The teacher sets a reading task from the text with regards to the Earth's magnetic field. They are required to find the answers to the following questions:

1. What is meant by the earth's magnetic field?
2. What is magnetic declination?
3. What is the purpose of a magnetic compass?
4. How does the earth's magnetic field protect the earth?

At the end of the reading the teacher asks for the correct answers and a class discussion takes place.

Creativity

The teacher asks the pupils to sit in groups of two and draw their understanding of the Earth's magnetic field.

Lesson Two: Electrostatics

Social/Cultural

The teacher asks pupils for stories they have heard about from their parents or grand-parents with regards to traditional beliefs about lightning. Pupils relate stories about witches sending lightning to enemies, to balls of fire in the sky, to dangers of lightning.

Theories/ laws

The teacher asks pupils to sit in pairs and write down a scientific explanation of lightning.

Lesson Three : Conservation of charge/ Insulators and conductors

Theories/laws

The teacher asks pupils to read the text and answer the following questions

1. What are protons?
2. What are electrons?
3. What happens to a substance that loses charge?
4. What is the law of conservation of charge?
5. Classify substances as conductors or insulators?

Cultural/ Social

The teacher asks pupils to sit in groups and read the text with regards to how electrostatics is applied in our daily lives. The teacher moves around the class assisting the groups.

Lesson Four : Electrostatics in Nature and Technology

Empirical basis

The teacher uses the textbook to explain the application of electrostatics used in technology. He discusses with the pupils the principles of electrostatics used in

1. photocopier
2. spray painting
3. ink jet printer

Social and Cultural

The teacher asks pupils about precautions to be taken during a lightning storm.

Pupils speak about the following aspects:

1. tyres on the roofs of informal settlements.
2. wearing rubber shoes.
3. covering mirrors.
4. lightning conductor on buildings.
5. not taking a bath during a lightning storm.

<u>Summary of Ben's classroom practice of the Nature of Science</u>

Ben's instructional strategy is to get students to read the text for 10 minutes with regards to the lesson. They then form groups of four to answer questions from the chalkboard or text. His focus is to get the students to answer the questions using science concepts and principles. In lesson one he uses creativity to get students to draw the Earth's magnetic field. Most of the students draw different diagram and Ben could have spent more time questioning them on these diagrams instead of drawing the correct diagram on then board. In lesson two, although he listens to stories about student's indigenous knowledge (IK) of lightning, namely, witchcraft, balls of fire, and angry Gods, but he quickly reverts to correct answers written on the board for students to take down for the test. Lesson three and four covers the technological applications of electrostatics. Lesson four covers precautions to be taken during a lightning storm and the students get into a lively debate as outlined under discussion lesson four. From my observations, Ben is integrating teaching NOS with IK as part of the new curriculum reform but the IK aspects are treated superficially as he goes back quickly to 'formal' science..

The following NOS views were recorded for Carl during his four lessons:

<u>Table 4.4.3 : Carl's NOS views addressed in lessons</u>

NOS views	**Lesson 1**	**Lesson 2**	**Lesson 3**	**Lesson 4**
Tentative				
Creative				
Subjective				
Empirical basis				
Social/Cultural				
Theories/ laws	# # #	# # #	# # #	
Observations/inferences	# # #	# # #	# # #	

 # provides a definition or affirmative response. # # provides a description in own words, examples from class.

 # # # provides a description in own words and additional supporting examples.

Lesson One : Reaction of magnesium with oxygen: Ionic bonding

Observations/Inferences

The teacher demonstrates the burning of magnesium in oxygen. He asks pupils to note their observations with regards to:

1. Flame colour.
2. Colour of oxide.
3. any other observations.
4. products formed
5. Practical applications of magnesium.

Theories/ laws

The teacher explains ionic bonding in detail on the chalkboard, including the ionization energy involved, Lewis dot structures, and ionic reaction. He then asks pupils to work in groups and follow the steps on the chalkboard to illustrate the ionic bonding of magnesium and chlorine. He moves around the classroom assisting pupils.

Lesson Two: Covalent Bonding

Observations/Inferences

The teacher demonstrates the burning of carbon in oxygen. He asks pupils to note their observations with regards to:

1. Flame colour.
2. Colour of oxide.
3. Any other observations.
4. products formed
5. Practical applications of carbon.

<u>Theories/laws</u>

The teacher explains the difference between ionic bonding and covalent bonding. He uses the Lewis dot structures to explain covalent bonding in detail. He explains the difference between valence electrons and valency. He explains further examples of covalent bonding using the nitrogen molecule and oxygen molecule.

<u>Lesson Three: Chemical reactions</u>

<u>Observations/Inferences</u>

The teacher demonstrates the following two reactions.

1. Potassium reacting with water.
2. Potassium reacting with iodine.

He asks pupils to note their observations with regards to:

1. Flame colour.
2. Colour of oxide.
3. Any other observations.
4. Products formed
5. Practical applications of potassium.
6. Precautions, when working with potassium.

<u>Theories/laws</u>

The teacher explains in detail the balancing of the reactions and the law of mass action. He then gives each pupil a worksheet on ionic bonding, covalent bonding and balancing reactions, to complete as seat work

Lesson Four: Polar covalent bonding/ investigation task

Theories and laws

The teacher explains in detail, polar covalent bonding, using hydrogen chloride as an example. He then assigns as homework further examples to show polar covalent bonding.

Investigation Task: Involves aspects of Science and Technology.

The teacher explains the worksheet on the investigation task. Pupils are required to conduct an investigation on electromagnetic waves. They will be assessed on

1. Creativity
2. Historical development.
3. Empirical evidence
4. The ability to explain in their own words their complete investigation, including problems encountered.

Summary of Carl's classroom practice of the Nature of Science

Carl enjoys starting his lesson with a 5 to 10 minute demonstration. He covers the principle of observations and inferences in lesson one, two, three. After questioning the student on their observations and inferences, he explains in detail ionic bonding in lesson one and covalent bonding in lesson two. He then divides the classroom into groups of five to complete the class work questions on the board. He goes around to each group assisting them in answering the class work questions. In lesson three, after the demonstrations on chemical reactions, he explains in detail the law of mass action. Students then work in groups to complete a worksheet on balancing of chemical reactions. In lesson four he explains the investigative task on Electromagnetic Waves that they will have to undertake in groups. They will be assessed on the NOS aspects of creativity, historical development, empirical evidence, the ability to explain their investigation in their own words, including problems encountered on how these problems were addressed. From my observations, Carl is focussing on developing the scientific skills and processes of science and in the teaching NOS in the new curriculum, these aspects are emphasized including collaborative work by students.

