Effects of an explicit reflective approach on Swaziland pre-service elementary teachers' understanding of the Nature of Science

by

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DECLARATION

The research project described by this dissertation was carried out in the Faculty of Education, University of Pretoria, from January, 2010 to 2013, under the supervision of

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I, **Khanyisile Brenda Nhlengethwa** declare that the dissertation is my own original work and has not been submitted for any degree at any university. Where other people's work has been used, this has been properly acknowledged and referenced in accordance with the departmental requirements.

Signed

Khanyisile Brenda Nhlengethwa (Candidate)

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ABSTRACT

In this study, the effects of an explicit reflective intervention on Swaziland elementary pre-service teachers' understanding of the Nature of Science (NOS) were investigated. The factors that had an impact on the development of participants' NOS views were also investigated. The intervention made use of de-contextualized and contextualized activities as well as historical narratives as contexts for reflecting about the empirical, creative, subjective as well as the tentative NOS. The intervention included a discussion of the relationships and differences between observations and inferences as well as scientific laws and theories in the context of the aforementioned learning activities.

Participants were 24 elementary pre-service teachers enrolled for their final year of their three year teacher development programme. An adapted version of the Views of Nature of Science Questionnaire-Form C (VNOS-C) was used in conjunction with individual interviews, to assess the participants' understanding of NOS at the beginning and conclusion of the intervention. At the end of the programme, data from interviews, concept maps and reflective journals of seven participants were analysed to ascertain their perceptions of the elements of the course and other factors that had an impact on their development of more informed NOS views. These participants were selected on the basis of their differential gains in NOS understanding.

The data that was analysed using both qualitative and quantitative techniques revealed that the intervention brought about significant gains in some participants' understanding of NOS. Information obtained from the document analysis of journals and concept maps as well as exit interviews of the selected group revealed that the pre-service teachers' development of more informed views was mediated by motivational and cognitive factors. These were the participants' perception of the value of teaching and learning NOS, their views about teaching and learning science, and their ability to engage deeply with the NOS concepts as well as their epistemic beliefs. The explicit reflective attention to NOS as well as metacognitive strategies was reported by most of the selected participants as responsible for changes in their NOS views.

ACRONYMS AND ABBREVIATIONS

CCM: Conceptual Change Model

HOS: History of Science

POS: Philosophy of Science

MOE: Ministry of Education

NOS: Nature of Science

PTD: Primary Teachers' Diploma.

VNOS: Views on Nature of Science Questionnaire

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CHAPTER 1

INTRODUCTION AND BACKGROUND

1.0 Introduction

Swaziland, like many other countries, has made scientific literacy a major goal for junior and secondary education. This is deduced from one of the statements produced by the science inspectorate in 1997 for grades 1 to grade 12 sciences (Ministry of Education, 2007). It states that "science should have a place in the education of all pupils who are in the school system, whether or not they are likely to go on to follow a career in the science and technology field". It goes on to highlight the logic of this vital place of science in primary and secondary education; "science permeates almost every aspect of daily life and therefore each of us needs to be able to bring a scientific approach to bear on the practical, social, economic and political issues of life" (Ministry of Education, 2007).

Even though the promotion of students' understanding of Nature of Science (NOS[1]) is not explicitly stated among the goals for science education in the country, an informed view of NOS is one of the major requirements for scientific literacy (Clough & Olson, 2004; Holbrook & Rannikmae, 2007, 2009). In line with this view, Irez and Cakir (2006) contend that the promotion of scientific literacy includes not only teaching students the products of science (facts, laws and theories) and the processes of science, but also an accurate understanding of the nature of these concepts and how science is similar or distinct from other means of understanding natural phenomena. Such an understanding is more especially critical when one considers the scientific and technological embeddedness of socio-political issues (Dass, 2005). In order to promote the public's ability to participate in making informed decisions on socio-scientific issues, science education programmes must therefore aim at developing students' and teachers' understanding of NOS.

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[1]Throughout this thesis NOS will be used to indicate Nature of Science. This is in line with usage in international literature. All acronyms are defined on page vi.

Clough (2000), highlighting the importance of an accurate understanding of NOS, asserts that students' and teachers' misconceptions of NOS are detrimental to scientific literacy because they affect students' attitudes toward science and science classes. Clough points out that NOS views affect students' comprehension of scientific concepts and the selection of further science classes. In support of this claim, Tobias' (1990) study revealed that a large percentage of successful science students reported having lost interest in science classes due to teachers' neglect of the philosophy of science.

Teachers of science play a crucial role in influencing learners' views of NOS (Naidoo, 2008). Clough and Olson (2004) contend that teachers unavoidably communicate ideas about NOS to students in their teaching. The question that then arises is whether the current teacher education programmes in Swaziland equip elementary teachers with an adequate understanding of NOS. The aim of this current study is therefore to assess the effects of an explicit reflective NOS programme on the Swaziland elementary pre-service teachers' understanding of NOS. The assessment of the impact of such programmes on the pre-service teachers' NOS views may play an important role in facilitating the development of more effective science teacher education programmes, and subsequently advance the country's goal of scientific literacy.

1.1 Background

NOS is about "what science is and how it operates" (Clough & Olson, 2004, p.28). Even though there is a lot of disagreement amongst philosophers, historians, and science educators concerning NOS, views regarding topics relevant to school science teaching are far less contentious (Abd-El-Khalick, Bell & Lederman, 1998; McComas, Almazroa & Clough, 1998). McComas, Almazroa & Clough (1998, p.513) present a consensus view of NOS objectives taken from eight international science standards documents[2]:

- "Science is an attempt to explain natural phenomena.
- Science is part of social and cultural traditions.

[2]These documents include: the American Association for the Advancement of Science in the very influential report: Project 2061 (American Association for the Advancement of Science), 1989; American Association for the Advancement of Science (The Liberal Art of Science), 1990; Benchmarks for Science Literacy (American Association for the Advancement of Science), 1993; Curriculum Corporation (Australia), 1994; the National Curriculum Council (1988, 1991) in Great Britain; California Framework, 1990; Council of Ministers of Education (Canada), 1996

- People from all cultures contribute to science.
- Scientists require accurate record keeping, peer review and replicability.
- Observations are theory-laden.
- Scientists are creative.
- The history of science reveals both an evolutionary and revolutionary character.
- Science and technology impact each other.
- Scientific ideas are influenced by their social and historical context.
- Science and technology impress each other.
- Scientific knowledge relies heavily, but not entirely, on observations, experimental evidence, rational arguments, and scepticism.
- Scientific knowledge while durable has a tentative character.
- New knowledge must be reported clearly and openly.
- Laws and theories have different functions; therefore students should be made aware that theories do not become laws even with additional evidence".

Various justifications have been put forward for incorporating the epistemology of science in science curricula. Tuberty (2011) points out that issues related to science are becoming more and more important in present-day society. Subjects such as "climate change, pollution, and available energy resources" make it obligatory that the public understands how science operates in order to make informed judgments pertaining to policy formulation and its execution (Foster & Shiel-Rolle, 2011, p. 86). It is in that vein that McComas, Almazroa and Clough (1996) contend that an appreciation of the norms and methods of science may enhance the public's ability to participate in social decision making on socio-scientific affairs.

Driver, Leach, Miller and Scott further argue that the public's appreciation of NOS will promote citizens' ability to handle technological gadgets and procedures in their day-to-day life (Driver, Leach, Miller & Scott, 1996 in McComas, Almazroa & Clough, 1998).

NOS insights promote an understanding of the strengths and shortcomings of science and the functions of different types of scientific constructs, such as scientific laws and theories (McComas, Clough & Almazroa, Clough, 1998). A populace that is aware of the limits of science is unlikely to have unrealistic expectations of science and for that reason, an accurate understanding of NOS is likely to promote the general public's support of science (Laukgsch, 2000). McComas, Almazroa & Clough (1998) also assert that an understanding of NOS is likely to boost interest in science and science classes and may also improve instructional delivery and the learning of science content.

Focusing on developing primary pre-service teachers' conceptions of NOS is important as it helps to influence learners' views while they are still at an early stage of their science education, and consequently minimize the development of misconceptions. Such misconceptions would be very difficult to undo at a later stage. Clough (2006) points out those mistaken notions about NOS that developed as a result of implicit experiences, will, just like misconceptions about the natural world, be resistant to change. If a child's experience, at an early stage, consists of accurate implicit and explicit experiences about NOS, they would likely develop a number of accurate conceptions from the beginning. Studies have shown that primary students as early as the first grade can develop accurate views of NOS (Akerson & Abd-El-Khalick, 2005; Akerson & Donnelly, 2010; Akerson & Volrich, 2006; Quigley, Pongsanon & Akerson, 2011; Smith, Macklin, Houghton & Hennessey, 2000).

1.2 NOS Research

The advancement of students' views of NOS has been the major goal of science education for almost a century and is currently being promoted through many science education reforms in various nations, such as Australia, Canada, South Africa, United Kingdom and United States of America (Akerson, Abd-El-Khalick & Lederman, 2000; Lederman & Lederman, 2004; Lederman, 2007). Several studies have however indicated that teachers hold inadequate views of NOS and in some cases have similar naive views of science as their students (Akerson & Buzzelli, 2007; Dekkers & Mnisi, 2003; Haidar, 1999; Linneman, Lynch, Kurup, Webb & Bantwini, 2003; Tan & Boo, 2004). Lederman and Abd-El-Khalick (1998) contend that a significant number of teachers and students still believe in common misconceptions such as that scientific knowledge is completely provable, objective, and does not involve creativity and human imagination. For example, Akerson, Abd-El-Khalick and Lederman (2000) found that 76% of graduate and 84% of undergraduate elementary teachers were not aware of the involvement of creativity and imagination in the development of scientific laws, theories and models. A majority of them therefore alleged, for example, that scientists were certain about the representation of an atom and believed science was a completely objective endeavour.

1.3 Improving teachers' views about NOS

Promotion of teachers' conceptions of NOS and their awareness of the importance of stressing this goal in their teaching is particularly important because of the bearing it has on classroom practice, and ultimately students' conceptions of NOS (Clough, 2006; Cochraine, 2003; Donovan-White, 2006). Clough, (2006) points out that even though possessing an accurate understanding of NOS is insufficient to enable teachers to address NOS in the classroom, it is one of the necessary conditions in promoting learners' conceptions. Lederman (2007) also asserts that it is an indisputable fact that teachers must have good knowledge of what they are expected to teach.

There are generally two NOS approaches that have been used in an attempt to augment pre-service and in-service teachers' conceptions of NOS. These are implicit and explicit teaching approaches. The implicit approach is based on a supposition that NOS conceptions simply develop as a by-product of doing science (Lederman, 1992; Khisfe & Abd-El-Khalick, 2002). Science educators holding this view make use of science process skills instruction, inquiry activities, or history of science episodes aimed at enhancing teachers' understanding of NOS. No attempt is made to overtly direct learners to specific aspects of NOS (Cochraine, 2003; Kim, Ko, Lederman & Lederman, 2005). There is very little empirical evidence to support the usefulness of this approach in improving teachers' views of NOS (Abd-El-Khalick, Bell & Lederman, 1998; Khishfe & Abd-El-Khalick, 2002; Schwartz, Lederman & Crawford, 2004).

Explicit reflective approaches, however, view instruction about NOS as a cognitive objective that should be "explicitly planned for and taught through direct examination and discussions by students rather than expected to occur simply by doing science" (Rudge & Howe, 2009, p.2). The reflective element suggests an instructional approach that involves the application of strategies aimed at guiding students to target aspects of NOS while they are engaged in inquiry, process skill or history of science instruction (Abd-El-Khalick & Akerson, 2009; Khisfe & Abd-El-Khalick, 2002; Schwartz & Lederman, 2002). Such strategies include the use of "questioning, discussions, and guided reflections" (Schwartz & Lederman, 2002, p. 207). Both earlier (Akindehin, 1988; Shapiro, 1996) and more recent studies (Akerson, Abd-El-Khalick & Lederman, 2000; Gess-Newsome, 2002; Kukuk, 2008; Lin & Chen, 2002; McDonald, 2008) have provided evidence pointing towards the utility of the explicit reflective approach in improving pre-service teachers' views of NOS.

Akerson, Abd-El-Khalick and Lederman (2000), therefore, recommend that an effective NOS instruction should be taught as an independent topic within a science course, instead of believing that it will be developed merely as a result of engaging students in inquiry, science process or science content lessons. A reflective approach is also recommended, in order to allow students, "opportunities to test, receive feedback, and revise their NOS ideas" (Scharman, Smith, James & Jensen, 2005, p. 28). This reflection should occur within an existing context, so that students can appreciate how science knowledge is developed and used (Abd-El-Khalick, 2001).

Akerson, Morrison and McDuffie (2006) contend that metacognitive strategies must also be utilized to facilitate pre-service teachers' retention of newly developed NOS views. They suggest that concept mapping, planning activities for teaching NOS, and practicing teaching NOS to peers should be used to improve their NOS ideas.

Several studies have also indicated that pre-service teachers do not realize equivalent gains in their appreciation of NOS as a result of NOS instruction. Several personal factors have been shown to impact on their development of NOS views. Pre-service teachers' perception of the value of NOS has been found by some studies to be a primary factor influencing their development of more informed NOS views (Abd-El-Khalick & Akerson, 2004; McDonald, 2010; Schwartz, Akom, Skjold, Hong, Kagumba & Huang, 2007). Teachers' learning dispositions, mainly their ability to reflect deeply on ideas and a strong need for cognition were also found to mediate teachers' gains of more informed NOS views (Abd-El-Khalick & Akerson, 2004; Southerland, Johnston & Sowell, 2006).

1.4 Problem Statement

Developing students' contemporary views of NOS is one major goal of teaching science. Students' perceptions of the epistemology of science have great impact on their understanding of scientific concepts as well as their attitudes towards science (Clough & Olson, 2004; McComas, Almazroa & Clough, 1998; Stein & McRobbie, 1997). In support of this claim, Tobias' (1990) study revealed that a number of students lost interest in science due to teachers' neglect of NOS.

Many studies however indicate that the majority of students hold erroneous views of NOS. In order for teachers to develop students' NOS conceptions, they need to have an accurate understanding of NOS themselves. However, as a science teacher educator, I have noted that many prospective teachers seem to hold misconceptions about NOS.

They are likely to pass these misconceptions on to their students. In one instance, for example, while I was teaching about atoms, many students questioned the knowledge of an atom when no one had ever seen one; the students seemingly held a 'seeing is knowing' view of scientific knowledge. They were seemingly uninformed of the role of creativity and imagination in addition to empirical evidence in the development of scientific knowledge. This anecdote indicates the possibility that the science education programme that the teachers are exposed to is not effective in developing their NOS views. The question that emerges therefore is: How do we develop the pre-service teachers' understanding of NOS? Although several studies provide evidence of the success of the explicit reflective approach in developing pre-service teachers' understanding of NOS (Akerson, Abd-El-Khalick & Lederman, 2000; Gess-Newsome, 2000; Kukuk, 2008; Lin & Chen, 2002), there is currently no literature on pre-service teachers' views in Swaziland. Moreover, many of the studies on pre-service teachers' development of NOS views were carried out amongst graduate and post graduate students. There is no study, to the best of my knowledge that has been carried out among student teachers who are pursuing a primary teachers' diploma (PTD). It is therefore not possible to find solutions to the problem from the literature.

The issue of elementary teachers' understanding of science is especially crucial in Swaziland, where the teaching of science begins as early as from the first grade of primary schooling. The primary teachers are therefore the ones that lay a foundation for the students' future understanding of not only scientific concepts and principles but also the nature of the scientific enterprise. Several studies indicate that misconceptions about NOS are very tenacious. It is in that vein that Kang, Scharman and Noh (2004) assert that "teaching accurate views of NOS at the elementary school level may be more beneficial than correcting secondary students' misconceptions" (p. 332). Their study among pre-college students did not reveal any clear differences among the different grade levels' perspectives about NOS. They speculated that these results could mean that experiences at secondary school level have little influence on the development of students' views and only serve to reinforce students' naive views. The lack of knowledge of how the elementary Swaziland pre-service teachers' understanding of NOS can be improved prevents effective intervention to ameliorate the problem. Therefore a study of this nature is required to provide information regarding the best strategies for enhancing the pre-service teachers' views of NOS.

1.5 The Rationale of the study

The study was undertaken because teachers' knowledge of NOS is of paramount importance in advancing Swaziland's goal that learners should develop scientific literacy. Learners' accurate understanding of NOS is likely to improve their understanding of scientific concepts and their attitudes towards science and science classes (Clough, 2000). The Swaziland primary teacher training college where the study was undertaken introduced a new programme that integrated the study of NOS with the learning of science content. When a new programme is introduced, it is essential that is evaluated and this prompted me to conduct this study. I was interested in finding out the pre-service teachers' conceptions of NOS prior to the intervention as well its effects on their understanding of the nature of the scientific endeavour. I also wanted to gain more insights into factors that have a bearing on the pre-service teachers' development of more informed NOS views. Even though I knew that possessing informed views of NOS is not enough to enable teachers to address the concept in their teaching, teachers' knowledge is one of the requirements for promoting learners' conceptions (Clough, 2006; Lederman, 2007).

My study was carried out while the participant pre-service teachers were engaged in the explicit reflective intervention. Of note, the study focused only on evaluating the effects of the programme on participants' NOS views. The development of the intervention itself was not part of the study.

1.6 Objectives of the study

The researcher's intentions in designing this study were therefore to:

- Determine the Swaziland pre-service elementary teachers' views of NOS prior to participating in an intervention programme.
- Explore the changes, if any, in the participants' NOS conceptions after participating in the intervention programme.
- Identify the aspects of the NOS intervention that the pre-service teachers report as helpful in enhancing their NOS views.
- Establish factors that facilitate or inhibit Swaziland pre-service elementary teachers' development of more informed NOS views.

1.7 Research questions of the study

The study was steered by the following research questions:

1.7.1 The main research question

How does an explicit reflective approach to teaching NOS influence Swaziland pre-service elementary teachers' views of NOS?

1.7.2 Research sub-questions of the study

- What are Swaziland pre-service elementary teachers' views about NOS prior to participating in an explicit reflective NOS intervention?
- How do the pre-service elementary teachers' views of NOS change from pre- to post instruction as a result of the explicit reflective approach?
- What specific elements of the intervention do the pre-service elementary teachers themselves report contribute to these changes?
- What factors enhance or impede the development of participants' NOS views in the context of the explicit reflective NOS instruction?