The following NOS views were recorded for Dan during his four lessons:

Table 4.4.4 : Dan's NOS views addressed in lessons

NOS views	**Lesson 1**	**Lesson 2**	**Lesson 3**	**Lesson 4**
Tentative	# #			
Creative	# #	# #	# #	# #
Subjective	# #	# #	# #	
Empirical basis	#	# #	# #	# #
Social/Cultural	# #	# #		
Theories/ laws	# #	# #	# #	# #
Observations/inferences	# #	# #	# #	# #

 # provides a definition or affirmative response. # # provides a description in own words, examples from class.

 # # # provides a description in own words and additional supporting examples.

The lesson observations for teacher D is described differently from the other three teachers, because teacher D used a learner centred approach for all four lessons.

<u>Lesson One: Waves</u>

The entire lesson is on Science and Society (LO3). The pupils are given a worksheet on spirits and spirit forces. The teacher divides the class into two groups to debate the issue of spirits and spirit forces. They have to take on the role of two scientists, one who is not ruling out the possibility of spirit forces and the other who says that people are just imagining spirits. The aspects of NOS are covered in the student-student and student-teacher interaction

Learner group A

These pupils say that everything has to be evidenced based. They require scientific proof for everything that happens in nature. They cite examples of lightning, hail, rain that occurs in nature because it has a scientific explanation. They believe that science cannot function well in a society where everything is explained by spirits. The teacher clarifies questions and answers and always redirects them to the issues on hand.

Learner group B

This group explained that spirit forces are part of our social and cultural heritage. It is pertinent especially for traditional healers who understand the spirit forces of our ancestors. They contend that if science cannot explain something, then it does not mean that it does not exist. There are limitations as to what science can and cannot prove.

The group argues on issues of:

1. the existence of the atom.
2. the existence of God.
3. viruses and germ theories
4. scientists' religious background and subjectivity

Lesson Two: Waves everywhere

The teacher hands each pupil a worksheet that covers the different types of waves for example: water waves, electromagnetic waves, sound waves, light waves. The pupils are required to read the worksheet and in their groups discuss the following:

1. four questions to carry out experiments on waves.
2. four questions on theory of waves.
3. four questions on waves in terms of science and society.

Here the teacher has covered all three learning outcomes in a very creative way. The pupils are forced to think, be critical, draw on past experiences, debate issues, set up methods for experimentation. The teacher does not reject any contributions made by pupils but rather asks fellow pupils to comment.

Lesson Three: Exploring our existing knowledge of waves

The teacher handed every pupil a worksheet with a picture on sunbathing trying to get pupils to talk about their existing knowledge of waves. They were divided into groups of four for reading, discussion and teacher assessment. Some of the questions included in the worksheet were:

1. What are some of the natural sources of light waves?
2. What do you think is the source of infra-red waves?
3. What do you think is the source of ultra-violet waves?
4. How can you tell that light waves can travel away from the Sun without a medium?
5. What detector makes us aware of sound waves coming from an aircraft?

Here the teacher looked at an important aspect of NOS, for example, the social construction of knowledge. The pupils argued, showed creativity, used past experiences, were critical and were also able to come to a consensus.

Lesson Four: Tranverse and longitudinal waves

The teacher handed each pupil a worksheet with instructions: They were required to:

1. create a pulse.
2. create a longitudinal wave
3. create a transverse wave
4. draw their understanding of the waves using dots.

They were then asked to talk in their groups about how waves are relevant to us in our daily lives.

Summary of Dan's classroom practice of the Nature of Science

Dan's lesson plans includes his NOS aspects for each lesson. In lesson one, he allows for group work and debates amongst his students on the topic of spirit forces in nature, thus allowing each student to challenge the other students views or the other group's view. He does not answer any question but merely redirects a question to the other student or other group. This is discussed in more detail under lesson one. In lesson two, his topic for the lesson is waves everywhere. He gets students to think of four questions to carry out experiments in waves, four questions on the theory of waves, and four questions of waves with regards to science and society. Lesson three involves a group work to discuss theories of our existing knowledge of waves. Here each group was given five picture on waves and had to build their own theories of waves. In lesson four group work investigations of longitudinal and transverse waves was undertaken by the students. Dan uses the NOS aspects of creativity, empirical evidence, theories and laws, and observations and inferences in all four lessons, while subjectivity and social and cultural influences are used in two of the four lessons. From my observations, Dan is integrating the teaching NOS as part of the new curriculum reform.

4.5 Interview Schedule

The following responses were recorded for the interview between the researcher and Alan for his lesson on Thermal Conductors.

Table 4.5.1 Alan's interview schedule

Interview Question	**Participant's Response: Alan**
1. Why is the Nature of Science valuable for science teaching?	It makes the lesson meaningful to the learner. It identifies the contexts for the learner. The value of NOS should not be under-

	estimated.
2. How do the resources and activity you have used portray the Nature of Science?	I looked at everything that affects the lives of the children. I also brought in their previous knowledge with regards to thermal flasks, wet suits, and housing materials.
3. How does the content of the lesson portray the Nature of Science?	I looked at materials that learners come across. I looked at historical examples and how the different countries adapt to heat and cold.
4. Do you think the lesson could have been changed so that it better illustrates the Nature of Science?	Yes. Some communities do not have electricity, but use their knowledge of heat and cold to make their lives comfortable. I could have exposed them to the internet for more information.
5. How would changes to your lesson better facilitate student understanding of the Nature of Science?	We need to make learners aware of their surroundings. They also need to question the science around them instead of just 'walking past it'.
6. From observing / listening to pupils, what conceptions of the Nature of Science do they have?	The learners do understand the social aspects, models, theories and laws, observations, creativity in science.
7. How will you structure future instruction to address these conceptions?	I am going to give them more investigative tasks, to work in groups, for them to appreciate the social construction of knowledge.
8. Is there any issue with regards to Nature of Science and classroom instruction that you would like to comment on?	We need more support in terms of resources to successfully implement NOS. The Department has not yet given our learners physical sciences text books. It is now the middle of April.

Comment: Alan is committed to teaching the NOS, and says that his students are aware of the principles of the Nature of Science. This is evident from his comments on question one and question six. Alan requests more support from the department of education with regard to workshops for NOS teaching and support for other new topics in the curriculum.

Interview Schedule:

The following responses were recorded for the interview between the researcher and Ben for his lesson on Electrostatics.