1.8 The significance of the study

The study is important because the study findings may be useful to elementary teacher education institutions. The knowledge of the Swaziland pre-service teachers' conceptions of NOS as well as factors that influence their development of NOS views may inform the design and implementation of programmes that can enhance their NOS views. Descriptions of participants' views of NOS will contribute to the existing understanding of the misconceptions that prospective elementary teachers possess about aspects of NOS. Moreover, the investigation of the effects of the explicit reflective NOS programme on the Swaziland pre-service teachers' views provides another opportunity to test the contention that an explicit reflective approach is effective in enhancing pre-service teachers' NOS views. Clough and Olson (2008) point out that it is necessary that the proposed strategies of developing students' and teachers' conceptions of NOS should be assessed more widely in order to gain better understanding of their effects in different contexts.

1.9 Clarification of terms

The following terms are defined as used in the study:

Scientific literacy: refers to what "the general public ought to know about science" (Durant, 1993 in Laugksch, 2000, p.71). It commonly includes an appreciation of the nature of, aims and general limitations of science, important scientific ideas and concepts and their impact on the daily lives of citizens (Jenkins, 1994 in Laugksch, 2000).

Science: refers to a human attempt to understand the natural world. It includes both the activities that scientists use to explain natural phenomena as well as the body of knowledge that is accumulated as a result of carrying out these processes (Bell, Lederman & Abd-El-Khalick, 2000; Lederman & Abd-El-Khalick, 1998).

Nature of Science (NOS): denotes the "epistemology of science, science as a way of knowing or the values and beliefs intrinsic to scientific knowledge and its development" (Lederman, 1992, p. 331). In this study, science is characterized as empirically based (based and/or derived from observations of the natural world), inferential, creative and imaginative, subjective (theory laden) as well as socially and culturally influenced. Two other important aspects are the distinctions and relationships between theories and laws and differences between observations and inferences (Abd-El-Khalick, Bell & Lederman, 1998).

Views of Nature of Science questionnaire (VNOS): an open ended questionnaire used to assess participants' conceptions of the nature of the scientific investigations as well as the knowledge it produces. Most of the items in the questionnaire used in this study were adapted and used by Dekkers and Mnisi (2003) from the version C of the VNOS questionnaire designed by Abd-El-Khalick, Bell and Lederman (1998).

Implicit approach: is an approach to NOS instruction that assumes that students can develop sophisticated conceptions of the different aspects of NOS simply by engaging them in doing science. It makes use of science process skills instruction, inquiry activities or History of Science episodes (Abd-El-Khalick & Lederman 2000a; Akerson, Abd-El-Khalick & Lederman, 2000; Donovan-White, 2006; Lederman 2007).

Explicit approach: denotes an approach to NOS instruction where the exploration and development of students' NOS conceptions is made an important part of instructional learning outcomes of science lessons instead of assuming it will occur simply by doing science (Abd-El-Khalick & Lederman, 2000a; Clough, 2006; Donovan-White, 2006; Rudge & Howe, 2009).

The reflective approach to NOS instruction: denotes an instructional approach that helps participants make their own connections between learning activities and targeted NOS aspects rather than a didactic approach; where the instructor informs scholars how each NOS aspect pertains to a given context. It includes the pre-service teachers' arrival at a realization of the importance of the discussed NOS issues for the pre-service teachers' own learning and teaching of science in general (Akerson, Hanson & Cullen, 2007; Clough, 2006; Donovan-White, 2006).

Conceptual change: the replacement of participants' prior NOS misconceptions with more sophisticated ones (Posner, Strike, Hewson & Gertzog, 1982).

Constructivism: a philosophy that contends that the knower constructs his or her own understanding of the world in consequence of deliberating on experiences and interactions with his or her environment (Staver, 1998).

Contextualized NOS instruction: this is an approach where participants are overtly guided to reflect on different NOS aspects in the context of learning content knowledge and using history of science episodes (Clough, 2006)

De-contextualised NOS activities: these are non-content specific activities used as context for developing participants' NOS views (Clough, 2006).

1.10 Summary and outline of the dissertation

Information about of Swaziland pre-service elementary teachers 'conceptions of NOS and how their views are influenced by the advocated explicit reflective NOS instruction is valuable in making decisions on how best their views can be enhanced. Development of elementary teachers' views of NOS may play an important role in promoting the country's science education goal of developing a scientifically literate citizenship. This is particularly important when one considers the fact that the learning of science in the country begins as early as the first grade.

The dissertation follows the following structure:

Chapter 1: Introduction to the study (this chapter)
In the first chapter, the introduction and background is presented. This is followed by a discussion of the problem and rationale of the study, the purpose of the study together with the research questions as well as the significance of the study.

Chapter 2: Literature Review
Chapter 2 provides detailed literature survey with regard to teachers' conception of NOS, development of teachers' understanding of NOS, as well as the factors that have been shown to impact on participants' development of NOS conceptions as indicated by various studies. Lastly, the theoretical and conceptual frameworks of the study are described.

Chapter 3: Research Methodology

The detailed description of the research design is provided in chapter 3. It incorporates the description of the participants, the context of the intervention, the intervention, as well as data collecting and analysis strategies.

Chapter 4: Research Results

The results are analysed and presented in chapter 4. They are presented according to the research questions. The chapter is divided into four sections. These are; pre-service teachers' pre-instruction NOS views, pre-service teachers' post-instruction NOS views; pre-service teachers' report of the influence of course components and factors mediating the development of NOS conceptions.

Chapter 5: Research Results

Chapter 5 provides a discussion of key findings presented in chapter 4. The findings are discussed according to the research questions.

Chapter 6: Conclusions, Limitations, Contributions of the study and Recommendations

Finally, chapter 6 focuses on the conclusions drawn from the study, the limitation and delimitations, contributions of the study, and recommendations.

In the next chapter, an overview of the literature will be provided.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.0 Introduction

This chapter presents a review of literature related to the current study. Firstly, it discusses the meaning of NOS as well as the different aspects of the construct that have been accepted as applicable to a scientifically literate society. Secondly, it presents relevant studies on teachers' NOS views and the development of their NOS understanding as a result of various interventions. Furthermore, factors that have been shown to be related to the development of teachers' understanding of NOS are discussed. Lastly, the theoretical and conceptual frameworks of the study are presented.

2.1 Nature of Science (NOS)

2.1.1 The meaning of NOS

There is no single specific definition of NOS (Abd-El-Khalick, Bell & Lederman, 1998; Halai & McNicholl, 2004; Liang, Chen, Kaya, Adams, Macklin & Ebenezer, 2009). This lack of consensus is most probably caused by the many-sided and dynamic nature of the scientific enterprise (Abd-El-Khalick, 2006). Vhurumuku and Mokeleche (2009) provide a broad definition of NOS that incorporates the different ways by which the construct has been used in the literature. They describe NOS as "an individual's conceptions, perceptions, images, ideas, views, beliefs and values about scientific knowledge (facts, laws, theories, and models), the processes of science (inquiry processes and the methods of science) as well as the scientific enterprise, which embraces the social, ethical, political, religious, philosophical contexts and paradigms guiding the work of scientists" (p. 97).

Clough (2006, p. 463) adds a fourth component, and states that NOS also includes a description of "how society influences and reacts to the work of scientists". This aspect of Clough's definition almost coincides with Aikenhead and Ryan (1992) who describe NOS as the "epistemology and sociology of science. In this study, NOS denotes the "epistemology of science or the values and assumptions inherent to scientific knowledge and its development" (Lederman, 1992, p. 331). In line with this understanding of NOS, Wenning (2009) points out that epistemological issues in science include issues about "what scientists mean about knowing something, how they get to know, how the reliability of scientific knowledge is established as well as the limitations of such knowledge" (p. 3). In support of the call to address such philosophical issues in the science classroom, Wenning (2009) states that science is not just a body of facts, but is also a way of understanding nature. For that reason, Wenning contends that an understanding of science goes beyond understanding scientific facts, but also an understanding of the processes of science, the nature of these processes and that of the body of knowledge that emanate from these processes.

Most teachers tend to confuse scientific processes with NOS (Abd-El-Khalick, Bell & Lederman, 1998). Bell, Lederman and Abd-El-Khalick, (2000, p. 564) define scientific processes as "activities that scientists use to collect and interpret data as well as in the derivation of conclusions". Making observations, data interpretation, measuring, and drawing conclusions from the collected data, are all examples of processes of science. On the other hand, NOS refers to the "epistemological assumptions inherent to these activities of science" (Bell, Lederman & Abd-El-Khalick, 2000, p. 565). They emphasize that it is not only important for students to learn the skills of observing and inferring for example, but they also need to understand the subjective nature of these activities. Lederman & Abd-El-Khalick (1998) highlight that it is these assumptions and values that set science apart from non-science. A good understanding of NOS is also necessary to help students discern good science from pseudo-science (Matthews, 1998).

Beliefs and views about NOS, just like scientific knowledge, have changed and will probably continue to change with time, as science and "systematic philosophising about its nature and how it operates develop" (Akerson, Abd-El-Khalick & Lederman, 2000, p. 298). Akerson and his colleagues, nevertheless, contend that at any given time, there is a certain level of agreement about what the characteristics of NOS are.

In the early part of the twentieth century, the positivist view was the dominant view of NOS (Haidar, 1999). This traditional theoretical framework postulates that natural and social phenomena can be observed, and understood with complete objectivity. It also contends that the single way of gaining knowledge in science is by using the induction method. Scientific knowledge is therefore believed to be absolute and does not involve human creativity and imagination (Haidar, 1999). Scientists are viewed as "completely objective people who are free from illusion and beliefs", which might interfere with the objectivity of their endeavour (Haidar, 1999, p.807). Also, according to this philosophy, only the observable and measurable could be researched and this was supposed to be done through the scientific method (Abd-El-Khalick & Lederman, 2000b; Haidar, 1999; Palmquist & Finley, 1997).

Current views in the areas of physics, philosophy, sociology and history of science have however, challenged these basic beliefs of the positivist view. This finally led to the establishment of the constructivist view of science. Constructivists contend that the "world cannot be observed and known objectively, but our observations and inferences are influenced by our current perspectives" (Haidar, 1999, p. 808). Scientific laws and theories are therefore our social understanding, rather than a true representation of natural phenomena (Staver, 1998). Contemporary understanding of NOS is influenced by this perspective.

2.1.2 Characteristics of NOS

Even though there is no single characterization of science relevant to all kinds of scientific endeavours and knowledge, there is an agreement among many concerned parties on the aspects of NOS that need to be addressed in science education (Karakas, 2011). Seven of these aspects are relevant to this study. These characteristics are that "scientific knowledge is tentative, empirically based (based and/or derived from observations of the natural world), subjective (theory-laden), partly the product of human inference, imagination, and creativity (involves invention of explanations), and socially and culturally embedded" (Akerson, Abd-El-Khalick & Lederman, 2000, p. 298).

Akerson and his colleagues' further point out that "two additional important aspects are the distinction between observations and inferences, and the functions of and relationships between scientific theories and laws" (Akerson, Abd-El-Khalick & Lederman, 2000, p. 298).

In the next section, clarification of each of the aforementioned NOS aspects will be discussed.

2.1.2.1 Observations and inferences

Observation and inference are fundamental scientific skills (Liang, Chen, Kaya, Adams, Macklin & Ebenezer, 2009). It is therefore important that a scientifically informed individual should make a distinction between the two constructs (Lederman, 2006). Observations are "descriptive accounts of natural phenomena as directly perceived by the senses or instruments that extend our senses" (Lederman & Lederman, 2004, p. 37). There is usually little controversy among different observers regarding such an account. For example, we can all agree that solids, when heated, change into liquids. Observations are however also often subjective, and thus, themselves flawed, but may become more objective when instrumentation is used to collect data.

On the other hand, the claim that the change of state has to do with particle motion is an inference. Inferences are "interpretations of observations" (Liang, Chen, Kaya, Adams, Macklin & Ebenezer, 2009, p. 991). They go beyond what is "directly accessible to our senses" (Lederman, 2006, p. 304). Inferences such as the particulate nature of matter may overtime become objective observations, such as through atomic field/electron and other microscope that are directly analogous to light-mediated sensory/visual perceptions. Scientific endeavour continually strives to test inferences to bring them to the realm of observations/facts. As a result, most inferences do not remain inferences forever, but become facts. The major question is: should the claims that were initially inferences but were ultimately objectively established, remain inferences when taught in school science?

In line with Bell (2006), this research takes the position that scientific knowledge is developed through making observations and inferences, and that observations provide the empirical base for scientific knowledge.

2.1.2.2 The distinction between scientific laws and theories

The distinction between laws and theories is linked to the distinction between observations and inferences (Bell, 2006; Lederman, 2006; Lederman & Lederman, 2004). Laws are statements that simply "describe or illustrate generalizations, principles or patterns as observed in nature", without offering explanations as to why they occur (McComas, 1998, p. 2). For example, Charles' Law describes a relationship that exists between the two observable events, volume and temperature of a gas at constant pressure (Bell, 2006). Theories are inferential in nature as they are human constructed explanations for the observed regularities (Abd-El-Khalick, 2006; Bell, 2006; Lederman & Lederman, 2004; McComas, 1998). The kinetic particle theory, for example, was postulated to explain observed regularities in the behaviour of matter, including Charles' law (Bell, 2006; Lederman & Lederman, 2004).

The kinetic particle theory explains Charles' law in terms of the energy possessed by the particles that constitute the gas. Both theories and laws are important, but since they have different roles, one being descriptive while the other explanatory, one can never develop into the other (Abd-El-Khalick, 2006; Bell, 2006; Dekkers & Mnisi, 2003; Lederman & Lederman, 2004; Lederman, 2006). Scientific theories are not tentative laws as it is commonly believed by a number of teachers and students. They are instead, "well recognized, highly supported by empirical data, and internally reliable systems of explanations" (Abd-El-Khalick, 2006, p. 403). Abd-El-Khalick further points out that theories explain many different types of observations, and play a very important role in guiding further research.

2.1.2.3 Even though scientific knowledge is empirically based, it also involves imagination and creativity

It is very important that students and teachers should be aware of the fact that all scientific claims are supported by empirical evidence. Empirical refers to that which can be verified by observations of nature (Lederman, 1998; Lederman & Lederman, 2004). Lederman (1998), however, points out that it is also equally important for students and teachers to appreciate that the development of scientific assertions also demands human creativity and imagination. Scientists do not follow a prescribed step by step method when doing their work (Bell, 2006). They however, "use their imagination and creativity throughout their investigations, including creating hypotheses, inventing theories, making predictions, and finding ways to test their ideas" (Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2009,p. 992). For instance, the role of intellectual creativity is clearly witnessed in Niels Bohr's invention of a detailed model of an atom only from the observations of atomic spectral lines. This however does not imply that every proposed explanation is acceptable, but invention of theories by scientists should explain or predict actual observations of the natural world and the current science knowledge base (Lederman & Lederman, 2004; Lederman, 2006).

2.1.2.4 Scientific knowledge is at least partially subjective (theory laden)

Science has often been portrayed as a completely objective endeavour. Scientists are believed to set aside their beliefs and perspectives when making observations, and inferences (Abd-El-Khalick, 1998). Contrary to this view, the history of science indicates that the development of an understanding of natural phenomena is not in actuality free from subjectivity (Bell, 2006; Lederman & Abd-El-Khalick, 1998). The work of scientists which includes the "choice of problems they pursue, the research methodologies they use, the observations and inferences they make are all guided by scientists' prior knowledge, beliefs, training, experiences, and expectations as well as accepted theories in the scientific community" (Lederman & Lederman, 2004, p. 37). These factors create a frame of mind that subsequently influences all their work.

Consistent with the above line of reasoning, Chalmers (1999) states that "what observers see, the subjective experiences they undergo, when viewing a phenomenon is not only determined by the images on the retina, but also depends on the experiences, beliefs, knowledge and expectations of the observer" (p.7).

2.1.2.5 Social and cultural influences

Science, being a human enterprise, is shaped by various cultural factors, within the society in which it is practiced (Lederman, 2006; Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2009). These contextual elements include "politics, socio-economic factors, philosophy, religion, and other factors" (Lederman, 2006, p. 306). Cultural factors, therefore determine the kind of scientific investigations, the manner in which these investigations are carried out, as well as the way collected data is interpreted. It is therefore a misconception to assume that scientific knowledge represents a universal truth that is not socially or culturally bound.

The different theories that have been put forth to explain the evolution of humans are an example of the impact of social and cultural factors on the development of scientific knowledge. One original well accepted theory was centred on the "male hunter and his important role in the evolution of humans" (Lederman & Abd-El-Khalick, 1998, p.21). This view was consistent with the white male culture that ruled science groups until the early 1970s. One recent theory, however, is in line with the feminist approach. Its focal point is on the "female gatherer and her significant contribution in the evolution of humans" (Lederman & Abd-El-Khalick, 1998, p.21).

2.1.2.6 Scientific knowledge is tentative

All the characteristics of science already discussed lead ultimately to an understanding that scientific knowledge is open to revision or subject to change (Lederman & Lederman, 2004). Even though scientific facts, theories and laws have elements of durability and reliability, the history of science reveals that they may be revised or replaced, not only in light of new evidence generated due to technology and theory developments, but also because of existing evidence being reinterpreted with an advanced theory (Lederman & Lederman, 2004; Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2009). The empirical characteristic of scientific knowledge, while partly a reason for the tentative character of scientific knowledge, also counteracts an "anything goes perspective" (Schwarts, Akom, Skyjold, Hong, Kagumba & Huang, 2007, p. 2). It emphasizes that not every idea is valid in science, but only those that can be substantiated by empirical evidence.

The tentativeness of scientific information is mainly based on the fact that none of these ideas (laws, theories, hypotheses and facts) can be proven in the absolute sense. This remains true in spite of the amount of evidence collected in support of an idea. For instance, for a law to be absolutely proven it has to be shown to be true for every case of the phenomenon it describes. It is however not possible to investigate all possible cases, therefore we can never be certain that a law is true in any absolute sense (Lederman, 2006). This is equally true for hypotheses, and theories. Laws are however, the least subject to change because of their lesser dependence on creativity, imagination and inference (Bell, 2006).

The current study was guided by the above discussed aspects of NOS. It is worth mentioning that these NOS ideas are not supposed to be transmitted to students or teachers as declarative statements, rather the focus should be on enabling students to apply them in context (Alchin, 2011; Clough, 2007; Mathews, 1998). This is especially necessary in light of the fact that most of the aspects of NOS are not equally applicable to all contexts (Clough, 2007). For example, Clough points out that there is a reason to believe that certain claims about the natural world have been discovered rather than invented. He therefore highlights that a good understanding of the role of creativity in science necessitates an awareness of the fact that the inventive/discovered character of science may depend on the concept being addressed.

Figure 2.1 shows a concept map that illustrates the characteristics of NOS described above.

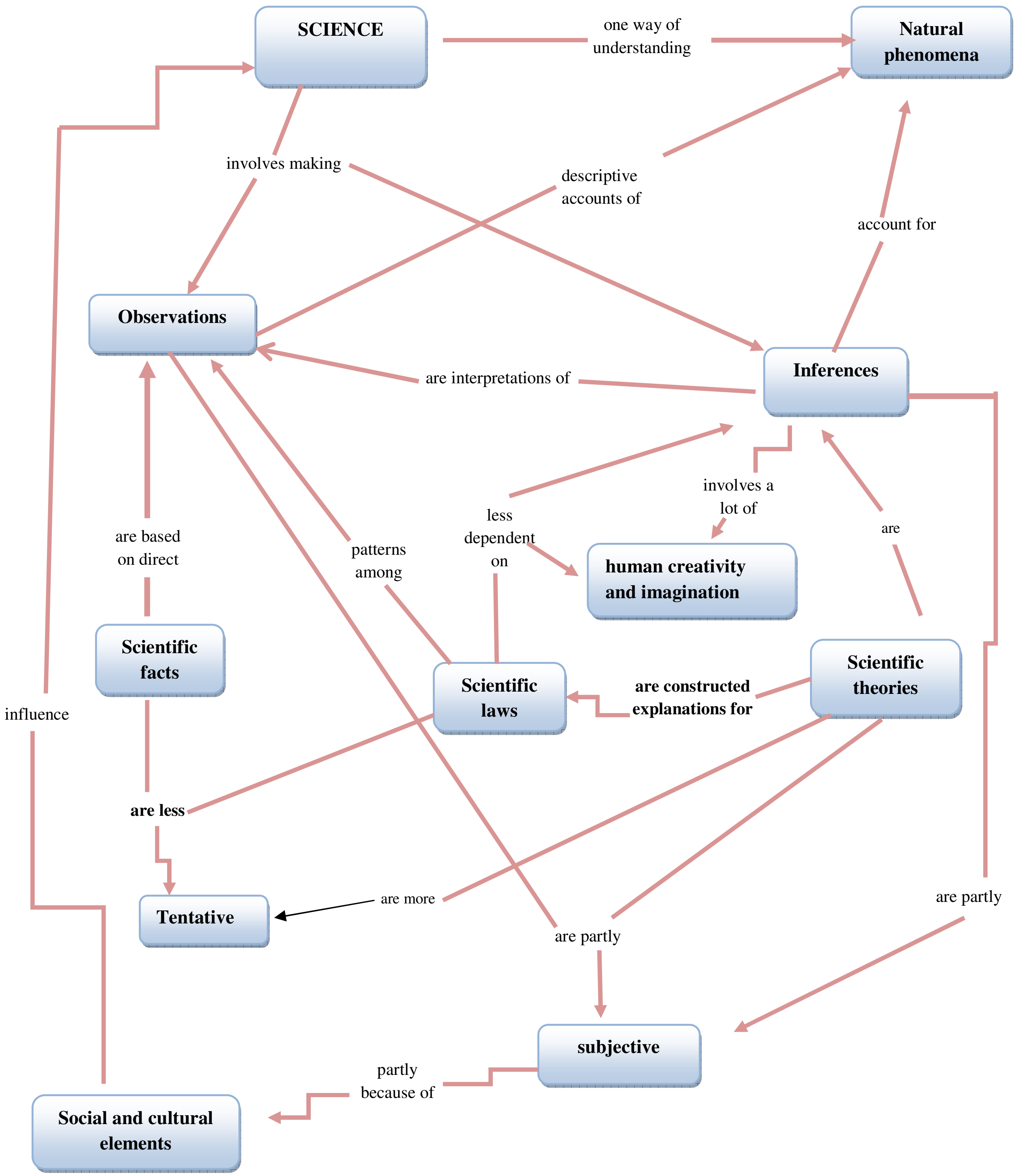

Figure 2.1 A concept map showing characteristics of NOS explored in this study

2.2 Research on teachers' views about NOS

2.2.1 Introduction

Both past and current research has consistently pointed out that students lack contemporary views of NOS (Akerson & Abd-El-Khalick, 2005; Celik & Bayrakceken, 2006; Dawkins & Dickerson, 2003; Dogan & Abd-El-Khalick, 2008; Kang, Scharman & Noh, 2004; Khisfe, 2008; Sahin & Koksal, 2009). The studies revealed many misconceptions held by pre-college students. Students lacked the fundamental understanding of theories as explanations arising from evidence (Dawkins & Dickerson, 2003; Kang, Scharman & Noh, 2004). They believe theories are discovered rather than arising from the creative and imaginative art of scientists. Most of them viewed theories as inferior to laws and also lacked an understanding of the qualitative difference between theories and laws (Dawkins & Dickerson, 2003).

There are many possible causes for students' alternative views about NOS. Among these, are "the language used by teachers in teaching science content, the cookbook nature of many laboratory activities, the textbooks that report the products of science while ignoring how the knowledge was developed, as well as the assessment strategies that focus only on the products of science" (Clough & Olson, 2004, p. 28). Science instruction in most classrooms portrays a positivist view of NOS (Clough, 2006), a view that science is an "objective, step by step value free process of discovering truth about natural phenomena" (Schwartz, Akom, Skyjold, Hong, Kagumba & Huang, 2007, p. 2).

Teachers' conceptions of science are therefore an important factor influencing teachers' classroom practices and consequently students' conceptions (Palmquist & Finley, 1997; Park & Lee, 2009).This claim has been supported by many earlier studies (Brickhouse, 1990; Tobin & McRobbie, 1997). Tobin and McRobbie's (1997) study only revealed minority similarities between the participating teacher's enacted curriculum and some of his beliefs about NOS, but significant similarities between the teacher's and his students' NOS views. A more recent study by Dogan & Abd-El-Khalick (2008) also found that teachers' views were for the most part not better than those of their students. Tsai (2002) also showed interrelationships among teacher beliefs about NOS and their views about teaching and learning science. All this evidence indicates that teachers' conceptions are likely to impact on their classroom practices which may subsequently influence students' views. Despite contradicting evidence pointing towards a lack of correlation between teachers' NOS views and their classroom practices (Lederman, 1999; Mellado, 1997; Mellado, Bermejo, Blanco & Ruiz, 2007; Waters-Adams, 2006), it is an indisputable fact that accurate understanding of NOS is a necessary, although inadequate requirement for addressing NOS in the classroom (Clough, 2006).

Literature has revealed that teacher knowledge, in general, is one of many other conditions essential to enable teachers to translate a curriculum into practice (Leach, Hind & Ryder, 2003; Okhee, Luykx, Buxton & Shaver, 2007). Leach, Hind and Ryder (2003) investigated the impact of a small scale project which designed teaching resources for use by teachers in developing students' conceptions of NOS. The teachers' lack of understanding of the NOS issues addressed hampered the clarity of teaching aims. Students' naive views were reinforced as a result of teachers holding the same misconceptions. It would be necessary, therefore, to find out if Swaziland pre-service teachers have this necessary epistemological understanding to portray a correct image of science to the young citizens.

2.2.2 Teachers' views of NOS

Many studies carried out, both in Western countries (Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick & Lederman, 2000; Lederman, 1992) and in non-western countries (Boo & Hoh, 2006; Buaraphan, 2011; Dekkers & Mnisi, 2003; Dogan & Abd-El-Khalick, 2008; Iqbal, Saiqa & Rizwan, 2009) have revealed that both pre-service and in-service teachers harbour views of NOS that are in conflict with contemporary conceptions of the epistemology of science. This lack of an accurate understanding of NOS has been consistently revealed regardless of the instrument used in the investigation.

Park and Lee (2009) carried out a comparative study of United States and Korean pre-service teachers. Their survey showed that 52% of Korean pre-service teachers, and 38% of the US pre-service teachers harboured a realistic view of scientific knowledge. They believed theories are statements about the natural world "that exist independently of the scientist's perception" (Park & Lee, 2009, p.8). Abd-El-Khalick (2001) found that 60% of the participating pre-service teachers seemed to fit into a broad "scientistic viewpoint". This view holds that scientific knowledge is "not tentative, but certain, objective, and organized into laws" (p, 221). Traditional conceptions of science, therefore, continue to inform most classroom practice in spite of the various calls for students to develop more contemporary views (Schwarts, Akom, Skyjold, Hong, Kagumba & Huang, 2007).

Other studies, however, revealed that most teachers hold mixed views of NOS, meaning that their NOS conceptions do not align with any particular philosophy of NOS (Akerson, Abd-El-Khalick & Lederman, 2000; Dogan & Abd-El-Khalick, 2008; Haidar, 1999; Mellado, 1997; Palmquist & Finley, 1997).

Below is a discussion of these various conceptions of the different features of NOS that have been identified over the many years of NOS research.

2.2.2 1 Observations versus inferences

Studies have consistently revealed that most pre-service teachers do not have an adequate understanding of the difference between observations and inferences. They do not comprehend the role played by inference in the construction of concepts in science (Abd El-Khalick, 2001, 2005; Akerson, Abd-El-Khalick & Lederman, 2000). Abd-El-Khalick (2001) for example, revealed that 60% of the pre-service teachers who participated in his study believed that "scientists were 100% certain about the structure of an atom because they have seen an atom under the microscope" (p. 222). Similarly, 30% of the participants in the same study also argued that there can be many hypotheses explaining the extinction of dinosaurs since there is "no written down or witnessed evidence of what caused the extinction"(p.223). This reveals that the pre-service teachers are uninformed of the role of inference in the development of scientific ideas (Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick & Lederman, 2000; Dekkers & Mnisi, 2003).

2.2.2 2 The relationship between laws and theories

Many studies have revealed that teachers believe that a "hierarchical relationship" exists between theories and laws (Abd-El-Khalick, 2001, p. 225; Abd-El- Khalick, 2005, p. 24; Akerson, Abd-El-Khalick & Lederman, 2000, p. 306; Dogan & Abd-El-Khalick, 2008, p. 1093). They hold the naive notion that theories, once proven, become laws. This indicates a lack of understanding of the fact that theories are well developed scientific constructs, well supported by empirical evidence (Abd-El-Khalick, 2001; Cochraine, 2003; Haidar, 1999; Halai & McNicholl, 2004). It is speculated that this belief is related to language. Theory, in certain cultures such as in the United States of America, is a common everyday expression which means a guess or a possibility (Dekker & Mnisi, 2003; Kang, Scharmann & Noh, 2005). Studies have therefore indicated that most teachers hold inadequate views of the different functional roles theories and laws play and how the two constructs interrelate (Cochrane, 2003).

2.2.2 3 The tentative nature of scientific knowledge

From the literature studied it can be concluded that most teachers correctly believe that scientific claims are susceptible to being modified or replaced (Dekkers & Mnisi, 2003; Dogan & Abd-El-Khalick, 2008; Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2009; Palmquist & Finley, 1997; Park & Lee, 2009). However, most of these teachers hold the view that theories are only modified or replaced in light of new evidence, only a very small number of teachers seem to believe that theories may be changed as a result of a different perspective in the interpretation of already existing data (Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick & Lederman, 2000; Dekkers & Mnisi, 2003; Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2009). Furthermore, some teachers seemed to believe only in the evolutionary change of scientific theories. The study of Dekkers and Mnisi (2003) revealed that only 50% of teachers in the Limpopo province believe theories can be falsified.

Abd-El-Khalick's (2001, 2005) studies indicated that the teachers, who contend that scientific theories change, seemed to wrongly believe that theories are opinions or speculations that become laws once verified. They were seemingly unaware that theories were "highly validated explanations for massive sets of empirical data" (Abd-El-Khalick, 2001, p. 222). The laws, since proven, are believed not to change (Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick & Lederman, 2000; Dekkers & Mnisi, 2003; Dogan & Abd-El-Khalick, 2008).

Some teachers seem to hold the naive view that scientific claims (theories and laws), not just laws, are proven facts, so they cannot change (Abd-El-Khalick, 2005). A sizeable fraction (73%) of the pre-service teachers who participated in Abd-El-Khalick's (2005) study seemed to hold this view. This could be a result of the way science was presented in their science lessons at school and/or in their teacher training programmes. Based on the assumption that teachers' NOS conceptions affect their classroom practice, these teachers are likely to present science to their students "as a body of absolute truth, instead of a creative work of scientists, making use of the methods of inquiry" (Palmquist & Finley, 1997, p.596).

2.2.2 4 The empirical and creative NOS

Most studies have shown that many teachers do not have a clear understanding of the element of imagination and creativity in the whole process used by scientists to generate scientific constructs (Abd-El-Khalick, 2001, 2005; Dekkers & Mnisi, 2003; Liang, Chen, Kaya, Adams, Macklin & Ebenezer, 2009). Teachers tend to believe that scientific knowledge is derived from the analysis of empirical data alone. Some of the teachers, who show an awareness of the involvement of inventiveness and imagination in science, believe scientists use these skills only when they are "designing experiments, collecting data, and/or making science interesting to the general public" solving problems, in the invention of equipment that help scientists in their investigations" (Akerson, 2001, p. 223; Akerson, 2005, p. 25; Akerson, Abd-El-Khalick & Lederman, 2000, p. 307). Some South African teachers revealed an unusual understanding of creativity. They use the term to mean "practical or improvisation skills" (Dekkers & Mnisi, 2003, p.29).

Liang, Chen, Chen, Kaya, Adams, Macklin and Ebenezer (2009) assert that participants who view science as a matter of following a universal method are less likely to believe in the involvement of creativity and imagination in the development of scientific knowledge. Liang and his colleagues base this assertion on their findings that indicated a relationship between participants' belief in "a step-by-step scientific method" (p.1004) and the view that creativity and imagination does not have a role in science. Indeed, in some qualitative studies, participants articulated that scientists do not use creativity and imagination in their work as this could compromise the "perceived objectivity of the scientific endeavour which is believed to be achieved by following systematic scientific methods" (Abd-El-Khalick, 2001, p. 223; Akerson, Abd-El-Khalick & Lederman, 2000, p. 308). This is believed to be a result of the verification approach followed in many traditional science classrooms and textbooks that have reduced scientific investigations to a list of steps to be followed (Clough, 2006; Clough & Olson, 2004; Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2009; McComas, 1998; Park & Lee, 2009). Such an approach also reveals scientific knowledge as arising solely from collected evidence (Kosso, 2009; McComas, 1998).

2.2.2.5 The theory-laden nature of scientific knowledge

Many pre-service teachers hold the misconception that scientists are particularly objective, and therefore would always make the same observations and/or inferences of the same phenomenon (Dekkers & Mnisi, 2003; Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2009; Tsai, 2006). This is mainly because they are uninformed of the theory laden nature of observations and inferences (Chen, 2006; McComas, 1998). Liang, Chen, Chen, Kaya, Adams, Macklin and Ebenezer's (2009, p.997) study found that 51% of Chinese pre-service teachers who participated in the study considered "observations as facts", signifying complete objectivity of the observation process. Sixty three percent of Taiwanese pre-service teachers and 69% of in-service teachers held similar views (Tsai, 2006). Twenty one percent of the South African's participants in Dekkers and Mnisi (2003) were however evidently aware of the theory laden nature of scientific knowledge. They articulated clearly that "different interpretations of data are due to subjectivity in science" (p.27). These participants pointed out that prior knowledge and hypothesis held by scientists affect their interpretation of data.

The review, however, indicates that teachers, in general, do not view the scientific enterprise as being influenced by any kind of human perspective (Tsai, 2006).

2.2.2.6 Social and cultural influence

Many teachers hold the view that the scientific endeavour is independent of culture and social context. Consequently, scientific knowledge is assumed to be universal truths or facts (Abd-El-Khalick, 2001, 2005; Akerson, Abd-El-Khalick & Lederman, 2000; Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer 2009; Park & Lee 2009; Tan & Boo, 2004). Fifty eight percent of Turkish pre-service teachers were shown to believe in one universal method of scientific research and 62 % also believed that scientists are trained to be particularly objective and not to allow any kind of prejudice to affect their work. A similar proportion (64%) of American participants shared a similar perspective (Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2009).

In emphasis of this overly objective perspective of science, one participant in Abd-El-Khalick's (2001) study pointed out that "religion and philosophy can accommodate opinions and beliefs; science however, has no room for points of views or personal subjective opinions, but with truth" (p. 222). Akerson, Abd-El-Khalick and Lederman, (2000) as well as Dekkers and Mnisi (2003) also revealed such an opinion among pre-service and in-service teachers respectively. The majority of both groups of participants attributed the possibility of two scientists coming with different conclusions out of the same data to a deficiency of the evidence and did not reveal any idea of possible cultural or social influences on data interpretation.

Park and Lee (2009, p.6) describe some of the Korean participants as having mixed views regarding the influence of social and cultural factors on the work of scientists. For example, one respondent believed the "economic value of scientific research" can impact on the investigations that scientist choose to carry out, but argued that this is not a universal characteristic of all scientists; "it all depends on people and their situation".

2.3 Developing pre-service teachers' understanding of NOS

2.3.1 Introduction

As a result of the empirical evidence confirming the speculation that teachers do not have adequate contemporary views of NOS, several efforts have been made to improve both pre-service and in-service teachers' NOS conceptions. Such attempts started only a few decades ago, and most of them have proved to be ineffective in developing teachers' deep understanding of NOS that will enable them to teach it in their own classrooms (Abd-El-Khalick, 2005).

2.3.2 Earlier attempts of improving teachers' conceptions of NOS

Such attempts began in the early 1960s with the investigation of the impact of existing intervention programmes, such as summer and academic year institutes funded by the National Science Foundation (NSF), on teachers' NOS views. Summer and academic year institutes are teachers' workshops and seminars offered annually to explore certain educational topics such as NOS. Some of these studies were carried out by Grubber (1960, 1963) and Welch and Weleberg

(1967, 1968 (all cited in Abd-El-Khalick & Lederman, 2000a). Gruber (1963) assessed the impact of an NSF summer institute aimed at augmenting the teachers' NOS conceptions. His study employed a survey of 314 participants. Consistently with the rest of the aforementioned studies, the findings indicated that such attempts were not significantly effective in enhancing teachers' NOS views (Abd-El-Khalick & Lederman, 2000a; Lederman, 2007).

In another attempt to enhance teachers' views of NOS several other studies investigated a number of background and academic factors that were considered related to NOS understanding (Billeh and Hasan, 1975; Carey & Strauss, 1968, 1970; Lavach, 1969; Scharman, 1988a, 1988b) (all cited by Lederman, 2007).These variables included "science teachers' content knowledge, science achievement, academic achievement, subjects taught, teaching experience, teaching level, as well as other cognitive abilities such as logical thinking; quantitative aptitude, verbal aptitude, and personal attributes such as gender" (Abd-El-Khalick & Lederman, 2000a; Lederman, 2007). None of the studies, however, reported a significant relationship between teachers' NOS conceptions with any of these variables. Based on this information, it was generally presumed that none of these variables could be used to enhance teachers' views of NOS.