Table 4.5.2. Ben's interview schedule

Interview Question	Participant's Response: Ben
1. Why is the Nature of Science valuable for science teaching?	It promotes science teaching. It gives some idea into the foundations of science. It makes science real and in context. The teacher needs to know NOS to teach science.
2. How do the resources and activity you have used portray the Nature of Science?	I used the examples from the text book. I brought in everyday examples like lightning. I also asked learners for examples from indigenous knowledge.
3. How does the content of the lesson portray the Nature of Science?	The content is related to everyday examples of electrostatics. I also looked at how electrostatics is applied in technology, for example, in a photocopier.
4. Do you think the lesson could have been changed so that it better illustrates the Nature of Science?	The resources can be improved, for example, .charts, videos, internet and I also need to explain the aspects of NOS for pupils to be aware of.
5. How would changes to your lesson better facilitate student understanding of the Nature of Science?	With improved resources and practical electrostatic kits I could make learners work in groups for creativity, observations, previous knowledge and subjectivity.

6. From observing / listening to pupils, what conceptions of the Nature of Science do they have?	They have very limited knowledge of NOS. They can relate stories of indigenous knowledge to electrostatics.
7. How will you structure future instruction to address these conceptions?	I will try to design worksheets to allow them to debate and question more with regards to the aspects of Nature of Science
8. Is there any issue with regards to Nature of Science and classroom instruction that you would like to comment on?	There should be more workshops for teachers on teaching the Nature of Science. It is very new to teachers and pupils. Teachers should form cluster groups and build resources.

Comment: Ben is also committed to teaching the NOS, but says that his students are unaware of the principles of the Nature of Science, except for some indigenous stories. This is evident from his comments on question one and question six. Ben also requests more support from the department.

Interview Schedule:

The following responses were recorded for the interview between the researcher and Carl for his lesson on Electromagnetic Waves

Table 4.5.3. Carl's interview schedule

Interview Question	**Participant's Response: Carl**
1. Why is the Nature of Science valuable for science teaching?	We need to take science out of the classroom. We need to use the learner's prior knowledge so that they become a part of the lesson.
2. How do the resources and activity you have used portray the Nature of Science?	I have given the pupils an investigative task, to work in groups. They need to access the information in their groups, using the internet and library books. I have provided guidelines as to how

	they should proceed.
3. How does the content of the lesson portray the Nature of Science?	The task portrays science as a mystery. Some learners have not heard about electromagnetic waves. This task will allow them a sense of achievement and ownership, and networking.
4. Do you think the lesson could have been changed so that it better illustrates the Nature of Science?	I could have given them some notes on electromagnetic waves, but this will narrow their thinking. It is best that they research the work themselves.
5. How would changes to your lesson better facilitate student understanding of the Nature of Science?	I could have brought in a microwave and explained how it operates, but then most learners will concentrate on microwaves and not the other types of electromagnetic waves.
6. From observing / listening to pupils, what conceptions of the Nature of Science do they have?	They realize that science is happening all around us. They bring to the lessons examples from their everyday lives. They do not understand indigenous knowledge very well.
7. How will you structure future instruction to address these conceptions?	I will allow for more open-ended questions in the worksheets. This will allow the learners to bring in their own understanding of Nature of Science.
8. Is there any issue with regards to Nature of Science and classroom instruction that you would like to comment on?	The Departmental workshops are ineffective. They are concentrating on assessment and allocation of marks. They should have workshops on the teaching of NOS. Allow teachers to facilitate NOS workshops and not Departmental officials.

Comment: Carl is also committed to teaching the NOS, and says that his students are aware of the science contexts outside the classroom as evident from his comments on question six and question eight. He is frustrated with the department's lack of curriculum development workshops.

Interview Schedule:

The following responses were recorded for the interview between the researcher and Dan for his lesson on Waves

Table 4.5.4. Dan's interview schedule

Interview Question	**Participant's Response: Dan**
1. Why is the Nature of Science valuable for science teaching?	Nature of science provides the context. Science cannot be taught in isolation. Different people see different things in the same situation.
2. How do the resources and activity you have used portray the Nature of Science?	I used a worksheet with two scientists debating. It gets the learners thinking about the tentative nature of science. Also the roles of the groups were reversed. This brings in creativity in science
3. How does the content of the lesson portray the Nature of Science?	It relates to theories and claims made by people. In this case, students looked at scientists understanding of spirits vs indigenous knowledge of spirits.
4. Do you think the lesson could have been changed so that it better illustrates the Nature of Science?	I think the groups could have been made smaller, with the rest of the class as independent observers. These observers could take down points for class discussions at a later stage.
5. How would changes to your lesson better facilitate student understanding of the Nature of Science?	I could have asked students to relate some stories they have read about or been told to by their families. I concentrated more on the questions in the passage.

6. From observing / listening to pupils, what conceptions of the Nature of Science do they have?	The pupils have a good understanding of creativity, subjectivity, social and religious aspects of science, theories and laws, tentative nature of science.
7. How will you structure future instruction to address these conceptions?	Pupils will work in groups and talk about issues of NOS constructively. We also need to gather more resources on NOS.
8. Is there any issue with regards to Nature of Science and classroom instruction that you would like to comment on?	It is difficult to find teaching resources for Nature of Science, even on the internet. It would be good for industries to put together some teacher and student packages for classroom practice of NOS.

Comment: Dan enjoys teaching his lessons through the principles of the Nature of Science and his students have a good understanding of the different principles of Nature of Science. These are evident from his comments in question six and question eight. Dan would like to see industries supporting curriculum reform and providing NOS resources for teachers to use in classrooms.

Summary of the four cases of teachers' NOS classroom practices

It is evident that Alan, Ben and Carl have adopted a teacher-centred instructional strategy. They include the nature of science aspects at different stages in the lesson. They have explicitly made provisions of including NOS in all lessons and they see the value of teaching NOS in the classroom lessons. Dan uses a student-centred instructional strategy. His entire lesson involves the NOS instructions and principles. He allows his students to explore their creative talents through experimentations, debates, searching questions. He always redirects the questions to the students to find their own answers.

Chapter Five is the conclusion chapter, in which I have briefly restated the purpose of this study. I state the deductions from the analysis of the data collected and how it links to other Nature of Science (NOS) studies with the science teacher as the focus. Lastly, I make some recommendations for further research in South Africa with regards to teachers NOS views and classroom practice.