The observed lack of relationship between participant teachers' background and academic factors and their understanding of NOS concur with findings of more recent studies (Akerson, Abd-El-Khalick & Lederman, 2000; Dogan & Abd-El-Khalick, 2008). Akerson, Abd-El-Khalick and Lederman (2000) did not find significant differences between undergraduate and graduate participants. Dogan and Abd-El-Khalick (2008) carried out a survey study among Turkish Grade 10 students and teachers, and found that teachers' NOS conceptions did not correlate with their "disciplinary background, teaching experience, and the type of teacher education programme". Dogan and Abd-El-Khalick (2008) argue that all the above experiences, including teacher programmes, do not provide teachers with structured and critical reflections to examine their views of NOS.

Moreover, teachers' graduate degree level may impact negatively on teachers' NOS views (Dogan & Abd-El-Khalick, 2008). Dogan and Abd-El-Khalick (2008) observed that teachers' NOS views became more naive as they advanced from BSc to a PhD degree in the science discipline. The researchers concluded that probably teachers' views of NOS become more erroneous with further specialization in sciences. This finding cannot however be generalized, as the quality of post-baccalaureate programme in the sciences in Turkey may be different from that of other countries with more advanced, research based doctoral scientific training (Dogan & Abd-El-Khalick, 2008). It is possible that a similar picture may be found in a developing country such as Swaziland.

In contrast to the aforementioned studies, Morrison, Raab and Ingram (2009) found that secondary school teachers, who had more academic science training had more informed understanding of NOS than elementary and middle school teachers. This, however, being a report of findings of just one study so far, cannot be used as a base for any attempts of enhancing teachers' NOS views.

2.3.3 Implicit versus explicit approaches

As a result of the failure of the aforementioned strategies, science educators began to think of other strategies that could be used to augment teachers' NOS views. Figure 2.2 below gives a summary of the different approaches and contexts that have been used to teach NOS.

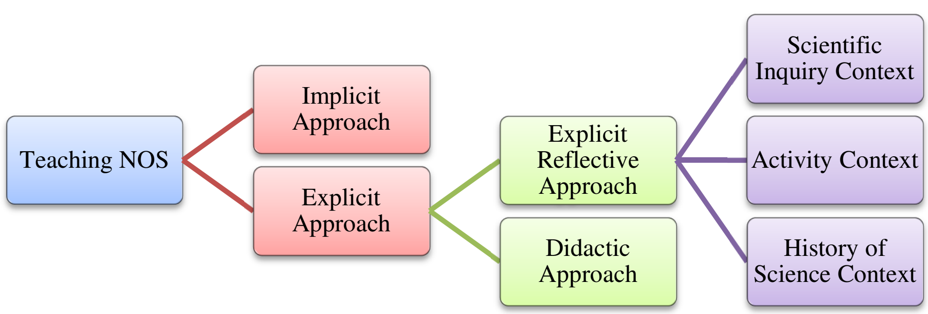

Figure 2.2 Different approaches to teaching NOS

Generally two approaches have been and are still being applied to develop both students and teachers' understanding of NOS. Earlier interventions aimed at improving pre-college and teachers' NOS views were labelled as implicit. The implicit approach was promoted by science educators such as Gabal, Rubba and Franz (1977) and Rowe (1974) (all cited in Lederman, 2007).

The implicit approach is based on an assumption that the development of NOS views is an affective objective that can be achieved through engaging students in science practical activities or in learning science content without any attempt to overtly address NOS issues (Abd-El-Khalick & Lederman, 2000a; Lederman, 2007). Studies that made use of this approach in an attempt to enhance pre-service teachers' views include those of "Barufuldi, Bethel and Lamb (1977), Riley (1979), and Trembath (1972)" (all cited in Akerson, Abd-El-Khalick & Lederman, 2000, p.297). These studies made use of "process skills instruction and/or scientific inquiry activities", without any explicit discussion of NOS issues inherent in the activities (Abd-El-Khalick & Lederman, 2000a, p.673; Akerson, Abd-El-Khalick & Lederman, 2000, p.297).

Trembath (1972 cited in Lederman, 2007) investigated the impact of a programme that was aimed at developing pre-service elementary teachers' understanding of NOS. The focus of the programme was on enhancing the participants' understanding of the development and testing of hypotheses, and the structure and functions of theories and laws. The pre-service teachers were presented with a set of narratives to read. They were subsequently required to formulate hypotheses, predictions or inferences based on these narratives. There was no explicit discussion about NOS tenets. Trembath (1972 in Lederman, 2007) reported a significant difference in NOS gains for the experimental group even though the score actually "increased from 7.0 to 10.7 points out of a total of 18 points" (Lederman, 2007, p.847). According to Lederman (2007), this cannot be described as a satisfactory gain that can warrant the use of this implicit approach in developing NOS conceptions.

Another study was carried out by Barufaldi, Bethel and Lamb (1977 cited in Lederman, 2007) who investigated the impact of an elementary methods course on elementary education majors' comprehension of the tentative NOS. Participants were engaged in many hands-on activities and inquiry oriented science experiences aimed at providing them with opportunities to implicitly understand the fact that scientific findings are subject to change. Based on Barufaldi, Bethel and Lamb's (1977) belief that NOS conception is an affective, rather than a cognitive outcome, no attempts were made to explicitly address NOS issues. Lederman (2007) argues that even though Barufaldi, Bethel and Lamb (1977) reported that the hands on approach integrated with problem-solving were effective in enhancing pre-service teachers' views, the reflected gains do not represent a significant growth in participants' appreciation of the provisional character of scientific constructs.

The results of the studies already discussed and many other more recent studies (Abd-El-Khalick & Lederman, 2000a; Khisfe & Abd-El-Khalick, 2002; Lederman, 1992; Moss, 2001) point out that the implicit approach is not very beneficial in augmenting teachers' conception of NOS.

The second approach described as explicit was advocated by science educators such as "Billeh and Hasan (1975), Hodson (1985), and Lavach (1969)" (Akerson, Abd-El-Khalick & Lederman 2000, p.297). These educators believe that understanding the character of science can only be achieved when the teacher makes teaching NOS issues a learning target, instead of "leaving them to emerge implicitly through engaging students in doing science" (Abd-El-Khalick & Lederman, 2000a, p. 690). Advocates of this approach therefore emphasize that NOS learning conceptions should be tackled in the same way as any other cognitive objective; they ought to be "planned for in a way that draws participants to important NOS issues when learning science" (Clough, 2006, p.466)

The explicit approach was initially used by "Akindehin (1988), Billeh and Hasan (1975), Carey and Strauss (1968, 1970), Lavach, (1969), and Ogunniyi (1983)"(all cited in Akerson, Abd-El-Khalick & Lederman 2000, p.297; Lederman, 2007, p. 852). These researchers used either "elements of the history of science (HOS), and philosophy of science (POS)" with or without instruction specially aimed at explicitly addressing various aspects of the NOS (Abd-El-Khalick & Lederman 2000a, p. 297). Review of such studies revealed that any kind of NOS instruction aimed at explicitly addressing NOS issues is more effective in improving participants' understanding of NOS in comparison to the implicit approach (Abd-El-Khalick & Lederman 2000a; Akerson, Abd-El-Khalick & Lederman 2000; Lederman, 2007).

Carey and Strauss (1968, 1970 in Abd-El-Khalick & Lederman, 2000a) carried out two parallel quantitative studies investigating the impact of an explicit NOS instruction incorporated in a secondary science methods course on the teachers' understanding of NOS. The science teachers received explicit NOS instruction through reading history and philosophy of science related articles. Throughout the rest of the course, participants were asked to discuss how the activities they were engaged in were in line with the NOS conceptions introduced in the course. Both of the studies indicated significant gains in participants' NOS understanding as indicated by the Wisconsin Inventory of Science Processes (WISP) (Abd-El-Khalick & Lederman, 2000a).

A more recent comparative study by Murphy, Kilfeather and Murphy (2007) has provided further and more convincing evidence of the superiority of the explicit approach. Their study involved 148 prospective elementary teachers. The participants were divided into two groups: the experimental and the control groups. Both groups were engaged in hands on activities where process and inquiry skills were developed. However, the experimental group was also explicitly instructed on certain aspects of NOS. The results of the study indicated that both groups had developed more elaborate and contemporary views of NOS after instruction. However, the experimental group developed significantly more elaborate and contemporary views than the control group.

Clough (2006), emphasizing the relative importance of the explicit compared to the implicit approaches, points out that if school science content instruction did not involve both activities as well as teachers' intention to help learners make sense of the activities, students' understanding of the science content would be poorer compared to other groups where a teacher helps them develop understanding of the same content. He therefore argues that discovery learning is not an effective strategy to develop understanding of both science content as well as NOS.

2.3.4 Explicit reflective approaches

It has been recommended that the explicit approach should be enhanced by incorporating a reflective component (Abd-El-Khalick, Bell & Lederman, 1998; Khisfe & Abd-El-Khalick, 2002). The reflective approach allows students tomake their own connections between learning activities and targeted NOS aspects rather than a didactic approach; where the instructor informs scholars how each NOS characteristic is applicable to a particular context (Akerson, Hanson & Cullen, 2007; Clough, 2006; Donovan-White, 2006). The explicit reflective approach has been used successfully to boost pre-service teachers' views of NOS (Abd-El-Khalick, 2001, 2005; Abd-El-Khalick & Akerson, 2009; Akerson, Abd-El-Khalick & Lederman, 2000; Cochraine, 2003; McDonald, 2010).

Abd-El-Khalick and Akerson (2009) assert that the explicit label is curricular, meaning that NOS must be included in the science course as an independent topic, while reflection implies an instructional approach. Reflectively teaching NOS refers to an instructional approach that helps students make connections between the activities they are experiencing and targeted NOS issues (Akerson, Hanson & Cullen, 2007; Clough, 2006). This include making use of "discussion, guided reflection, and specific questioning in the context of activities, investigations, historical examples, and other science education experiences intended to improve students' conceptions of NOS" (Cochraine, 2003, p. 6).

2.3.4.1 Different contexts for NOS instruction

Different studies have utilised different contexts for the development of teachers' NOS views. Context refers to the learning experiences that acts as a basis upon which students can reflect upon NOS aspects (Lederman, 2007). The different contexts are discussed below:

Developing NOS views within a scientific inquiry context

During a science research internship course, Schwartz, Lederman and Crawford (2004) studied the impact of authentic scientific inquiry activities in developing pre-service secondary science teachers' views of NOS. The internship course also incorporated explicit NOS instruction and guided reflections. Participants, as a result of the intervention developed deeper coherent conceptions of a number of NOS aspects. The researchers assert that the authentic research experience on its own had little impact on the participants' NOS views; it was rather the addition of the explicit and guided reflection that played a major role in developing their understanding. This study is consistent with other studies that utilized a scientific inquiry context to develop NOS views (Bell, Blair, Crawford & Lederman, 2003; Khisfe & Abd-El-Khalick, 2002; Morrison, Raab & Ingram, 2009).

Morrison, Raab and Ingram (2009) studied the impact of a professional development programme making use of an explicit, reflective NOS instruction within a context where teachers were exposed to the practices and techniques fundamental to scientific research, on elementary, middle, and secondary teachers' views of NOS. Teachers were also involved in one-to-one discussions about science with scientists. The elementary and middle teachers' NOS views were enhanced. They cited the explicit reflective NOS instruction as one of the factors that contributed most in affecting their views.

In agreement with Schwartz, Lederman and Crawford's (2004) and Morrison, Raab and Ingram's (2009) findings, Bell, Blair, Crawford and Lederman (2003) observed that students who were involved in an authentic scientific inquiry did not improve in their NOS views in the absence of the explicit reflective instruction. They state that the participating students only appeared to have gained knowledge about the processes of scientific inquiry; their understanding of NOS remained the same. They also pointed out that reflection appeared essential, as was indicated by a single participant who was able to make significant gains in her understanding of NOS. This student was able, on her own, to reflect on the relationship between the work of her apprenticeship and knowledge generation in science.

Lederman and Lederman (2004) concur that some learners might "independently reflect on what they are doing and come to understand some aspects of the nature of scientific enterprise"; they, however, quickly point out that it is an obvious fact that "most students do not learn NOS simply by doing science" (p. 39). Students and teachers need to be guided to deliberate on NOS issues in the context of all activities they are engaged in. This is critical in developing their conception of the "abstract and complex nature of the scientific inquiry" (Bell, Blair, Crawford & Lederman, 2003, p. 504).

Using the History of Science (HOS) as a context for developing NOS conceptions

Some other studies embedded NOS instruction within history of science episodes (Lin & Chen, 2002; Rudge, Geer & Howe, 2007). This approach may engage students in reading about key events from the HOS, and/or past noteworthy investigations. This approach differs from an implicit approach because the instructor makes use of the particular historical context to overtly guide students to targeted NOS aspects, such as discussing the provisional nature of scientific theories, after learning about the historical development of the atomic model (Bell, Lederman & Abd-El-Khalick, 2000).

HOS episodes present valuable contexts for enhancing students' and teachers' views of NOS (Kim & Irving, 2010). Moreover, historical studies can also play a motivational role as teachers and students "share the experiences and excitement of early scientists in the process of creating scientific knowledge" (Yip, 2006, p. 165). Several other studies have also provided further empirical evidence supporting this claim (Lin & Chen, 2002; Rudge, Geer & Howe, 2007; Yip, 2006).

Yip (2006) carried out a small scale study aimed at determining the impact of teaching history of science (HOS) on 36 in-service science teachers' understanding of NOS. Teachers made significant gains in their NOS understanding as a result of the intervention. They developed more informed conceptions of the role of hypotheses, theories and laws. However, some participants still considered a scientific law as a theory after the intervention. Yip speculated that this could be caused by the inconsistent use of the term 'law' in the literature. With respect to Boyle's Law and the law of gravity, it refers to the "generalisation of the relationship between different variables"; however, with Mendel's Laws of inheritance, it refers to the "hypothetical or theoretical suggestions constructed to explain observations in genetic crosses" (Yip, 2006).

Lin and Chen (2002) also presented evidence supporting the contention of the effectiveness of the HOS in promoting NOS conceptions. The intent of the study was to explore the impact of teaching chemistry through history on pre-service secondary teachers' NOS conceptions. The results indicated that the group that was exposed to the intervention gained more NOS conceptions than the control group.

Using activities as context for developing NOS views

Several studies have revealed that an explicit reflective-activity-based approach to NOS instruction, carried out in a context of science content or methods course can enhance pre-service primary teachers' conceptions of NOS (Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick & Lederman, 2000; Cochraine, 2003; Kattoula, 2008; Kukuk, 2008). Such studies made use either of contextualised or content embedded activities such as the study by Abd-El-Khalick (2001) or de-contextualised or generic activities, such as Akerson, Abd-El-Khalick and Lederman's (2000) study as contexts for the explicit reflective treatment of NOS.

Akerson, Abd-El-Khalick and Lederman (2000) assessed the impact of a set of de-contextualised activities designed by Lederman and Abd-El-Khalick (1998) on primary educators' views of

NOS. The activities were used to address seven targeted NOS aspects. Participants included equal numbers of undergraduate and postgraduate pre-service elementary teachers who were enrolled in two sessions of a science methods course. The results of the study indicate that participants made significant gains in several targeted NOS aspects. However, these gains varied across the NOS aspects. This is consistent with results of subsequent studies (Abd-El-Khalick, 2001, 2005). Participants improved substantially in their understanding of the "tentative, creative, imaginative NOS, the distinction between observation and inference", as well as the "functions of, and relationship between theories and laws". There were fewer gains in their conceptions of the "subjective (theory laden), and social and cultural NOS" (Akerson, Abd-El-Khalick & Lederman 2000, p.312).

Misconceptions about the subjective, social and cultural NOS seem to be more difficult to change, as Abd-El-Khalick (2005) obtained findings that were similar to Abd-El-Khalick (2001) study. Abd-El-Khalick's (2005) study also found that changes in pre-service teachers' views regarding the aforementioned aspects of NOS were less pronounced compared with the rest of the aspects. Kukuk's (2008) study, however, provides a different picture as the number of Turkish elementary pre-service teachers who held the "subjective, social and cultural NOS ideas increased from 16% to 91%" (p.34) as a result of an activity based reflective explicit instruction. This was the highest gain in understanding compared to the rest of the targeted NOS aspects. These differences in participants' gains in NOS understanding as a result of similar interventions may indicate a possible influence of participants' world view and cultural factors on the development of NOS conceptions. It is worth finding out how the activity-based explicit reflective instruction will impact on Swaziland pre-service elementary teachers' ideas of NOS.

2.4 Factors affecting pre-service teachers' development of informed NOS views within an explicit reflective approach

A review of literature on the improvement of educators' conceptions of NOS has revealed several contextual and personal factors that are likely to have a bearing on pre-service teachers' gain of more informed NOS views in the context of an explicit reflective NOS instruction. These can be characterized as contextual or personal factors.

2.4.1 Contextual factors impacting on NOS development

Explicit reflective NOS instruction is usually categorized as either contextualized or de-contextualized according to the type of context and the degree to which it is embedded in a context. This characteristic of NOS instruction may have an influence on pre-service teachers' learning of NOS (Clough, 2006) as well as on their ability to translate their understanding to other contexts (Abd-El-Khalick, 2001).

Figure 2.3 provides the different types of contexts that have been shown by previous studies to affect pre-service teachers' learning of NOS.

De-contextualised instruction normally involves engaging pre-service teachers with various generic (not content specific) activities that give them an opportunity to explicitly and reflectively examine the relevant NOS aspects (Lederman & Abd-El-Khalick, 1998). A good example of such generic activities is the black-box activities used to simulate how scientists work. Students study a 'phenomenon' and eventually construct a model to explain how it works. The activity involves students in the same processes used by scientists, such as "collecting data through making observations, drawing inferences, suggesting hypotheses to explain the data, and making predictions that they test in order to test their hypotheses" (Lederman & Abd-El-Khalick, 1998). One advantage of this approach is that it is not complicated by science content (Akerson & Donnelly, 2009; Clough, 2006). Such an approach however, may not be seen by pre-service teachers as representing real science (Clough, 2006).