CHAPTER FIVE

CONCLUSION

This study was a small-scale exploratory case study of four physical science teachers' understandings of the Nature of Science (NOS) and their classroom practice. The four teachers had completed a module on Nature of Science in their Bachelor of Education (Honours) degree at the University of KwaZulu-Natal.

The study looked at the following research questions:

1. What are post-graduate honours physical science teachers' understandings with regards to the content knowledge of Nature of Science in terms of the outcomes based education?
2. How do postgraduate honours physical science teachers translate their Nature of Science understandings into classroom pedagogical practice in terms of Outcomes Based Education?

In answering question one, the study analysed a Value on the Nature of Science (VNOS) questionnaire (Appendix D). Thirty-eight (38) postgraduate science teachers (life sciences and physical sciences) completed the VNOS questionnaire. Analysis of the data from the questionnaire revealed that 60% post-graduate science teachers have an adequate knowledge of NOS. This was corroborated by other studies of teachers' NOS understandings after completing a NOS module (Eflin, Glennan, & Reish, 1999; Finley, 1997; Lederman, 1999; Lederman & Khalick, Lumpe et al., 1998 2000; Ogunniyi, 2006; Ogunniyi 2008).

All these studies reported that teachers NOS views had improved after completion of a module in NOS. I also used a VNOS questionnaire to see NOS postgraduate science teacher's views after the completion of an NOS module. Studies that were conducted to ascertain science teachers' views, who were not subjected to NOS module (Akerson & Volrich, 2008; Bryan & Atwater, 2002; Dekkers & Mnisi, 2003; Lederman, 1992; Linneman, 2003), reported that science teachers held inadequate NOS views and understandings.

From the above literature data, the evidence suggests that science teachers that undertook NOS workshops or university modules held correct views and understandings of the Nature of Science. They were also more comfortable to teach NOS concepts in class. One of the positive ways to support teachers' NOS development for the South African National Department of Education, is then to provide deep-level NOS in-service training sessions and /or for teachers to enrol in higher education programmes, for example the Honours and ACE.

In answering question two of this study, I used two research instruments, an observation schedule, and a structured interview. The teachers in this study did not consider teaching the NOS using the history of science as suggested by Eflin et al., (1999). For example when Alan taught the atomic model, he could have taught it showing the successes and failures of scientists such as Thomson, Rutherford and Millikan through the experiments that they conducted and the data that was analysed. In this way the students would have become curious and start to enquire more about the scientific construction of knowledge and the tentative nature of science knowledge.

Only Dan used a student-centred approach to teaching the Nature of Science (NOS) as suggested by Aikenhead (1994), while Alan, Ben and Carl taught NOS using the teacher-centred approach. They are missing the important advantages of teaching the NOS through a social, historical and technological perspective (Aikenhead, 1994). The teachers (except Dan) did not ground the science pedagogical content in a social and technological context. Dekkers and Mnisi (2003) found that teachers' understandings of NOS differ from the Curriculum 2005 (C2005) and this matched similar international findings. They found that culturally-determined views are found on the status of different knowledge systems, that is, indigenous knowledge systems vs science. Jegede (1999), Naidoo (2001), Raza (2003) and Wyk (2002) stress the importance of the inclusion of indigenous knowledge systems for NOS teaching and learning. The teachers in this study agreed about the importance of indigenous knowledge for NOS teaching, but were unsure of how to teach it, mainly because of the lack of resource and training in a new curriculum theme. Furthermore, the Department of Education has not made any documentation available to them as teaching resources in the NOS aspect of their science curriculum. Thus, science teachers rely on authentic resources for their classroom lessons and activities.

Aldous's study (2004) found that teachers have "discernible misconceptions" about C2005 and "raises questions about the ability of teachers to implement C2005 faithfully in their classroom" (p. 65). The teachers in this study had adequate views of the NOS, but are finding it difficult to teach it explicitly as can be seen from the data. Furthermore, the teachers have requested resources with regards to the successful implementation of NOS teaching in the classroom. These resources could be developed by the Department of Education in collaboration with the universities and private enterprises in the technology and engineering sector.

Rogan (2004, p. 175) indicates that very little of the outcomes (1998-2002) has changed in science classrooms since the introduction of C2005. While this is true, the NOS outcomes now has to be taught in every lesson as all tests and examinations must include NOS questions. Therefore, teachers have to update their teaching instructional strategies with regards to the teaching of NOS. This could be in the form of workshops, university modules, on-line course modules in the NOS.

Dekkers (2006, p. 81) showed how inquiry and reflection can contribute to both teachers' and learners' understandings of NOS. Teachers' views were adequate for teaching the lessons but learners' views, although "coherent and sensible", were not entirely in agreement with contemporary views. Science teachers are the key agents of change to influence learners' views of the Nature of Science. Those discussed in the literature review (Bryan, 2002; Clough and Almazroa, 1998; Lederman, 1999; McComas, 1998) furnish five reasons why NOS should be part of everyday science lessons. They are: NOS enhances the learning of science content, NOS enhances understanding of science, NOS enhances interest in science, NOS enhances decision making, and that NOS knowledge enhances instructional delivery. These reasons for teaching NOS are also expected to improve learners' conceptual understanding of science and its applications in society.

In conclusion the analysis of the observation schedule shows that Alan, Ben and Carl, while committed to teaching the NOS, are implicitly teaching it (also reported in Bell, 2001), while Dan is explicitly teaching NOS. This is evident in their differing instructional strategies. Alan, Ben and Carl use the teacher-centred instructional strategy, while Dan uses a student-centred instructional strategy.

Analysis of the interview schedule shows that the four physical science teachers know what is expected of them in terms of NOS inclusions in classroom lessons and I have commented on this finding in the data analysis This was shown in the observation schedule and the interview schedule for each teacher. They do not have support materials and packages to rely on and hence teach each lesson separately, with 'add-on' NOS aspects, (except Dan), instead of teaching it as a unit with NOS themes and social contexts. **Hence with regards to their classroom practice of NOS, Alan, Ben and Carl are teaching NOS issues implicitly and as 'add-on'.** This kind of pedagogical teaching strategy was also reported in Aikenhead (2005, p. 385), where science teachers (90%), endorse teaching the NOS principles, but when asked to implement the NOS curriculum, furnish different reasons for not implementing it successfully. These reasons are discussed in implications of this study.

IMPLICATIONS

I found that teacher's need more support from the department of education in terms of NOS classroom practice as part of curriculum reform development and training. In spite of some curriculum development initiatives, science teachers' need more NOS education programmes and training, curricular support package and resources, textbooks that explicitly include NOS activities. Also the development of a curriculum model as suggested by Taber (2008), that proceeds from the scientific model (current scientific knowledge), to the curricular model (representation in curriculum documentation and guidance), to the teaching model (representation in classroom model), to the students model (representation in students' work) needs to be looked at and designed, if science teachers' are to successfully implement NOS explicitly in the classroom.

"Lack of teaching materials, unfamiliarity with student-centred instructional strategy, greater than normal emphasis on oral and written language, lack of confidence with integrated content, fear of losing control over class, uncertainty about the teachers' role in the class, an unease with handling controversial issues, uncertainties about assessing students on subjective content, inadequate background knowledge and experience, predictions that students will not enjoy philosophical, history and policy issues in a science class, preoccupation with preparing students for examinations". These are some of the reasons furnished by science teachers for not implementing NOS successfully in the classroom (Aikenhead, 2005, p. 385). Alan, Ben and Carl agree that they need more support in the form of NOS workshops. They have a positive attitude to teaching NOS aspects in classroom lessons and have integrated aspects in their science lessons. It is possible then, that South African science teachers might also furnish some of these or different reasons for not explicitly teaching NOS in the classroom. This then brings us to the need for further research in the Nature of Science and classroom practice, with the focus on teachers.

Further research in NOS needs to look at: The inclusion of NOS modules in undergraduate teacher training degrees, the value and need for in-service teacher NOS training workshops and NOS teaching packages and resources, the evaluation of science textbooks in each Grade for NOS activities and context-based links, to meaningfully link difficult science concepts as the student progresses to the next grade, an internet survey to identify the needs and support material required by science teachers of different grades.

NOS teaching must include the history and philosophy of science; it must include the social construction of knowledge; it must allow learners to debate the truth and beliefs of how this knowledge became accepted in time; and it must include the contextual relationships between science, technology and society. The importance and advantages of NOS teaching and learning is clearly evidenced in the literature review.

REFERENCES

AAAS. (1993). *Benchmarks for Scientific Literacy*. Retrieved 31 August, 2006, from http://www.project 2061.org/publications/bsl/online/bolintro.htm

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (2001). Preservice Teachers' understandings and Teaching of Nature of Science: An intervention study. *Canadian Journal of Science Mathematics and Technology Education, 2*, 135-159.

Aikenhead, G. (1994). What is science teaching. In G. Aikenhead & J. Solomon (Eds.), *STS Education: International perspectives on reform*. New York: Teachers College Press.

Aikenhead, G. S. (June,1999). *Barriers to Accommodating Culture in Science Classrooms.* Paper presented at the 9th Symposium of the International Organization for Science and Technology, Durban, South Africa.

Aikenhead, G. S. (2003). Chemistry and Physics Instruction: Integration , Ideologies, and Choices. *Chemical Education: Research and Practice*.

Aikenhead, G. S. (2005). Research into STS Science Education. *Education Quimica, 16*, 384-397.

Aikenhead, G. S., & Otsuji, H. (2000). Japanese and Canadian Teachers' views on science and culture. *Journal of Science Teacher Education, 11*, 277-299.

Aikenhead, G. S., & Ryan, A. G. (1992). The development of a new instrument on Science-Technology-Society " VOSTS". *Science Education, 76*, 477-491.

Aikenhead, G. S., Ryan, A. G., & Fleming, R. W. (1989). *Views of Science-Technology*, University of Saskatchewan: College of Education

Akerson, V. L., & Volrich, M. L. (2006). Teaching Nature of Science Explicitly in a First Grade Internship Class. *Journal of Research in Science Teaching, 43*, 377-394.

Akerson, V. L., & Volrich, M. L. (2008). Improving preservice elementary teachers' views of nature of science using explicit reflective teaching in science, technology and society course. *Australian Journal of Teacher Education, 33*. 1-25

Aldous, C. (2004). Science and mathematics teachers' perceptions of C2005 in Mpumalanga secondary schools. *African Journal of research in SMT Education, 8*(1), 65-76.

Anderson, G. (1990). *Fundamentals of Educational Research*. Basingstoke: Falmer Press.

Ayayee, E., & McCarthy, S. (1996). *What is science? Who Knows?* Paper presented at the Proceedings of the Fourth Annual Conference of the South African Association for Research in Mathematics, Science and Technology Education, Howard College.

Babbie, E. (2004). *The Practice of Social Research* (10th ed.): London:Thomson Wadsworth.

Bell, B., Jones, A., & Carr, M. (1995). The Development of the Recent National New Zealand Science Curriculum. *Studies in Science Education, 26*, 73-105.

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

Bianchini, J. A., & Colburn, A. (2000). Teaching the Nature of Science inquiry to prospective elementary teachers: A Tale of Two Researchers. *Journal of Research in Science Teaching, 37*, 177-209.

Bianchini, J. A., & Solomon, E. M. (2003). Constructing views of science tied to issues of equity and diversity: A study of Beginning Science Teachers. *Journal of Research in Science Teaching, 40*, 53-76.

Bodner, G. M. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education, 63*, 872-878.

Bryan, L. A., & Atwater, M. A. (2002). Teacher beliefs and cultural models: A challenge for science teacher preparation programs. *Science Teacher Education*, 86, 821-839.

Clough, M. P. (1998). Integrating the Nature of Science with Student Teaching: Rationales and Strategies. In W. F. McComas (Ed.), *The Nature of Science in Science Education: Rationales and Strategies* (pp. 197-208). Dordrecht: Kluwer Academic Publishers.

Cohen, L., Manion, L., & Morrison, K. (2000). *Research Methods in Education* (5th ed.). London: Routledge.

Collins, S., Osborne, J., Ratcliffe, M., Millar, R., & Duschl, R. (2001). *What ideas about science should be taught in school? A delphi study of the expert community.* Paper presented at the Annual conference of the American Educational Research Association, Seattle.

Dawson, C. (2002). *Practical Research Methods: A user -friendly guide to mastering research techniques and projects*. Wilshire: Cromwell Press.

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

Dekkers, P., & Mnisi, E. (2003). The Nature of Science - Do teachers have the understandings they are expected to teach? *African Journal of research in SMT Education, 7*, 21-34.

Dekkers, P., & Mnisi, E. (2003). *Science Teachers conceptions of the Nature of the Science- the impact of an Advanced Certificate in Education Programme.* Paper presented at the

Proceedings of the 11th Annual conference of the South African Association for Research in Mathematics, Science and Technology Education., Swaziland.