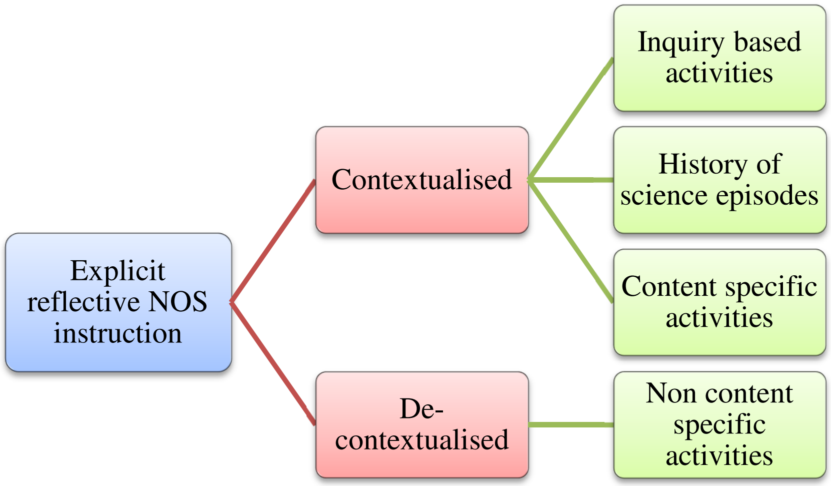

Figure 2.3 Contextual factors influencing NOS learning

Contextualised instruction makes use of history of science or inquiry-based activities within the science content being taught to develop teachers' understanding of NOS (Abd-El-Khalick, 2002; Akerson & Donnelly, 2009; McDonald, 2008). It is believed that such approaches provide a better environment for the development of learners' NOS views. Ryder and Leach (2008) contend that a variety of content areas may be necessary to advance an appropriate understanding of the epistemology of science.

Moreover, some of the NOS ideas are actually context-bound, meaning that they are more relevant in some contexts than others. The theory about the extinction of dinosaurs, for example, is a more appropriate context of the tentative NOS than the claim that the earth is flat (Elby & Hammer, 2001). Providing an appropriate context to develop a specific NOS aspect, therefore, seems necessary. The subjective, social and cultural NOS factors in the generation of scientific knowledge may be conveyed more effectively when highly and extensively contextualised, such as making use of historical case studies to illustrate the development of some scientific construct or discipline (Abd-El -Khalick, 2005; Akerson, Abd-El-Khalick & Lederman, 2000).

The elementary pre-service teachers who participated in Abd-El-Khalick's (2001) study, where NOS instruction was embedded in a physics content course, were more able to expound their newly learnt NOS ideas within familiar context issues that they had covered in the course as compared to less familiar contexts. This confirms and justifies pre-secondary teachers' allegations that the NOS activities embedded in science methods course is not very useful in enabling them elucidate NOS issues in their teaching (Akerson, Abd-El-Khalick & Lederman, 2000). Abd-El-Khalick (2001) therefore contemplates that learning NOS explicitly within a science content course is probably more effective in helping teachers convert their NOS understanding into instructional practice than in science methods courses.

In light of the aforementioned advantages and disadvantages of the contextualised and de-contextualised approaches, Clough (2006) advocates the use of both contextualised and de-contextualised approaches in developing learners' conceptions of NOS. He asserts that the use of de-contextualised instruction to introduce students to targeted NOS aspects, followed by contextualised instruction may provide learners with opportunities to modify their NOS views. As a result, many of the research studies aimed at developing pre-service teachers' views of NOS have made use of this approach (Abd-El-Khalick, 2005; Akerson, Abd-El-Khalick & Lederman, 2000; Bell, Lederman & Abd-El-Khalick, 2000). All these studies provided evidence supporting Clough's (2006) contention of scaffolding learners' views by first using de-contextualised followed by contextualized NOS instruction.

2.4.2 Personal factors impacting on NOS development

Several studies have revealed that pre-service teachers' development of NOS is influenced by a number of personal factors. Below is a discussion of these factors.

2.4.2.1 Perception of the importance of learning and teaching about NOS

Effective NOS instruction should help pre-service teachers appreciate the value or significance of teaching and learning about NOS. This assertion is based on studies that have indicated that there is a relationship between pre-service elementary teachers' development of informed NOS views and their understanding of the importance of teaching about NOS (Abd-El-Khalick & Akerson, 2004; Akerson & Donnelly, 2008; McDonald, 2010; Schwartz, Akom, Skjold, Hong, Kagumba & Huang, 2007). NOS conceptions of participants who believed that learning and teaching about NOS was important improved more than those who did not hold such a view. Abd-El-Khalick and Akerson (2004) therefore concluded that an "internalisation of the importance of teaching about NOS plays a significant role in motivating teachers to critically examine and revise their NOS view" (p.802).

Schwartz, Akom, Skjold, Hong, Kagumba and Huang, (2007) found that teachers' internalization of NOS as an important learning outcome was related to their dedication to becoming a better science teacher, as well as values and perceptions of science teaching and learning. They therefore assert that teachers' appreciation of learning and teaching NOS can be investigated by making use of questions such as: what science should I teach, how, and why should I teach my students? In agreement with this assertion, Southerland, Johnston and Sowell (2005) found that teachers' realization of the 'fruitfulness' of NOS in their classroom was linked to their view of science as an enterprise. They noted that teachers, who viewed science mainly as a product, and learning as a process of receiving information, did not view NOS as important for their teaching.

Southerland, Johnston and Sowell's (2005) study corroborates that of Tsai (2002) who also found that there is a connection between teachers' NOS views and their views about learning and teaching science. Teachers who held an empiricist or logical positivist view of science tended to view teaching as a process of transmitting established knowledge to students whilst learning is a process of reproducing knowledge. Similarly, teachers who held a constructivist view of science; a view of science as a way of making sense of natural phenomena expressed more constructivist view of teaching and learning science as well.

Tsai (2002) described these matching views as nested epistemologies. Mellado, Bermejo, Blanco and Ruiz (2007) provide further evidence in support of this relationship. A prospective teacher's relativist view of NOS was found to closely link with her constructivists views of teaching and learning. Tsai (2002, p.779) also found that these "nested epistemologies tend to increase with years of teaching experience". It would be interesting to find out if the relationship among these epistemologies would be observed among the Swaziland pre-service teachers, most of whom do not have much experience in teaching.

2.4.2.2 Participants' prior NOS conceptions

Firstly, in accordance with the constructivist view of learning, participant's prior conceptions of NOS could act as a barrier to new learning, and therefore some NOS researchers have suggested that participants must first be given an opportunity to examine their alternative views of NOS, at the beginning of an intervention so they can "experience cognitive dissonance regarding their NOS views" (Akerson, Abd-El-Khalick & Lederman, 2000, p.313). According to constructivism, this is necessary to bring about accommodation (Abd-El-Khalick & Akerson, 2004; Akerson, Abd-El-Khalick & Lederman, 2000; Ryder & Leach, 2008; Shapiro, 1996).

In addition to the explicit reflective approach, pre-service teachers must therefore be presented with plenty of occasions to examine their NOS views and to reconcile these NOS views with the various aspects of the nature of the scientific enterprise. The above contention was supported by Abd-El-Khalick and Akerson (2004). As a result of an intervention that integrated the explicit reflective NOS instruction within a conceptual change framework, significant gains in pre-service teachers' NOS understandings were realized. Within this conceptual framework, more importantly, discussion of students NOS ideas was made one of the major goals of the classroom discourse. This was aimed at offering students with occasions to judge their NOS conceptions, in relation to the contemporary NOS view framework. Moreover, the validity of their NOS views was overtly discussed by providing them opportunities to model and justify their NOS ideas. Abd-El-Khalick and Akerson (2004, p.792) contend that "discussion of the status of intelligibility, plausibility and fruitfulness of NOS ideas is essential to ensure conceptual change".

2.4.2.3 Perceived previous knowledge about NOS

Some studies have indicated a relationship between pre-service teachers' perceived previous knowledge about NOS and their development of more informed NOS views (McDonald, 2010). McDonald's (2010) study indicated that pre-service teachers who pointed out that they had never been exposed to NOS issues prior to the programme were able to make more advances in their NOS development, than those who believed they already knew about NOS. This suggests that discernment of one's lack of knowledge of NOS plays a role in motivating the pre-service teacher to deeply engage with the NOS subject matter. This factor is closely related to Posner, Strike, Hewson and Gertzog's (1982) assertion that students need to be dissatisfied with their prior ideas in order to experience conceptual change.

2.4.2.4 Learning dispositions and related epistemic beliefs

Teachers' learning dispositions and related epistemic beliefs have also been shown by some studies to influence their learning about NOS (Abd-El-Khalick & Akerson, 2004; Akerson & Donnelly, 2008; Akerson, Morrison & McDuffie, 2006; Schwartz, Akom, Skjold, Hong, Kagumba & Huang, 2007; Southerland, Johnston & Sowell, 2005). Learning NOS is considered conceptual change as learners' prior views are usually at odds with the target views. One's inclinations towards thinking and learning and "beliefs about the nature of knowledge, knowing and learning" (Rebich and Gautier, 2005, p.356) has a bearing on one's ability to engage with the NOS material and consequently on his or her ability to achieve conceptual change (Rebich & Gautier, 2005; Southerland, Johnston & Sowell, 2005).

These learning tendencies and epistemic beliefs are cognitive and developmental in nature (Rebich & Gautier, 2005; Sherry, Southerland & Enderle, 2012). Abd-El-Khalick (2001) observed that some pre-service teachers' NOS views tend to shift from a pre-instruction scientistic to a post-instruction naive relativism, where any idea is acceptable, instead of the targeted relativism view. Students' realization of the indefinite nature of scientific knowledge made them shift from believing in science towards adopting the naive view that scientific knowledge is "someone's opinions about what is going on in the natural world". When these students' feelings about the tentative NOS were probed, the interviewees expressed a discomfort with ambiguity. This may suggest that these students were most probably at the absolutist stage of their "beliefs about the nature of knowledge; a view that knowledge is absolute, certain and non- problematic, right or wrong" (Rebich & Gautier, 2005, p.356).

Akerson, Morrison and McDuffie's (2006) study also revealed that there is a correlation between pre-service teachers' retention of NOS and their cognitive developmental levels as measured using Perry's scheme. Perry's scheme is a system that describes how adult cognition develops and relates it with different learning styles. Akerson, Morrison and McDuffie (2006) construe therefore that pre-service teachers at higher positions of the Perry's developmental scheme, a position where they understand all knowledge to be contextual and relative were more likely to retain their newly learnt NOS ideas. They also assert that adult learners at the higher levels of cognition development have also developed a metacognitive consciousness of their own thinking, are able to accept ambiguity and tentative answers, and are probably more likely to exercise a stronger commitment to the newly learnt ideas which consequently explains why they are more likely to retain their learnt NOS ideas.

Metacognition refers to the "self-conscious ability to reflect on, control, and understand one's own learning and cognition" (Schraw & Dennison, 1994, p.460). Akerson, Morrison and McDuffie (2006) therefore, contend that learners must be engaged in activities where they can think, apply and reflect upon the results of using the newly learnt NOS ideas in order to help them retain them. This line of thinking corroborates Abd-El-Khalick and Akerson's (2004) findings that pre-service teachers who searched for precise meanings of the various key NOS concepts and applied them consistently in all contexts, and who also monitored their changes in their NOS understandings were able to develop more informed NOS views.

A recent study by Abd-El-Khalick and Akerson, (2009) has shown that training in metacognitive strategies can indeed significantly enhance the usefulness of an explicit- reflective NOS instruction in developing pre-service primary educators' conceptions of the epistemology of science. Metacognitive strategies that can be used to enhance pre-service teachers' NOS views include the use of concept maps to follow denotations of crucial NOS terminologies and the different contexts where such meanings can be correctly ascribed, as well as co-teaching NOS ideas to peers (Abd-El-Khalick & Akerson, 2009; Akerson, Morrison & McDuffie, 2006). Structured reflections and modelling through classroom discourse can also provide opportunities for pre-service teachers to think deeply about NOS ideas (Abd-El-Khalick & Akerson, 2004). The writing of reflective journal was actually rated by the selected group participants as being the most influential factor in the development of their views.

Alternatively, pre-service teachers could be encouraged to relate their newly developed NOS views to a context that is more meaningful to them. Making such a connection could compel them to address their NOS ideas in a way that could ultimately help them embrace more informed views (Akerson, Morrison & McDuffie, 2006). Akerson, Morrison and McDuffie (2006) also suggest that providing the pre-service teachers' opportunities to view explicit reflective NOS instruction in elementary classrooms may help them recognize the value of retaining these concepts for their upcoming education venture.

2.4.2.5 Pre-service teachers' worldviews

Teachers' worldviews and cultural values have been shown to have a significant influence on their understanding of NOS (Abd-El-Khalick & Akerson, 2004; Akerson & Donnelly, 2008; Haidar, 1999; Halai & McNicholl, 2004; Schwartz, Akom, Skjld, Hong, Kagumba & Huang, 2007). Haidar (1999) inferred that the United Arab Emirates pre-service and in-service constructivist teachers' views about NOS were due to their religious beliefs. This contention is strongly supported by Halai and McNicholl (2004) who carried out a study where they compared the NOS views of in-service teachers from schools in Pakistan with those of pre-service teachers from the Oxford University in England. They noted that religious beliefs had more influence on the teachers' conceptions of NOS than the place where they came from. In contrast to the English teachers, Pakistan teachers failed to view science and religion as two different means of making sense of the natural world and tended to judge scientific claims on the grounds of their religion.

Pre-service teachers who view science and religion as two separate worldviews are more likely to improve their NOS understanding than their colleagues who insist that science and religion are in opposition (Abd-El-Khalick & Akerson, 2004). Abd-El-Khalick and Akerson's (2004) study showed that pre-service teachers who were able to discriminate religious and scientific viewpoints were able to undergo conceptual change and embraced more informed NOS views. However, pre-service teachers who did not understand science and religion as independent worldviews tend to evaluate the target NOS ideas from the religious point of view, which may cause conflicts such as the students' failure to reconcile the highly commended validity of scientific knowledge with its tentativeness. This interferes with the students' ability to adopt the presented NOS ideas (Abd-El-Khalick & Akerson, 2004).

Sherry, Southerland and Enderle, (2012) contend that NOS instruction should include a discussion of the bounded NOS. Pre-service teachers should be made aware that since science demands empirical evidence; questions which cannot be empirically tested are outside the realm of science. Such a discussion should aim at helping students understand "science and religion as separate ways of knowing, and as such, values and assumptions of one cannot, and should not, be used to pass judgment on the validity of the other's claim" (Abd-El-Khalick & Akerson, 2004, p.807). Consistently with this view, Akerson and Donnelly (2008) also contend that in science classrooms, participants should be given an opportunity to build scientific concepts alongside their indigenous explanations of phenomena.

Such emphasis possibly prevents any negative feeling or emotions that may interact with the pre-service teachers' development of more informed NOS views. Southerland, Johnston and Sowell's (2006) study provide evidence in support of this contention. In their intervention that included a discussion of the "bounded nature of science as one of the target aspects of NOS" (p.899), the religious belief seemed not to be a factor in participants' development of NOS views. They point out that unlike in Abd-El-Khalick and Akerson's (2004) study, religious belief was not useful in explaining the teachers' NOS conceptions. They nevertheless believe that religion could have had an indirect influence through such learning dispositions as "students' need for a single right answer, comfort with ambiguity and such epistemological beliefs as the need for a singly authority" (p.897).

2.4.2.6 Self-efficacy

Pre-service teachers' understanding of NOS could be related to their self-efficacy. Self-efficacy in the learning of science can be understood as an individual's confidence in his or her own ability to tackle a difficult task or activity (Akerson & Donelly, 2008; Linnenbrink & Pintrich, 2002). A study by Hanson (2006) has revealed that there is a relationship between self-efficacy and a personal understanding of science (Hanson, 2006). However, the findings by Akerson and Donnelly's (2008) study could not reveal a significant relationship between NOS views of pre-service teachers' and their self-efficacy. They assert that this lack of significant relationship was probably caused by the narrowness of the range in the participants' outcome expectancy which was used as indicator of self-efficacy.

Figure 2.4 summarises the factors that have been shown by previous studies to influence NOS learning.

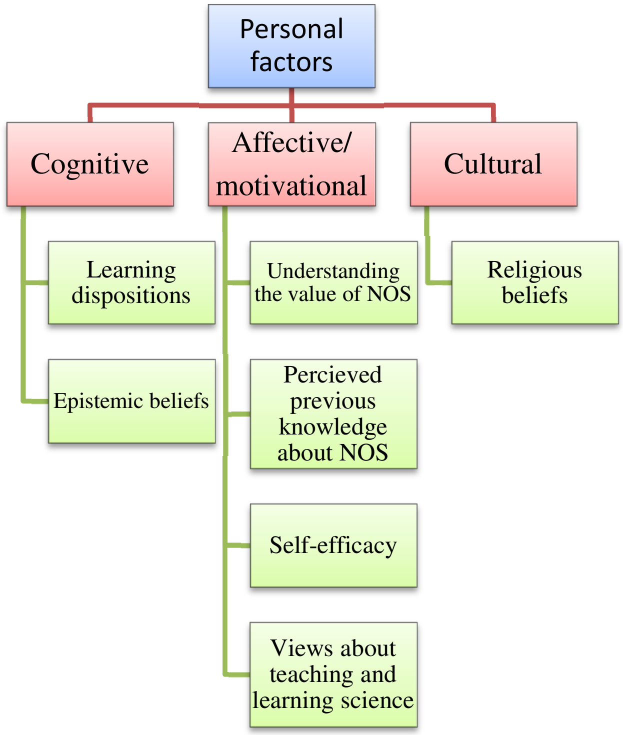

Figure 2.4 Personal factors influencing NOS learning

2.5 Assessing participants' NOS conceptions

In order to ascertain participants' understanding of NOS, researchers have made use of different data collecting strategies that include survey questionnaires, interviews, classroom observations, concept maps and document analysis.

2.5.1 Questionnaires

Administering questionnaires is among the most common means of collecting data. Questionnaires can consist of "closed (structured questions) and/or open (unstructured questions)" (Maree & Pietersen, 2007, p.161).

Closed ended questions "provides for a set of responses from which the respondent has to choose one or sometimes more than one response" (Maree & Pietersen, 2007, p.161). Haidar (1999) made use of a closed ended questionnaire to assess 224 Emirates in-service chemistry teachers' and 31 Emirates female prospective teachers' beliefs about NOS. The same instrument was adopted by Igbal, Saiga and Rizwan (2009) in their investigation of Pakistan secondary school science teachers' views NOS. Yalvac, Tekkaya, Cakiroglu and Kahyaoglu (2007) employed an adapted form of a structured questionnaire called the "Views on Science–Technology–Society (VOSTS)" questionnaire to investigate Turkish prospective science teachers' conceptions on variety of themes including the societal control on science, social construction of scientific knowledge and the nature of scientific knowledge. The VOSTS questionnaire was originally developed by Aikenhead, Ryan and Fleming (1989b). Buaraphan (2011) developed the closed ended Myths of Science Questionnaire (MOSQ) to assess 17 Thailand prospective physics educators' conceptions of NOS.

The main advantages of structured questions are that they can be answered within a short period of time; generate data that can be analysed relatively easier and faster than open ended questions (Maree & Pietersen, 2007). However, traditional closed ended methods of assessment have been shown to be less effective in assessing developments in students' conceptual understanding. The validity of such methods have been questioned on the basis that most of them lack content or construct validity, and in most cases discrepancies were noted between researchers' understanding of written reactions and the intent of the respondent (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). Moreover, limiting participants' responses to pre-defined categories does not provide them an opportunity to elaborate on their views, giving researchers very limited comprehension of participants' views (Vhurumuku & Mokeleche, 2009).

Open ended questionnaires are therefore now viewed as a better alternative as they reduce constraints on participants' responses, allowing them to give honest detailed responses that result in richer data than closed questions (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). Such rich data is necessary to ensure deeper interpretations of participants' views (Vhurumuku & Mokeleche, 2009). Unstructured questionnaires, however, require the respondent to be able to express themselves in writing. Other disadvantages of such questionnaires are that they take a long time to answer and analysing responses is much more demanding (Maree & Pietersen, 2007). Many more current studies such as those of Akerson, Abd-El-Khalick and Lederman (2000) and Dekkers and Mnisi (2003) have made use of such unstructured questionnaires in their assessment of participants' views. Liang Chen, Chen, Kaya, Adams, Macklin and Ebenezer (2009) used a questionnaire that blended Likert-type items with unrestricted questions in order to get a more comprehensive understanding of pre-service teachers' understanding of NOS.

2.5.2 Interviews

Several studies have indicated that questionnaires, on their own, are less valid in assessing participants' NOS views. Good, Cummings, and Lyon (1999 in Fishwild, 2005) used follow up interviews to test the consistency of the Natural Science (INS) survey which was administered to college chemistry students and pre-service teachers. The closed ended questionnaire assessed students' understanding of a number of different ideas of NOS, including the tentative and empirical nature of scientific knowledge. Based on the results of the follow-up interviews, Good, Cummings, and Lyon (1999) concluded that the survey was invalid as students held "different meanings of certain words (such as *confident*, *assume*, and *reliable*) than those intended by the designers of the questionnaire" (Fishwild, 2005, p.19).

Similarly, assessment of the open ended Views of Nature of Science (VNOS-A) instrument revealed problems of validity of some of the items. Interviews revealed that three of the seven items did not assess the intended participants' beliefs (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). Abd-El-Khalick, Bell and Lederman (1998) found that the respondents understood the "words *evidence, opinion,* and *creativity"* differently from the inquirers (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002, p. 504). As a result, some studies have either used interviews only for assessing students' views or triangulated questionnaires with semi-structured interviews in order to obtain more valid data (Fishwild, 2005). Semi-structured interviews involve asking participants the same set of pre-established questions. Follow up questions are used to probe and elucidate participants' answers (Nieuwenhuis, 2007). This interview strategy offers sufficient suppleness to approach different respondents differently while still focusing on the same areas of the inquiry (Noor, 2008).

2.5.3 Concept maps

Concept maps assessment has emerged as another alternative to the use of multiple choice assessments (Stoddart, Abrahams, Gasper & Canaday, 2000). Concept maps, originally developed by Joseph Novak, are "a procedure that is used to measure the structure and organization of an individual knowledge" (Stoddart, Abrahams, Gasper & Canaday, 2000, p. 1223). Shavelson, Lang and Lewin (1993) define a concept map as a "graph that consists of nodes representing concepts and labelled lines denoting relationships between a pair of nodes or concepts" (p.4). The labels can be words or phrases, which together with the pair of concepts linked, form a complete thought or proposition (Novak & Canas, 2008; Stoddart, Abrahams, Gasper & Canaday, 2000)

Cognitive psychologists apparently agree that "internal representations of knowledge are more like a structured and organized web or network of facts and ideas" (Williams, 1998, p. 414). Concept maps are therefore seen as a way of looking into this structure of a student's organization of knowledge within a particular domain (Shavelson, Lang & Lewin, 1993; Williams, 1998). The propositions comprised by the concept map are seen as units of psychological meaning. A students' meaning or of a concept is therefore, according to this view, represented by all propositional linkages that the person can construct (Shavelson, Lang & Lewin, 1993). The more valid connections constructed among relevant concepts, the better the understanding.

Concept maps have been found useful in assessing prior student knowledge, in identifying gaps, or misconceptions in student's knowledge (McClure, Sonak & Suen, 1999; Stoddart, Abrahams, Gasper & Canaday, 2000) as well as "an assessment tool to determine the extent and quality of new connections that students are able to make after instruction" (Mason, 1992 in Stoddart, Abrahams, Gasper & Canaday, p.1223). Kattoula (2008) employed concept mapping as one of the strategies that he used to investigate changes in prospective science educators' views of NOS as they learnt about the science of waves. It is therefore a viable tool to use in assessing the impact of the science programme in developing the Swaziland pre-service teachers' understanding of NOS.

2.5.4 Document analysis

Creswell (2007) asserts that documents are a good source of information in qualitative research. Documents used in research include all types of public and private records that may provide insights into the phenomenon under study. Students' essays, lesson plans, and reflective journals, are some of the documents that have been used to investigate either students' views of NOS and/or perceived reasons for such changes during NOS instruction. Lederman, Wade and Bell (1998) assert that the ability to apply newly learnt NOS knowledge in designing instruction is a more valid assessment of students' understanding than either direct questions on paper or interviews. For example, some studies indicate that pre-service teachers are likely to confuse NOS with science processes (Abd-El-Khalick, Bell & Lederman, 1998; Bell, Lederman & Abd-El-Khalick, 2000). Such misconceptions are more likely to surface when they are asked to prepare lessons for teaching NOS. Mellado (1997) attempted to investigate teachers' understanding of NOS and how they influenced classroom practice by using classroom diaries.

Documentary data may be collected concurrently with other data sources such as interviews and observations, for the purpose of triangulation (Wiersma & Jurs, 2008). One strong point of documentary data is that these are in the language and words of the participants. However, such documentation may be inaccurate. Handwritten documents may also be in a handwriting that is difficult to read, making it difficult to access the information (Creswell, 2007).

2.5.5 Classroom observations

Comprehension of NOS is one of the factors needed to enable a teacher to explicitly teach NOS in the classroom. Schwartz and Lederman (2002) noted in their study that the level of understanding of NOS affects a teacher's ability to teach NOS. The secondary science teacher who had developed sophisticated conceptions of NOS was more able to address such issues in the classroom than the teacher who had made relatively lesser gains in NOS understanding. This teacher was able to select appropriate examples and anecdotes to substantiate the target NOS issues. Classroom observations aimed at investigating of NOS teaching could therefore be another useful strategy in assessing a teacher's level of understanding of NOS issues. However, the presence of other factors that hinder a teacher's ability to translate NOS knowledge into practice, such as the teacher's knowledge of the content, may prevent the use of such strategy in assessing teachers' views of NOS.

Classroom observations, together with other types of data collection methods, have however been used extensively in studying whether there is a link between teacher's NOS views and their classroom practice (Hanuscin, Lee & Akerson, 2010; Mellado, 1997) and the ability of teachers to explicitly address and/or assess NOS issues in the classroom (Hanuscin, Lee & Akerson, 2010; Naidoo, 2008; Schwartz & Lederman, 2002). Such a strategy has also been used by Abd-El-Khalick and Akerson (2004) when investigating factors that facilitate or inhibit pre-service teachers' development of more informed NOS views.

Nieuwenhuis (2007, p.83) defines observation as a "systematic process of recording the behavioural patterns of participants, objects and occurrences without necessarily communicating with them". Similar to interviews, observations can either be structured or unstructured, or fall in-between the two extremes. Most observations in educational research have at least a tentative schedule to start off with.

The above discussion indicates that previous research has used a variety of data collecting strategies to investigate pre-service teachers' views of the epistemology of science. The type of strategy used is in most cases is determined by the nature and purpose of the study and the availability of time and resources. Studies that are more interpretive in nature tend to use, for example, more interviews than questionnaires in order to understand the meanings that participants, ascribe to different NOS issues. Nevertheless, regardless of the type of instrument used, most studies indicate that pre-service teachers, in general, hold naive views of NOS prior to any explicit intervention aimed at augmenting their views.

2.6 The theoretical framework for the study

This and the next section respectively describe the theoretical and conceptual frameworks that were used in this study. The study investigated the effects of an explicit reflective NOS intervention on Swaziland pre-service teachers' NOS conceptions. The research questions are stated in section 1.7.

The Conceptual Change Model (CCM) formed the theoretical framework of the study. A theoretical framework refers to an underlying theory of a study. A theory is an idea created for the purpose of explaining a phenomenon such as the process of learning (Duit & Treagust, 2003; Staver, 1998). The CCM therefore formed the basis for understanding the pre-service teachers learning of NOS. The reviewed literature revealed that there are a number of specific interrelated contextual and personal factors that influence participants' development of NOS conceptions. The CCM model together with some of the identified factors was developed into a conceptual framework that clarified the main concepts and proposed relationships among the concepts in the study, and therefore guided the development of the study.

In Chapter 1, the conceptual framework guided the formulation of research questions. In chapter 3, it acted as a base for the interview schedule. It was finally used in chapter 4, 5 and 6 to analyse the data and to derive conclusions regarding factors that influence Swaziland pre-service development of NOS views as a result of the NOS instruction. It would be useful also to find out the applicability of such a framework in the context of studying conceptual change in NOS views, more especially in a developing country like Swaziland. Most studies involving this framework occurred in western countries, such as Abd-El-Khalick and Akerson's (2004) study as well as Southerland, Johnston and Sowell's (2005) study.

Figure 2.5 summarizes the conceptual framework of the study. It shows the development of informed views of NOS as well as the relationship between initial conceptions, the teaching and learning of NOS and CCM.

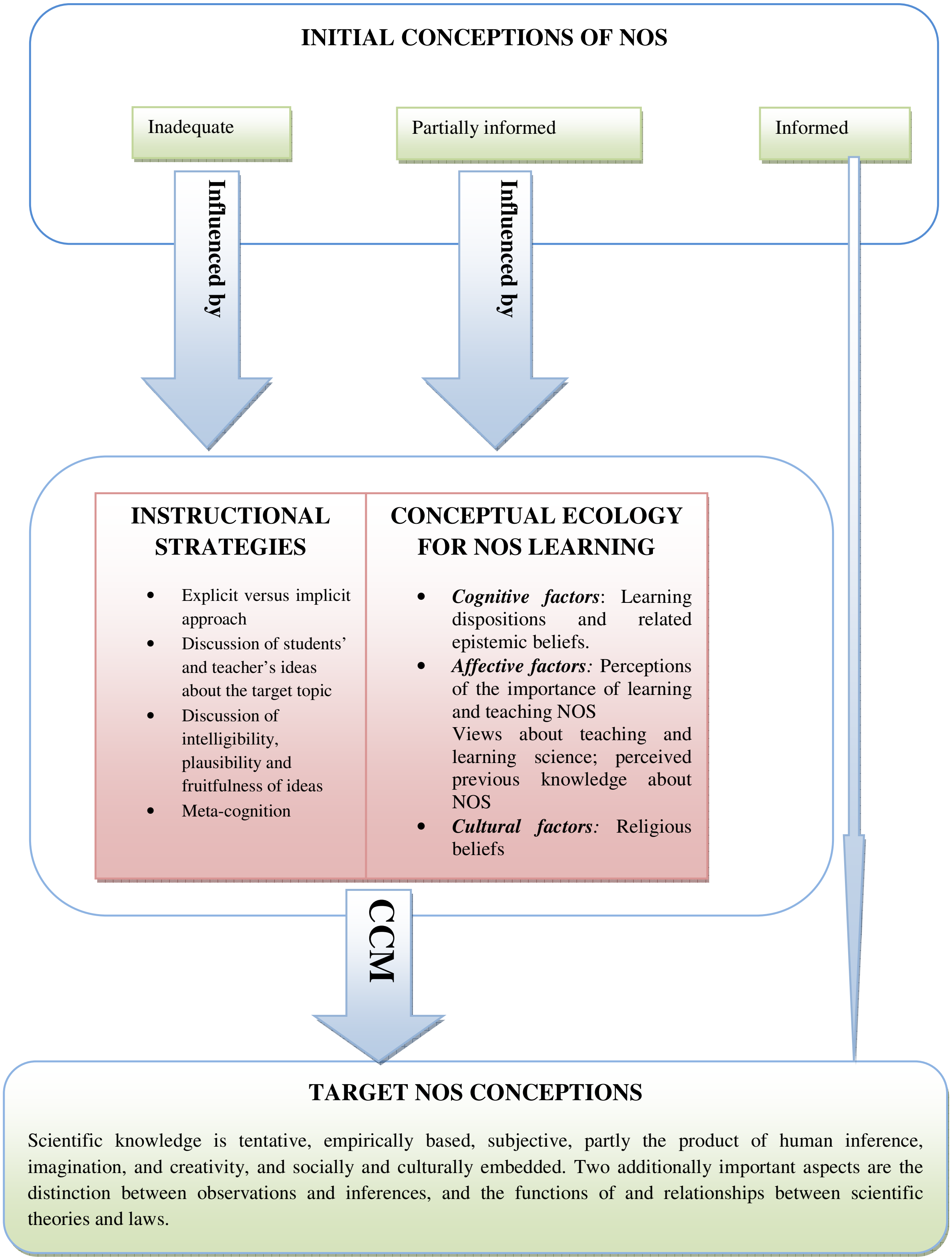

Figure 2.5 Development of informed conception of NOS, showing relationships between initial conceptions, teaching and learning, and CCM

2.6.1 The Conceptual Change Model

Many studies in the field of science teaching and learning have indicated that students come into classrooms with deeply rooted prior conceptions that are often different from those intended by the science instruction (Duit & Treagust, 2003; Nussbaum & Novick, 1982; Thorley & Stofflett, 1996; Yuruk, Ozedemir & Beeth, 2003). Consequently, many science educators and cognitive psychologists have put forward different theoretical frameworks in their attempt to "explain the nature of students' prior conceptions and how they change their pre-conceptions into scientifically accepted ones" (Yuruk, Ozedemir & Beeth, 2003, p. 3).

A majority of the aforementioned researchers agree that conceptual change involves restructuring of existing cognitive structures, although they hold different views regarding the meaning of the concept of restructuring. Some of them understand restructuring as the replacement of prior conceptions with new ones, while for others; it is about bringing together pieces of information in order to create a coherent view of a concept (Kattoula, 2008). Restructuring could also refer to the allotment of a concept into its appropriate category (Chi, 2008, p. 65). Chi (2008) argues that correct categorization of concepts is fundamental to conceptual change as it allows a learner to make correct inferences about the features and attributes of a concept. He, for example, points out that a child who has correctly categorized a change of state such as melting as a "process" rather than an "entity" will not attribute properties such as volume or colour to such a concept. Chi (2008) therefore argues that many tenacious misconceptions are a result of incorrect categorization of concepts, and believe that conceptual change cannot occur until a concept has been assigned to its correct category. Other researchers believe that restructuring can only occur when students undergo changes in their epistemological and ontological beliefs (Vosniadou, 1994). Yuruk, Ozedemir and Beth (2003) contend that all these different theoretical frameworks suggest that conceptual change goes beyond replacing an existing conception with a new one, but it requires one to "recognize, integrate, and evaluate the existing and new conceptions and related beliefs, everyday experiences as well as contextual factors (p. 3). This therefore highlights that personal and contextual factors have a bearing on an individual's ability to experience conceptual change.

2.6.2 The Initial Conceptual Change Model (CMM)

The view of learning as conceptual change was first developed into a model of learning by Posner, Strike, Hewson & Gertzog (1982). The model, based on constructivism, explains how an individual learner's conception changes as a result of instruction. Individual learning is understood to be similar to the way scientific knowledge is constructed, a view that originated from the work of philosophers and historians of science (Yuruk, Ozedemir & Beeth, 2003, p. 5).

According to this perspective, students' pre-existing knowledge structure plays a crucial role in the learning process (Hewson, 1992; Rebich & Gautier, 2005). Rebich and Gautier assert that the students' pre-existing framework act both as a "base for integration of new concepts and as a potential hindrance to conceptual change" (2005, p.356). Prior knowledge therefore plays a key role in one's understanding of the world as the learner's mind will always "interpret any new concept not as a new objective idea, but as a subjective idea filtered or perceived through his or her conceptual structure" (Kattoula, 2008, p.11).

There are two main theoretical elements of the CCM (Posner, Strike, Hewson & Gertzog, 1982). The first element consists of the requirements of accommodation. Accommodation is conceptual change that demands that a learner replaces or reorganizes her or his central conceptions in order to grasp a new phenomenon successfully (Posner, Strike, Hewson & Gertzog, 1982). These prerequisites are intelligibility, plausibility, and/or fruitfulness of the new conception (Hewson, 1992; Duit & Treagust, 2003; Posner, Strike, Hewson & Gertzog, 1982). If the learner experiences discontentment with his/ her pre-existing conception, and the new conception is "intelligible, plausible, and fruitful, then accommodation of this conception may result' (Posner, Strike, Hewson & Gertzog, 1982, p.214). An intelligible conception is one that allows a student to make better sense of his or her experiences; plausible means that additionally to knowing the meaning of the concept, the student finds it believable, and fruitful means it allows the student to resolve other puzzles including revealing new explorations (Duit & Treagust, 2003; Hewson, 1992). For an idea to be plausible, it must be first be intelligible, and also, an idea to be perceived as fruitful, it must be intelligible and plausible (Posner, Strike, Hewson & Gertzog (1982). Southerland, Johnston and Sowell's (2006) study findings, however contradict this rational, logical model. Their study showed that some learners can quickly move on into consideration of the fruitfulness of the new NOS concepts in their classroom, while they still struggled with their intelligibility. It would be of value to find out whether the current study would corroborate such findings.

The second theoretical component of the CCM is the learner's conceptual ecology which may have some bearing on an apprentice's conceptual change process (Hewson, 1992; Talib, Matthews & Secombe; Yuruk, Ozedemir & Beeth, 2003). "The conceptual ecology includes many different kinds of factors which include epistemological commitments, metaphysical beliefs about the world, past experiences, knowledge in other fields, and analogies and metaphors that becomes part of a student's rationality to accept or reject new ideas" (Talib, Matthews & Secombe, 2005, p. 31).

Hewson (1981 cited in Yuruk, Ozedemir and Beeth, 2003, p. 6) developed the CCM further by bringing in the idea of status, which was viewed as the "hallmark of conceptual change". The status of a person's conception was defined as "the extent to which the conception meets the conditions of intelligibility, plausibility, and fruitfulness" (Hewson, 1992, p. 8). Hewson (1992) point out that meaningful learning of a new conception only occurs when its status is raised. Competition between rival conceptions is therefore explained in terms of their status (Duit & Treagust, 2003). If a new conception is in conflict with the learner's existing knowledge structure, it can only be embraced when the status of the current conception falls (Yuruk, Ozedemir & Beeth, 2003). Yuruk, Ozedemir and Beeth (2003) further point out that the components of a students' conceptual ecology plays a crucial role in deciding "the status of a conception" as it influences the extent to which an idea is understandable, believable, and useful (p. 6).