Denscombe, M. (2004). *The Good Research Guide: for small-scale social research projects*. Glasgow: Bell & Bain.

Denzin, N. K., & Lincoln, Y. S. (2000). *Handbook of Qualitative Research*. London: Sage.

Duveen, J., Solomon, J., & Scot, L. (1992). Teaching About the Nature of Science through history: Action research in the classroom. *Journal of Research in Science Teaching, 29*, 409-421.

Education, A. f. S. (1981). *Nature of Science*. London: Heinmann Educational Books.

Education, D. o. (2003). *National Curriculum Statement: Grades 10-12 (General) Physical Sciences*. Pretoria: Department of Education.

Eflin, J. T., Glennan, S., & Reish, G. (1999). The Nature of Science: A perspective from the Philosophy of science. *Journal of Research in Science Teaching, 36*, 107-116.

Fensham, P. J. (1992). Science and Technology. In P. W. Jackson (Ed.), *Handbook of Research on Curriculum* (pp. 789-823). New York: Macmillan Publishing Company.

Finley, B. C., & Palmquist, F. N. (1997). Preservice teachers' views of the Nature of Science during a postbaccalaurate science teaching program. *Journal of Research in Science Teaching, 34*(6), 595-615.

Fosnot, C. T. (1996). Constructivism: A psychological theory of learning. In C. T. Fosnot (Ed.), *Constructivism: Theory, Perpectives, and Practice* (pp. 8-33). New York: Teachers College Press, Columbia University.

Glasersfeld, E. Von. (1996). Introduction: Aspects of constructivism. In C. T. Fosnot (Ed.), *Constructivism: Theory, Perspectives, and Practice* (pp. 3-7). New York: Teachers College Press, Columbia University.

Govender, N. (2009 in press). Rural Lesotho pre-service students' cultural and indigenous experiences of astronomy (ethnoastronomy) and implications for science education. *Education as Change*, 14(1).

Holbrook, J., & Rannikmae, M. (2007). The nature of science education for enhancing scientific literacy. *International Journal of Science Education, 29*, 1347-1362.

Jansen, J., & Vithal, R. (1997). *Designing Your First Research Proposal*. Cape Town: Juta.

Jegede, J. O. (1999). Science education in non western cultures: Towards a theory of collateral learning. In S. Kincheloe (Ed.), *What is indigenous knowledge?: voices from the academy*.

New York: Falmer Press.

Kuhn, T. (1963/1970). *The Structure of Scientific Revolutions*. Chicago:University of Chicago Press.

Ladyman, J. (2002). *Understanding Philosophy of Science*. London: Routledge.

Leach, J., & Lewis, J. (2002). The Role of students' epistemological knowledge in the process of conceptual change in science. In M. Limon & L. Mason (Eds.), *Reconsidering Conceptual Change: Issues in Theory and Practice*. Dordrecht: Kluwer

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

Lederman, N. G. (1999). Teacher understanding of the Nature of Science and classroom practice. *Journal of Research in Science Teaching, 36*, 916-929.

Lederman, N. G., & Abd-El-Khalick, F. (2000). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching, 37*, 1057-1095.

Lederman, N. G., & Niess, M. (1998). The State of Science Education: Subject matter without context. *Electronic Journal of Science Education*.

Lemke, J. (2005). *Research for the Future of Science Education: New Ways of Learning, New Ways of Living.* Paper presented at the 7th International Congress on Research in Science Teaching, Granada, Spain.

Linneman, R. S., Lynch, P., Karup, R., Webb, P., & Bantwini, B. (2003). South African science teachers perceptions of the nature of science. *African Journal of Research in SMT Education, 7*, 35-50.

Lonsbury, J. G., & Ellis, J. D. (2002). Science History as a Means to Teach Nature of Science Concepts: Using the Development of Understanding Related to Mechanisms of Inheritance. *Electronic Journal of Science Education, 7*, 1-42.

Lumpe, A. T., Haney, J. S., & Czerniak, C. M. (1998). Science teachers beliefs and intentions to implement Science -Technology-Society (STS) in the classroom. *Journal of Science Teacher Education, 9*(1), 1-24.

Macdonald, D. (1996). Making both the Nature of Science and science subject matter explicit intents of science teaching. *Journal of Science Teacher Education, 7*(3), 183-196.

Mathews, M. R. (1994). *Science Teaching: The role of History and Philosophy of Science.* London: Routledge.

Matthews, M. R. (1998). The nature of science and science teaching. In B. J. Fraser & K. G. Tobin (Eds.), *International Handbook of Science Education* (pp. 981-999). London: Kluwer.

McComas, W. F. (1998). *The Nature of Science in Science Education. Rationales and strategies*. Dordrecht: Kluwer.

McComas, W. F. (2005). *Teaching the nature of science: What illustrations and examples exist in popular books on the subject.* Paper presented at the IHPST Conference, Leeds.

McComas, W. F., Clough, M. P., & Almazroa, H. (1998). The role and character of the nature of science in science education. In W. F. McComas (Ed.), *The Nature of Science in Science Education: Rationales and strategies*: Dordrecht: Kluwer

Mouton, J. (2001). *How to succeed in your Master's & Doctoral Studies: A South African Guide and Resource Book*. Pretoria: Van Schaik.

Naidoo, P. D. (2001). *Teachers perceptions of integrating indigenous knowledge systems (iks) into the science curriculum.* Paper presented at the Proceedings of the 9th Conference of the South African Association for Research in Science, Mathematics and Technology Education, Maputo.

Neuman, W. L. (2000). *Social Research Methods: Qualitative and Quantitative Approaches*. Needham Heights, MA: Allyn & Bacon.

Ogunniyi, M. B. (2006). Effects of a discursive course on two science teachers' perception of the nature of science. *African Journal of Research in SMT Education, 10*(1), 93-103.

Ogunniyi, M. B., & Hewson, M. G. (2008). Effect of an argumentation-based course on teachers' disposition towards a science-indigenous knowledge curriculum. *International Journal Environmental and Science Education, 3*, 159-177.

Okasha, S. (2002). *Philosophy of Science*. Oxford: Oxford University Press.

Popper, K. (1959). *The Logic of Scientific Discovery*. New York: Basic Books.

Ravetz, J. R. (1971). *Scientific knowledge and social problems*. Oxford: Oxford University Press.

Raza, G., & Plesis, H. D. (2003, 30 September). Science and Indigenous Knowledge in a Culturally Diverse World. *African Insight*.

Rogan, J. (2004). Out of the frying pan..?: Case studies of the implementation of Curriculum 2005 in some science classrooms. *African Journal of Research in SMT Education, 8*(2), 165-179.

Schreiner, C., & Sjoberg, C. (2004). Sowing the Seeds of ROSE: A comparative study of students' views of science and science education. *Acta, Didactica, 4*, 1-126.

Schwartz, R. S., Lederman, N. G., Khishfe, R., Lederman, J. S., Mathews, L., & Liu, S. Y. (2002). *Explicit/Reflective Instructional Attention to Nature of Science and Scientific Inquiry:Impact on student learning.* Paper presented at the Annual International Conference for the Education of Teachers in Science, North Carolina.

Society, M. R. (2003). *Questionaire Design Guidelines*. Retrieved 30 September, 2005, from http://www.mrs.org.uk/standards/download/revised/active/Questionnaire

Spector, B., Strong, P., & Portia, T. L. (1998). Teaching the Nature of Science as an element of Science, Technology and Society. In W. F. McComas (Ed.), *The Nature of Science in Science Education* (pp. 267-276). Dordrecht: Kluwer.

Taber, K. S. (2008). Towards a curricular model of the Nature of Science. *Science and Education, 17*, 179-218.

Taylor, P. C. (1998). Constructivism: Value Added. In B. J. Fraser & K. G. Tobin (Eds.), *International Handook of Science Education* (pp. 1111-1123). London: Kluwer.

Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Process*. Cambridge: Harvard University Press.

Vygotsky, L. S. (1996). Thought and language. In A. Kozulin (Ed.). Cambridge: MIT Press (Original work published 1934).

Wyk, A. J. V. (2002). Indigenous Knowledge Systems: Implications for natural science and technology teaching. *South African Journal of Education, 22*(4), 305-312.

Ziman, J. (1988). *An Introduction to science studies. The philosophical and social aspects of science and technology*. Cambridge: Cambridge University Press.

Appendix A

PROVINCE OF KWAZULU-NATAL
ISIFUNDAZWE SAKWAZULU-NATALI
PROVINSIE KWAZULU-NATAL

DEPARTMENT OF EDUCATION
UMNYANGO WEMFUNDO
DEPARTEMENT VAN ONDERWYS

Tel: 033 341 8610
Fax:033 341 8612

Private Bag X9137
Pietermaritzburg
3200

228 Pietermaritz Street
Pietermaritzburg, 3201

INHLOKOHHOVISI — PIETERMARITZBURG — HEAD OFFICE

Enquiries:
Imibuzo: Sibusiso Alwar
Navrae:

Reference:
Inkomba: 0064/05
Verwysing:

Date:
Usuku: 24 October 2005
Datum:

RE: PERMISSION TO CONDUCT RESEARCH

TO WHOM IT MAY CONCERN

This is to serve as a notice that **Mr. K. K. Naidoo** has been granted permission to conduct research with the following terms and conditions:

- That as a researcher, he/she must present a copy of the written permission from the Department to the Head of the Institution concerned before any research may be undertaken at a departmental institution.
- Attached is the list of schools she/he has been granted permission to conduct research in. however, it must be noted that the schools are not obligated to participate in the research if it is not a KZNDoE project.
- **Mr. K. K. Naidoo** has been granted special permission to conduct his/her research during official contact times, as it is believed that their presence would not interrupt education programmes. Should education programmes be interrupted, he/she must, therefore, conduct his/her research during nonofficial contact times.
- No school is expected to participate in the research during the fourth school term, as this is the critical period for schools to focus on their exams.

SUPERINTENDENT GENERAL
KwaZulu Natal Department of Education

UHULUMENI WAKWAZULU NATAL
UMNYANGO WEMFUNDO
DEPARTMENT OF EDUCATION
DEPARTEMENT VAN ONDERWYS
2005 -10- 24
ISIKHWAMA SEPOSI
PRIVATE BAG / PRIVAAT SAK X04
ULUNDI 3838
RESEARCH, STRATEGY AND POLICY DEVELOPMENT

Appendix B

Informed Consent Letter

Research Topic: Science teachers' knowledge and classroom practice of nature of science

Dear Sir or Madam,

I am a final year M.Ed student registered at the University of Kwa-Zulu Natal. I am required to complete a mini dissertation as part of my studies. I am especially interested in science teachers' knowledge of nature of science and to what extent it reflects in the classroom. I humbly request permission to use your school and grade 10 science class for this research study. Your school was chosen because your science teacher has kindly agreed to be a participant in this research project. The study should take approximately 3 months and will include lesson observations, audio tapes and post lesson interviews.

Confidentiality will be maintained throughout the research. You will have an opportunity to listen to the audio tapes and voice your opinions and concerns.
Care and sensitivity will be maintained throughout the study

My contact details are as follows:

Name	**telephone**
KK Naidoo	031-7072675
Supervisor	
2. Dr N. Govender	031-2603469

I appreciate your co-operation in this important study.

DECLARATION

We…………………………………………………(full names of Principal) and

……………………………………………………..(full name of GB chairperson)

hereby confirm that we understand the contents of this document and the nature of this research project, and we consent to allow you the use of our school in this research project.

We understand that we are at liberty to withdraw from the project at any time, should we so desire.

Signature of Principal Signature of GB Chairperson:

…………………………… -------------------------------------

Date: Date:

Appendix C

Informed Consent Letter

Research Topic: Science teachers' knowledge and classroom practice of nature of science

Dear Sir or Madam,

I am a final year M.Ed student registered at the University of Kwa-Zulu Natal. I am required to complete a mini dissertation as part of my studies. I am especially interested in science teachers' knowledge of nature of science and to what extent it reflects in the classroom. I humbly request permission to use you and your grade 10 science class for this research study. Together we can understand and explore this topic further and assist science teachers in their classroom practice. The study should take approximately 3 months and will include lesson observations, audio tapes and post lesson interviews.

Confidentiality will be maintained throughout the research. You will have an opportunity to listen to the audio tapes and voice your opinions and concerns.

Care and sensitivity will be maintained throughout the study

My contact details are as follows:

Name	telephone
KK Naidoo	031-7072675
Supervisor	
2. Dr N. Govender	031-2603469

I appreciate your co-operation in this important study.

<u>DECLARATION</u>

I …………………………………………………(full names of participant) hereby confirm that I understand the contents of this document and the nature of this research project, and I consent to participating in this research project.