2.6.3 The Revisionist Conceptual Change Model

Although original CCM framework has been very useful in guiding a lot of research and instructional practices, it has been criticized by many researchers on grounds that the model was overly rational, focusing only on student cognition and as a result ignored other dimensions of learning (Abd-El-Khalick & Akerson, 2004; Southerland, Johnston & Sowell, 2005; Yuruk, Ozedemir & Beeth, 2003). Solomon (1987 in Abd-El-Khalick and Akerson, 2004) pointed out that the model ignored social dimensions of learning (Abd-El-Khalick & Akerson, 2004). Solomon argued that students may adopt a particular view for the sake of being in line with his or her society. Pintrich, Marx and Boyle (1993) described the model as "cold as it ignored the impact of students' motivational beliefs and classroom contextual factors on conceptual change". (p.170). Such criticisms led to a "revisionist theory of conceptual change" in which the originators of the model admitted that the conceptual ecology needs to be extended beyond "epistemological factors suggested by the history and philosophy of science" (Yuruk, Ozdemir & Beth, 2003, p.7). They agreed that conceptual change is influenced by "beliefs, goals, emotions, and motivation" (Southerland, Johnston & Sowell, 2005, p. 876).

The revisionist CCM also proposes that learners' misconceptions are a component of the learners' conceptual ecology as they play a very important role in influencing how a student views a new idea. Strike and Posner (1992) contend that misconceptions may not only be formed prior to instruction, but may also develop during the course of instruction as a result of some components of the learner's conceptual ecology. In line with this view, Abd-El-Khalick (2001) and Akerson, Abd-El-Khalick and Lederman (2000) in their separate studies, observed that that some pre-service teachers' NOS views tend to shift from a pre-instruction "scientistic" to a post-instruction naive relativism, where any idea is acceptable, instead of the targeted relativism view. Ozdemir and Clark (2007) therefore allege that the revision of one conception must go hand in hand with the revision of other related conceptions within the students' conceptual ecology.

Consequently, current conceptual change frameworks used in science education, go beyond the consideration of only rational processes on conceptual change, but focus on the nature of learners' misconceptions, and related knowledge, as well as beliefs and attitudes (Yuruk, Ozdemir & Beeth, 2003).

2.7 Conceptual framework: Conceptual change and NOS development

2.7.1 Learning NOS

From the literature reviewed it is clear that pre-service teachers come to class with many misconceptions about NOS that are often resistant to change (Abd-El-Khalick & Akerson, 2004; Akerson, Abd-El-Khalick & Lederman, 2000; Kukuk, 2008). The CCM is concerned with the modification of conceptions that in one way or the other are central and also play "an organizing role in thought and learning" (Strike & Posner, 1992, p. 148). The CCM model is therefore particularly appropriate for the current study, as NOS conceptions play a significant role in directing students' thinking about scientific knowledge (Southerland, Johnston & Sowell, 2006). Furthermore, Clough (2006) points out that the CCM can be used effectively to explain "learners' responses to NOS instruction" (p. 463). In agreement with this view, a number of studies have successfully used this framework to study the factors mediating pre-service or in-service teachers' development of NOS views (Abd-El-Khalick & Akerson, 2004; Chan, 2005; Southerland, Johnston & Sowell, 2006).

Chan (2005) postulates that raising the status of one NOS conception is likely to impact on the status of other closely related NOS conceptions. He asserts that this interconnectedness among NOS conceptions explains their tenacity to change. He therefore argues that learning NOS is a dynamic mind restructuring process whereby the status of one NOS conception is raised above its rivals. In line with this hypothesis, the results of his study demonstrate a negative relationship between the creative and the testable NOS. Raising the status of one conception was found to simultaneously lower the status of the other. Below is a discussion of strategies that are likely to bring about pre-service teachers' development of a more balanced view of NOS.

2.7.2 Instructional strategies likely to bring about conceptual change in pre-service elementary teachers' NOS conceptions

According to Akerson and Abd-El-Khalick (2004), the following strategies are likely to enhance participants' views of NOS. These strategies integrate an explicit reflective approach to NOS with a general structure of teaching for the purpose of bringing about conceptual change as postulated by Hewson, Beeth & Thorley (1998 in Akerson & Abd-El-Khalick, 2004).

2.7.2.1 An explicit versus an implicit instructional approach to NOS

An explicit reflective attention to NOS is likely to boost students' development of more informed NOS views. Abd-El-Khalick and Akerson (2004) strongly argue against the implicit approach apparently adopted by Hewson, Beth and Thorley (1998). In their revision theory of CCM, they proposed that it is "enough to share epistemological commitments with students" (Abd-El-Khalick & Akerson, 2004, p. 792). Such an implicit approach to NOS is in line with initial attempts to improve students' and teachers' NOS conceptions. These attempts were based on the belief that if participants were involved in doing science (e.g. inquiry) they would consequently develop an accurate understanding of NOS. Several research studies have however, nullified such a belief (Khishfe & Abd-El-Khalick, 2002; Murphy, Kilfeather & Murphy, 2007).

Clough (2006) asserts that students often carry deeply held misconceptions about NOS. Implicit NOS instructions designed to challenge these mistaken beliefs are in most cases interpreted to fit students' misconceptions and consequently does not lead to dissatisfaction with prior ideas. Students, like scientists will always interpret a new experience on the basis of their prior knowledge (Clough, 2006; Kattoula, 2008). Clough (2006) therefore strongly argues that in order for NOS instruction to be effective in bringing about conceptual change, it must be explicit and reflective. Several studies have provided evidence substantiating the effectiveness of the explicit reflective approaches in bringing about conceptual change among pre-service teachers (Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick & Lederman, 2000)

2.7.2.2 Discussion of students' and teachers' ideas about the intended subject

Hewson, Beeth & Thorley (1998 in Abd-El-Khalick & Akerson, 2004) also highlight the importance of making students' and teachers' ideas about the tackled topic part of the classroom discussion. They propose that teachers should be given structured opportunities to express, justify, and evaluate the stability of their views. Consistent with this guideline, NOS researchers have suggested that participants must first be given an opportunity to examine their alternative views of NOS at the beginning of instruction so they can experience cognitive dissonance regarding their NOS views. According to constructivism, this is necessary to bring about accommodation (Abd-El-Khalick, 2001; Abd-El-Khalick, 2004; Ryder & Leach, 2008; Shapiro, 1996). Hammrich (1997) used a cooperative controversy strategy, where participants are assigned into small groups and asked to reflect on their existing conceptions of NOS, and to finally reach a group consensus on what they consider the most reasonable conception. He realized that this group effort was very useful in challenging teacher participants' naive conceptions of NOS, as revealed by their evaluation of the strategy.

2.7.2.3 Discussion of the 'intelligibility, plausibility, and fruitfulness' of ideas

Another factor that is likely to bring about conceptual change is the discussion of concepts and ideas in relation to their "intelligibility, plausibility, and fruitfulness" (Hewson, Beeth & Thorley, 1998 in Abd-El-Khalick & Akerson, 2004, p. 792). Hewson (1992) argues that "conceptual exchange does not occur without concomitant changes in the relative status of changing conceptions" (p. 9). The main aim of this discussion is therefore to lower the status of students' alternative ideas while raising that of the targeted ideas (Hewson, Beeth & Thorley, 1998 in Abd-El-Khalick & Akerson, 2004). Abd-El-Khalick and Akerson (2004) assert that the status of an idea can be lowered by "exploring their unacceptable implications, considering experiences that they cannot explain, or finding ways of thinking about them in a way that reveals their inadequacies. The status of targeted ideas may be raised by presenting, developing, and applying them in different situations, or connecting them to other ideas" (2004, p. 792). Hewson (1992) points out that once a learner views a new conception as intelligible, plausible, and also fruitful, learning progresses without difficulty. The above contention was supported by Abd-El-Khalick and Akerson (2004). As a result of an intervention that integrated the explicit reflective NOS instruction with strategies aimed at facilitating conceptual change, significant gains in pre-service teachers' NOS conceptions were achieved.

2.7.2.4 Metacognition

Metacognition is a prerequisite for conceptual change (Yuruk, Ozdemir & Beeth, 2003). Yuruk, Ozdemir and Beth (2003) contend that if conceptual change is thought to result from the lowering of the status of existing conceptions while raising those of the new conception, students must be encouraged to think about their conceptions, and to examine and appraise the status of the rival conceptions. Thomas (2002) defines metacognition as an individual's knowledge, awareness and control of his/her learning processes.

Metacognition differs from metaconceptual as the latter refers to reflecting on the actual concepts that are being learnt (Hewson, Beeth & Thorley, 1998 in Abd-El-Khalick & Akerson, 2004). Hewson, Beeth and Thorley (1998) emphasize that both processes are necessary for conceptual change. Baird, Fensham, Gunstone and White's (1991) study demonstrated that adequate reflection can develop students' and teachers' knowledge, awareness, as well as self-control and classroom practice. Training in metacognitive strategies has also been shown to significantly improve the efficiency of an explicit reflective approach in developing pre-service primary teachers' conceptions of NOS (Abd-El-Khalick & Akerson, 2009). These metacognitive activities provide opportunities for learners to think deeply about the NOS ideas which may consequently lead to an improvement in their NOS views (Abd-El-Khalick & Akerson, 2004).

2.7.3 Conceptual ecology for NOS learning

Several studies have indicated that pre-service teachers do not achieve similar gains in their NOS conception as a result of NOS instruction (Abd-El-Khalick, 2001; Abd-El-Khalick & Akerson, 2004; Akerson, Abd-El-Khalick & Lederman, 2000; Akerson, Morrison & McDuffie, 2006). Certain learner characteristics have been shown to impact on their ability to develop more informed NOS views. These characteristics are described as a "conceptual ecology for NOS learning" (Southerland, Johnson & Sowell, 2006; Akerson & Donnelly 2008). The conceptual ecology for NOS learning has been found by Abd-El-Khalick and Akerson (2004) to include cognitive, motivational and other affective factors as well as worldview factors. Below, is a discussion of characteristics that the researcher believes may also impact on the Swaziland pre-service teachers' development of more informed NOS views.

2.7.3.1 Cognitive factors

Several studies have indicated that "learning dispositions" and some closely related "epistemic beliefs" have a bearing on an ability of a learner to achieve conceptual change (Mason, 2002, 2003 in Rebich & Gautier, 2005; Qian & Alvermann, 2000).

Learning dispositions

Rebich and Gautier (2005) point out that conceptual change as opposed to any other form of learning, demands deep engagement with knowledge. They point out that it involves "revising and fitting new information into existing mental schemata" (Rebich & Gautier, 2005, p. 355). Students' motivation to examine one's own belief and to accept evidence that conflicts with one's prior knowledge is linked to their learning dispositions and related epistemic beliefs (Rebich & Gautier, 2005; Southerland, Johnston & Sowell, 2006). Southerland, Johnston and Sowell (2006) define learning dispositions as tendencies toward learning and thinking. They also assert that learning dispositions include an ability to think more deeply about ideas, as well as metacognition which refers to an ability to reflect "about one's knowledge and thoughts in relation to what is learnt" (p. 882).

Epistemic beliefs

Epistemic beliefs are personal "beliefs about knowledge and knowing" (Harteis, Gruber & Hertramph, 2010, p.201). Rebich and Gautier (2005) point out that such beliefs are developmental, meaning that they progress through stages. Kuhn (1999 in Rebich and Gautier, 2005) identify these stages as absolutist, multiplist and evaluativist. The absolutist stage is characterized by beliefs that knowledge is absolute and certain since it comes from observations of reality or from authorities. People with this view of knowledge have a tendency to seek for a single right answer and are unable to tolerate ambiguity (Southerland, Johnston & Sowell, 2006). The multiplist views knowledge as overly subjective, and ambiguous. Each person is believed to be entitled to his or her own view and truths. The evaluativist, on the other hand, has a balanced view of objectivity and subjectivity. The fact that people may draw different conclusions from similar experiences is not regarded as meaning that every idea or point of view is valid; some ideas are viewed as more reasonable and justifiable than others. Researchers and students with a more evaluativist view of knowledge are more likely to be open-minded and to consider evidence that conflict with their prior beliefs and consequently achieve conceptual change (Rebich & Gatier, 2005).

Some studies (Abd-El-Khalick & Akerson, 2004; Southerland, Johnston & Sowell, 2006) provide evidence in support of the claim that learning dispositions do impact on teachers' development of more informed NOS views. Southerland, Johnston and Sowell (2006) found that a certain level of "reflection and a need for cognition" was found to be valuable in mediating conceptual change (p.897). Abd-El-Khalick and Akerson's (2004) study found that pre-service teachers who searched for precise meanings of the various key NOS concepts, and who also monitored their changes in their NOS understandings were able to develop more informed NOS views. Southerland, Johnston and Sowell (2006) assert that such ability to deeply process material was facilitated by their reflection and need for cognition.

Furthermore, Southerland, Johnston and Sowell's (2006) study revealed that a "teacher's intolerance of ambiguity and need for external authority would also influence his or her evaluation of the plausibility and fruitfulness of NOS" (p.897). Learning dispositions and related personal epistemological beliefs are therefore more likely to influence teachers' engagement with NOS views, and such engagement is likely to directly impact on the status of these ideas for participants, consequently influencing their conceptual change.

The aforementioned claim is also supported by other studies that have also shown that students' cognitive development have a bearing on learning about the constructivist NOS aspects (Abd-El-

Khalick, 2001; Akerson, Morrison & McDuffie, 2006). Akerson, Morrison and McDuffie's (2006) study showed that pre-service teachers at a higher cognitive level where they understand all knowledge to be contextual and relative are more likely to retain their newly learnt NOS ideas. Akerson, Morrison and McDuffie (2006) also contend that adult learners at the higher levels of cognition development have also developed a metacognitive consciousness of their own thinking, are able to accept ambiguity and tentative answers, and are probably more likely to exercise a stronger commitment to the newly learnt ideas. Even though a later study by Akerson and Donnelly (2008) did not find a relationship between intellectual levels and NOS views, they still uphold that there is a strong relationship between the two constructs. They assert that the nature of their study could have not allowed this supposed association to be revealed from their data.

2.7.3.2 Affective factors

Influences on conceptual change go beyond cognitive factors and include many affective factors such as motivational learner characteristics, learners' goals for learning and others (Linnenbrink & Pintrich, 2002; Pintrich, Marx & Boyle, 1993).

Motivational factors

Pintrich, Marx and Boyle(1993) assert that motivation to deeply engage with material is linked to "goals, values, self-efficacy, and control beliefs" (p.167). In agreement with this assertion, several NOS studies have also revealed that the aforementioned characteristics play a motivational role in the development of teachers' NOS views (Abd-El-Khalick & Akerson, 2004; Akerson & Donnelly, 2008; McDonald, 2010; Schwartz, Akom, Skjold, Hong, Kagumba & Huang, 2007; Southerland, Johnston & Sowell, 2006).

Goals for learning

Motivation is inherently linked to learning goals. This assertion is based on studies that have indicated that students with mastery goals more readily achieve conceptual change than those with performance goals (Linnenbrink & Pintrich, 2002; Pintrich, Marx & Boyle, 1993; Southerland, Johnston & Sowell, 2006). While students with mastery goals focus on learning and understanding, those with performance goals tend to focus more on good grades or on displaying ability. Pintrich, Marx and Boyle (1993) interpret the relationship between goals and conceptual change. They contend that students with more mastery goals tend to engage deeper with the learning tasks than those with performance goals, leading to differential gains in understanding. A difference in learner goals is therefore likely to influence students' gains in NOS understanding. This influence is however expected to be mediated by learning dispositions (degree of engagement with NOS material) (Southerland, Johnston & Sowell, 2006).

Perception of the importance of learning and teaching about NOS

Teachers' development of more informed NOS views is mediated by teachers' beliefs about the importance of learning and teaching about NOS (Abd-El-Khalick & Akerson, 2004; McDonald, 2010; Schwartz, Akom, Skjold, HangHwa Hong, Kagumba & Huang, 2007; Southerland, Johnston & Sowell (2006). Based on the results of their study Abd-El-Khalick & Akerson (2004) assert that an "internalization of the importance of teaching about NOS plays a significant role in motivating teachers to critically examine and revise their NOS view" (p.806). Teachers' perception of the usefulness or fruitfulness of NOS ideas is believed to be linked to their view of the capability of learners to learn NOS. Southerland, Johnston & Sowell's (2006) study showed that if a teacher believed learners can learn NOS, he or she perceived NOS as an important learning and teaching goal.

View of science

Teachers' perception of the importance of NOS is also linked to participants' view of science as an enterprise. Southerland, Johnston and Sowell (2006) showed that participants who view science as a product find it difficult to appreciate the usefulness of NOS for their teaching, which is likely to impact on their understanding of NOS. In order for students to deeply engage themselves with all the NOS aspects, it is necessary that they view science both as a process as well as a product (Southerland, Johnston & Sowell, 2006). Their study revealed that teachers who only viewed science as a process, failed to deeply engage themselves with aspects of NOS that were closely linked to the products of science. In contrast, teachers who understood science both as a product and a process deeply engage themselves with the entire NOS framework. These findings support the CCM's claim that a student needs to find a new idea fruitful in order to enable learning to occur without difficulty (Hewson, 1992). Fruitful in this context would mean that the teacher must find the target idea useful in terms of her or his teaching of science.

Pre-service teachers' views of learning and teaching science

Teachers' view of learning and teaching is likely to have an impact on participants' development of more informed constructivist view of NOS. The connection between NOS views and the nature of teaching and learning was studied by Tsai (2002) among Taiwanese secondary science teachers. He found that teachers who viewed science teaching as being about transmitting information to learners were more likely to harbour more traditional positivist views about NOS. Likewise, teachers who harboured more constructivist views of learning and teaching were also more likely to have more constructivist NOS views. In line with this observation, Southerland, Johnston and Sowell (2006) point out those teachers who view teaching science as a transmission of information, find it difficult to appreciate the fruitfulness of NOS for their teaching. This is more likely to impact negatively on their development of more informed views of NOS. On the other hand those teachers, who hold constructivist view of learning and teaching, are more likely to engage themselves with the NOS issues and hence develop more informed NOS views.

Perceived previous knowledge about NOS

Teachers who believe that they already know NOS prior to the NOS instruction are much less motivated to change their pre-existing views. This highlights the importance of dissatisfaction with prior conceptions in initiating conceptual change. McDonald's (2010) study points towards the impact of perceived previous knowledge about NOS on participants' development of NOS views. In his study, participants who did not show confidence in their previous NOS view exhibited the most substantial development in NOS. On the other hand, participants, who believed that they already knew about NOS at the commencement of the study, were much less motivated to change their pre-existing views.