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

Signature of Participant Date:-----------------------------

Appendix D

NATURE OF SCIENCE QUESTIONNAIRE FOR POST GRADUATE SCIENCE TEACHERS.

I am a M.Ed student at the UKZN. I am currently conducting research on the Nature of Science. My study aims to investigate teachers' views on the Nature of Science and to what extent these views reflect on their practice as teachers of science. This study aims to add to teachers conceptions of the nature of science as well as their instructional strategies.

All information supplied by you will be treated as confidential and will not be seen by other students or teachers. If you have any queries or concerns, kindly contact the following persons.

Researcher: K.K. Naidoo

Tel: 031-7072675

Supervisor: Dr. N. Govender

Tel: 031- 2603469

Thank you for agreeing to participate in this study. Kindly return the completed questionnaire my supervisor.

<u>Section 1 : Biographical data</u> : Please complete the following information

Name of Teacher	
Gender	
Number of completed years of teaching experience.	
Teaching Qualification	
Your major subjects in your degree.	
What is your main teaching subject at your school.	

SECTION 2: VIEWS OF THE NATURE OF SCIENCE

There are no right or wrong responses to the 15 statements . Please read each of them carefully and then place a tick in the box to indicate whether you strongly agree, agree, not sure, disagree, strongly disagree with the statements.

No	STATEMENT	Strongly disagree	disagree	Not sure	agree	Strongly agree
1.	If observations are made carefully, two different skilled observers should see the same thing.					
2.	It makes no sense to talk about 'African Science' because there is only one science and it is universal.					
3.	Two technological societies could have very different but valid theories about he same idea (e.g., state of matter).					
4.	A theory such as atomic theory describes substances as they really are.					
5.	Scientists always do things in the same order. First they collect					

	data and then generate theories by looking for patterns in the data.					
6.	The status of 'facts and theories' depend on the values that scientists hold.					
7.	Technologists have their own body of knowledge to build on.					
8.	Co-operations eg mining, forestry, pharmaceuticals should control scientific research.					
9.	Scientists are not isolated from their society.					
10.	Religious or ethical views do not influence scientific research.					
11.	Science and technology can help in the social problems of poverty, crime and unemployment.					
12.	The mass media,(T.V.,newspapers , magazines , movies), give a more accurate picture of science , than science classes.					
13.	Scientific discoveries made by women will tend to be different from those made by men.					
14.	Scientific knowledge is tentative knowledge					
15.	Science should be treated as a separate discipline largely unrelated to the nature of science.					

(Modified from Aikenhead et al., 1989 & Linneman et al., 2003)

In the boxes below, please justify your responses to statements 1 and 12.

Statement number	**Justification**
1	
12	

Section 3 : Open –ended response questions.

3.1. Is science and technology related? What is your viewpoint?

3.2. Explain the following components as they relate to science and scientific knowledge. **Subjectivity:**
Creativity:

DECLARATION

I ………………………………………………(full names of participant) hereby confirm that I understand the contents of this document and the nature of this research project, and I consent to participating in this research project.

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

Signature of Participant Date:----------------------------

Appendix E

OBSERVATION SCHEDULE:

The study will observe the following aspects of NOS in classroom lessons. It will record the extent to which the teacher uses one or more aspects of NOS , with explanations , descriptions and supporting examples.

1. **Tentativeness**: Scientific knowledge is subject to change with new data and with reinterpretation of existing data.

2. **Creativity**: Scientific knowledge is created from human imagination and logical reasoning .

3. **Subjectivity**: Science progress is influenced and guided by presently accepted scientific knowledge as well as by the personal subjectivity resulting from individual scientists' values , agendas and prior experiences.

4. **Empirical Basis** : Scientific knowledge is based on observations of the natural world.

5. **Social / cultural embeddeness**: the values and expectations of the culture and society determine what and how science is conducted , interpreted, and accepted.

6. **Theories and laws**: theories and laws are different kinds of scientific knowledge produced in different ways . Laws describe relationships , observed or perceived , of phenomena in nature. Theories are inferred explanations of natural phenomena.

7. **Observations and inferences**: science is based on both observations and inferences. Observations are gathered through human senses or extensions of theses. Inferences are interpretations of those observations. There may be more than one valid interpretation of those observations. Scientific models are based on inferences to represent an understanding of a mechanism or relationship and do not necessarily represent the actual phenomenon.

(Modified from Abed-El-Khalick et al., 2001)

Table: Teachers NOS Views addressed in lessons.

Name	**Tentative**	**Creative**	**Subjective**	**Empirical**	**Social/cultural**	**Theoretical laws**	**Observations/ inferences**	**Overall**
Teacher A								
Teacher B								
Teacher C								
Teacher D								

 # provides a definition or affirmative response. # # provides a description in own words, examples from class.

 # # # provides a description in own words and additional supporting examples.

Appendix F

Structured interview: Post lesson.

1. Why is the nature of science valuable for science teaching?

2. How does the resources and activity you have used portray the nature of science?

3. How does the content of the lesson portray the nature of science?

4. Do you think the lesson could have been changed so that it better illustrates the nature of science?

5. If Yes to Q4: How would you present the lesson differently next time?

6. If No to Q4: What were the strong points in your lesson that portrayed the nature of science?

7. How would changes to your lesson better facilitate student understanding of the nature of science?

8. From observing / listening to pupils, what conceptions of the nature of science do they have?

9. How will you structure future instruction to address these conceptions?

10. Is there any issue with regards to nature of science and classroom instruction that you would like to comment on?

(modified from Clough, 1998)

Appendix G

A consensus view of the NOS objectives as extracted from eight international science standards document in (McComas, Clough, & Almazroa, 1998, p. 6) are :

1. Scientific knowledge while durable has a tentative character.
2. Scientific knowledge relies heavily, but not entirel , on observation, experimental evidence, rational arguments, and scepticism.
3. There is no one way to do science. Therefore, there is no universal step-by-step scientific method.
4. Science is an attempt to explain natural phenomena.
5. Laws and theories serve different roles in science, therefore students should note that theories do not become laws even with additional evidence.
6. People from all cultures contribute to science.
7. New knowledge must be reported clearly and openly.
8. Scientists require accurate record keeping, peer review and replicability.
9. Observations are theory laden
10. Scientists are creative.
11. The history of science reveals both an evolutionary and revolutionary character.
12. Science is part of social and cultural traditions.
13. Science and technology impact each other.
14. Scientific ideas are affected by the social and historical milieu.