Cultural factors and Religious beliefs

Teachers' religious beliefs also mediate teachers' development of more informed NOS views (Haidar, 1999; Halai & McNicholl, 2004; Abd-El-Khalick & Akerson, 2004; Akerson & Donnelly, 2008. The study of Abd-El-Khalick and Akerson (2004) found that pre-service teachers' view of the relationship, (or lack) between religion and science impacted on their development of more informed views of NOS. Pre-service teachers who held the view that science and religion are two separate means of knowing developed more informed NOS conceptions than their colleagues who viewed science and religion as in conflict (Abd-El-Khalick & Akerson, 2004). This finding is consistent with both earlier and later studies that also indicated a relationship between teachers' NOS views and their socio-cultural beliefs (Akerson & Donnelly, 2008; Haidar, 1999; Halai & McNicholl, 2004; Liu & Lederman, 2007; Schwartz, Akom, Skjld, Hong, Kagumba & Huang, 2007).

2.8 Summary

From the reviewed literature, it is apparent that most teachers hold many different misconceptions of the different aspects of NOS, which they are likely to pass on to their students. Various strategies that include the use of closed and open ended questionnaires, interviews, concept maps and documentary analysis have been used to assess participant teachers' understanding of NOS. It has also been revealed that an explicit NOS instruction has a positive impact on teachers' development of more accurate views. Various contextual and personal factors have also been found to impact on teachers' gain in NOS understanding. Some studies have also revealed that NOS conceptions are influenced by the background as well as the worldviews of participants. It thus becomes vital to investigate the elementary pre-service teachers' understanding of NOS as well as the impact of an explicit NOS instruction in a context of a developing country like Swaziland. The study adds to the understanding of elementary prospective teachers NOS conceptions and how such conceptions are influenced by an explicit reflective NOS instruction. The next chapter describes the methodology of the study.

CHAPTER 3

RESEARCH METHODOLOGY

3.0 Introduction

This chapter describes the methodology for the study. It encompasses the research design, sample and participants, context of the study, description of the NOS programme, data collecting strategies, validation of the questionnaire, data analysis as well as ethical deliberations.

3.1 Research design

Rowley (2002) defines a research design as an action plan that an inquirer employs to move from initial research questions to the formulation of conclusions. This study made use of a pretest-posttest design to evaluate the effects of an explicit reflective NOS programme on an individual science classroom of Swaziland elementary pre-service teachers. Based on the pragmatism paradigm, it involved collecting both quantitative and qualitative data to address the research questions. Pragmatism is essentially based on a belief that qualitative and quantitative methods are not in conflict and can therefore be used together to address the same research problem (Creswell & Plano Clark, 2007). Creswell (2007, p.263) contends that "the combination of both approaches allows answers to both 'what and why' questions and therefore gives a complete understanding of a research problem". Such a design therefore enabled the researcher to make conclusions regarding the effectiveness of the programme in enhancing the selected prospective educators 'conception of the target NOS aspects and to gain understanding of the factors that mediate their growth in NOS understanding (Abd-El-Khalick & Akerson, 2004). Paulsen and Dailey (2002) assert that the use of a single case is best suited for acquiring useful information necessary to understand how a programme is working in a particular setting and to "inform more vigorous and larger studies" (p. 11).

3.2 Sample and Participants

Participants in the study were 24 (15 females and 9 males) pre-service elementary teachers in an elementary teacher training college located in one region of Swaziland. The prospective teachers were pursuing a diploma in primary teaching in order to become classroom teachers. Their ages ranged from 20 to 40, with the majority (83%) of the students falling in the 20-30 age range. The student teachers were enrolled for general biology, chemistry, physics and a science methods course, within the science programme.

This college was conveniently and purposively selected because it had introduced an explicit reflective NOS instruction in the teaching of the science course. It was therefore a suitable study sample for the investigation of the effectiveness of this approach in developing pre-service teachers' NOS views in Swaziland.

At the time of the study, the participants were enrolled for their final year of their three year teacher development programme. The pre-test results of this sample therefore also provided a rough estimate of the impact of the preceding science programme on the pre-service teachers' views of NOS. Such information is also valuable in making decisions on the type of programme that maybe most suitable for augmenting the elementary pre-service teachers' views of NOS.

Additionally, a focus group of seven students was purposively selected for an in-depth study. They will be referred to using pseudonyms. There were 4 female and 2 male participants. The female participants are referred to as Futhi, Fortunate, Hlobi, Londiwe and Sizakele; the males are referred to as Muzi and Themba. The selection for the smaller group was done in such a way that the study sample was composed of participants who have satisfied two conditions: (a) possessing almost identical and inadequate NOS views prior to instruction and (b) and also showing maximum difference in their gain in NOS conceptions.

3.3 Context of the study

The study took place in the context of primary teachers' science content course. At the time of carrying out the study, the major goals of the course as prescribed in the pre-service science syllabus document were to develop among the pre-service teachers:

- The ability to use and apply the processes of science.
- Scientific attitudes such as curiosity, scepticism and open-mindedness.
- An understanding of a body of scientific knowledge greater than that which they are required to teach.
- An awareness of the contributions of science to the society and some problems created as a result of unwise use of scientific discoveries and technology locally and globally.
- Abilities and confidence in the teaching of science at the primary school in ways that facilitate critical thinking skills, stimulate interest and learner' understanding of basic scientific concepts.
- A positive attitude toward science and the teaching of science.

The course was divided into two sections. One section dealt with the science content area including biology, chemistry, and physics, while the other focused on science teaching methods. NOS instruction was not taught as a separate subject but was integrated within the chemistry and biology content sessions. Each session had duration of one hour and was scheduled twice a week for a period of twelve weeks.

As it can be seen from the list above, the development of NOS understanding was not included as one of the major goals of the programme. The absence of such an important goal was probably based on an initial belief that students can develop an understanding of NOS as a consequence of carrying out the processes of science; that is through the implicit approach. On the contrary, the newly introduced NOS programme was based on a conviction that learning NOS is a cognitive learning outcome that must be explicitly planned for and taught. The aim of the evaluation was therefore to find out if there are any improvements in the prospective educators' understanding of NOS as a result of introducing the explicit reflective NOS instruction in the science teacher training programme.

3.4 The NOS intervention

As a science teacher educator I observed that the elementary prospective elementary teachers that I was teaching seem to harbour misconceptions about NOS. They were apparently unaware of the role of creativity and imagination in the development of scientific knowledge. They seemed to believe that scientific knowledge was solely based on observations or experiments. After a formal discussion with other members of staff in the department, a decision was taken that NOS should be made an essential part of the science curriculum in order to improve the pre-service teachers' understanding of how science works. Since several studies have provided evidence supporting the effectiveness of an explicit reflective approach in enhancing pre-service teachers' understanding of NOS (Akerson, Abd-El-Khalick & Lederman, 2000; McDonald, 2010), this approach was therefore adopted. To begin with, the NOS intervention was integrated in the teaching of biology and chemistry content.

Below is a description of the intervention. The aim of this study was to investigate the effects of the explicit reflective on the participants' NOS views. The intervention itself was not part of the study. It is only described here to enable the reader to understand the context in which this study was carried out.

The NOS intervention was aimed at augmenting pre-service teachers' understanding of NOS was based on a conceptual change framework and included the following aspects:

- An explicit attention to NOS issues.
- Both de-contextualised and contextualised activities.
- History of science episodes.
- Guided reflection.
- Self-regulatory strategies.

3.4.1 Discussion of students' prior ideas about the target aspects of NOS

In order to enhance dissatisfaction with prior naive conceptions and adoption of more informed views, participants were first engaged in discussions of their prior NOS conceptions that afforded them an opportunity to express, reflect and be challenged about their conceptions of NOS (Hammrich, 1997). For example, student teachers were asked to argue in small groups and in whole class discussions whether scientific knowledge is tentative or durable. Students were expected to provide a justification of their views. The activity that took two sessions was aimed at enabling them to identify the strengths, limitations, and consistencies or otherwise of their prior ideas (Hewson, Beth & Thorley, 1998 in Abd-El-Khalick & Akerson, 2004).

A summary of students' views was recorded by the instructor, and during the following session students were asked if the list represented their understanding of what science is and how it works. This was then followed by a whole class discussion of whether it was important to explicitly address such issues when teaching science as well as how NOS differs from the processes of science that they had previously learnt about.

3.4.2 Explicit reflective contextualised NOS instruction

In the context of learning biology and chemistry content, students were provided with learning experiences that were explicitly aimed at lowering the status their alternative ideas while raising those of the targeted ideas (Posner, Strike, Hewson & Gertzog, 1982). Through reflective questioning, student teachers were guided to reflect on the following NOS issues:

- Science as a human attempt to make sense of natural phenomena, rather than as a data gathering endeavour.
- The role of inference, creativity and imagination in the development of scientific ideas.
- The empirical and tentative nature of scientific knowledge.
- The subjective nature of the scientific endeavour.
- The influence of social and cultural values on the development of scientific knowledge.
- The different functions of scientific laws and theories.

3.4.2.1 Chemistry content

As part of the content learnt, students learnt about Dalton's atomic theory. In order to enable participants to understand how science works, the history of science approach was used. A short narration of the development of the idea that matter is made of particles originated and finally became the well accepted scientific theory of Dalton was discussed. This was aimed at enabling participants to realize the creative, imaginative as well the empirical elements of NOS. Still as a component of the NOS intervention, pre-service teachers were asked to either use the particulate or the continuous view of matter to explain a list of a variety of observations. The list included data relating the pressure of a gas to its volume. This was meant to help participants to view theories as "inferred explanations for observed regularities in nature" (Abd-El-Khalick, 2006. p.406), rather than actual representations of reality and to also appreciate that a new theory in science is accepted mainly based on its explanatory power or its ability to explain many different types of observations.

Also, as part of the requirement of the content programme, students investigated and discussed the laws of conservation of mass as well as the laws of definite proportion. This was again followed by a discussion of NOS issues. The context of the kinetic particle theory and the laws already discussed was used as context to reflect on the functions of, and relationship between, scientific laws and theories. Students were told that the description of the observed relationship between the pressure of a gas and its volume is called Boyle's law. To further lower the status of the belief that theories develop into laws, the sequence of events in the development of Boyle's law and the kinetic particle theory was narrated so students could reflect on the implausibility of the idea that theories develop into laws.

As an introduction to the model of an atom, Rutherford's content embedded activity (Abd-El-Khalick, 2002) was used as context to enable the pre-service teachers to reflect on the:

- Difference between observations and inferences.
- Role of inference, creativity and imagination in the development of scientific models.
- Empirical as well as the tentative nature of such models.

Rutherford's content embedded activity is of a black box type. It is used to illustrate to students how Rutherford used alpha (helium particles) to establish the planetary model of an atom, and consequently help them understand the abovementioned aspects of NOS (Abd-El-Khalick, 2002). The activity uses a large box that measures approximately 45cma side. Two opposite sides of the box are each cut along two vertical edges and one horizontal edge to get the sides to flip open like doors. The cutting is done in such a way that 1cm from the edge of the box remains. A sharp pencil is then used to punch holes around the edges of the box surrounding the open flaps on one of the cut sides. These holes are pierced at 7cm intervals. A thin wire is then used to form a 6 x 6 grid along this side of the box leaving a grid with 36 cells. Two holes are punched at the top of the box and another two opposite the two holes in the bottom of the box. Two glass rods are then passed through the holes in the top and bottom of the box and tied up so that they remain in a fixed position. Styrofoam balls are then taped onto the glass rods in any arrangement.

The whole set-up is then placed in front of students in a way that does not allow them to see inside the box. The students are then told that there is something inside the box, and their role is to figure out its shape, without looking inside. Students are given a Ping Pong gun to shoot balls across the inside of the box, through the grid on the side of the box, and according to whether the ball comes through the opening on the opposite side or not; the students infer the shape of the object inside the box. Prior to the activity, students are asked to come out with views about how they could systematize their data collection. The discussion is guided towards an agreement that drawing a 6x6 grid in their notebook, and recording with ticks and crosses to represent whether or not a ball comes through the box as it is shot through each cell in the grid, can be the best way of systematizing the data collection process. Students are asked to draw the image of the object in the box, based on the data they collected. Through guided reflection, students are led towards understanding that the marks on the grid in their exercise books represent their observations of whether the ball comes through the box or not, while the images drawn represents their inferences about the objects inside the box. This ultimately leads to a discussion of the difference between observations and inferences, and to the fact that "knowing is not always seeing". Students are therefore led towards an appreciation of the fact that scientists also use inference in the development of scientific constructs. Just as students come up with different images from the same set of data, it is possible for scientists to come with different inferences from the same set of data. The activity was therefore also used to discuss the role of creativity and subjectivity in making inferences.

Furthermore, the history of the development of the atomic model, starting from Thompson's model up to Bohr's model of an atom was discussed. Through questioning students were guided to reflect further on the aforementioned aspects of NOS and the role of theories in guiding further research (e.g. Rutherford's experiment was based on Thompson's idea of an atom). Students were also guided to reflect on the influence of prior ideas on the acceptance of newly developed theories (such as the influence of the plum pudding idea of an atom on the scientist's lack of acceptance of Rutherford's model, as well as the lack of belief on Plank's quantum theory on the acceptance of Bohr's model of an atom). The main aim of this discussion was to dispute students' prior belief that scientists are exceptionally objective people who readily let go of their prior ideas in light of new evidence.

In the context of discussing the history of the Periodic Table, students were required to identify laws that were put forward as a result of the classification of elements, such as the Law of Octaves and the Dobereiner's triads. Students were further asked to justify why these postulations qualify to be called laws rather than theories. They were also led to note the changes in the laws, with improvement in technology that allowed more accurate measurements or data collection. Students were also asked to state similarities and differences between the modern periodic table and the periodic table proposed by Dmitri Mendeleev in 1869. To reinforce students' understanding of the relationship between laws and theories, students were specifically asked to use Bohr's theory or model of an atom to explain the observed periodicity of elements, the Periodic Law. Students were also guided towards a realization of the limitations of theories, by discussing how Dalton's theory though helpful in finding the formulae of compounds, it cannot explain some observations such as the pattern of elements in the periodic table nor the fact that some atoms join together in elements to form compounds. The pre-service teachers were guided towards the understanding that different theories can coexist and be used to explain different aspects of a phenomenon.

3.4.2.2 Biology content

Most of the NOS issues that were related to the study were discussed within the context of learning genetics. Given the definition of genetics as the a field of science (biology) that attempts to explain both similarities and differences between parents and their offspring, students were asked to reflect on how this definition relates to the prior definition of what science is about. The discussion that followed focused on the attempts in science to make sense of observable phenomena by making generalizations and constructing explanations for them. Such explanation, called theories, must meet certain standards such as: an explanation proposed must be based on empirical evidence and must be open to falsification or modification. These criteria were then used to discuss how science differs from religion. The main aim of the discussion was to help students understand that the demand for empirical evidence is what distinguishes science from other ways of knowing and to appreciate that science and religion are not in conflict, but just separate ways of knowing. This was not however used as a data collecting strategy.

In the context of Mendel's monohybrid and di-hybrid experiments, students were guided to reflect further on the differences between observations and inferences. Students were asked to use Mendel's experiments to support or refute the statement that "knowing is not seeing" and also to state the role of experiments in the development of scientific knowledge. The discussion focused on the idea that Mendel never saw genes or chromosomes, but based on experimental evidence, he inferred that inheritance involves the transmission of such factors from parent to offspring via gametes, and that such factors existed in pairs. Students were asked to explain what they think caused the replacement of the prior view of inheritance as the blending of characteristics, and the implications of this for the nature of scientific knowledge.

After stating Mendel's first and second Laws, which were developed based on his experiments,' students were asked to state whether we are justified to call them laws. The aim of this prompt was to get students to reflect on similarity and differences between these laws, and the laws that they had previously encountered in chemistry such as the law of conservation of mass. Students were able to note that whilst Mendel's first and second laws were similar to the other laws as they describe regularities or patterns in the inheritance of traits in monohybrid and di-hybrid crosses respectively, they differ in that they are inferential rather than descriptions of regularities among observations.

To further develop the understanding of the different functions of laws and theories as well to further lower the status of the belief that theories develop into laws, the pre-service teachers were told that according to the history of genetics, Gregor Mendel presented his laws of inheritance in 1866 while the laws were only interpreted in terms of the chromosome theory, much later in 1915, as a result of studies conducted by Thomas Morgan and his co-workers (Lederman & Abd-El-Khalick, 1998). Pre-service teachers were then asked to debate whether or not the chromosome theory qualifies to be called a scientific theory and whether a law can develop into a theory.

In the context of learning about the human circulatory system, students were further guided to reflect on the empirical, inferential, creative and tentative NOS. For example, students discussed how Harvey used deductive reasoning to demonstrate that blood flows towards the heart in the cutaneous vein of the arm, hence refuting the original belief that blood in vertebrates was pumped from the heart and subsequently drawn back into it in the same vessels. Within the specific context of learning about the rhythmic contraction of the heart, students were asked to classify certain statements as observations or inferences, such as these two statements: 'the heart is known to continue beating rhythmically even after its nerve supply has been cut off'; 'the sino-atrial-node is the pacemaker'. Discussion of observational and experimental investigations used by physiologists to test the hypothesis that the sino-atrial node is the pacemaker were discussed in order to help student teachers appreciate the difference and the validity of both kinds of investigations in the development of scientific knowledge.

3.4.3 De-contextualised NOS instruction

The subjective, social and cultural NOS aspect, which the instructor felt was not comprehensively addressed within the learning of science content, was also discussed within the context of five de-contextualised learning activities (Appendix A) taken from literature: the "*Aging President, That is Part of Life!, Young? or Old? Rabbit or Duck, Mass Extinction controversy"* (Lederman & Abd-El-Khalick, 1998, pp. 23-27). The pre-service teachers in this study strongly held a view that scientific claims were developed by induction from experiments. It was therefore very difficult for them to accept the element of subjectivity in the generation of scientific constructs. It was hoped therefore that these de-contextualised activities would provide the pre-service teachers with an opportunity to deeply think about the nature of both observations and inferences. Also, because of the fact that these activities are not complicated by science content, it was assumed that they would promote a deeper engagement with the NOS issues.

Each activity was used to draw the pre-service teachers to the different aspects of subjectivity in science. The *Young? Old?* and the *Rabbit or Duck* activities were used to help the pre-service teachers understand that observations made when viewing a phenomenon are not completely objective, but are influenced by our "experiences, beliefs, knowledge and expectations" ((Lederman & Abd-El-Khalick, 1998, p. 23). *The Aging President* was used to draw pre-service teachers' attention to the role of our mind-sets on the way we interpret a phenomenon. It was also used to further emphasize that scientists do not eagerly abandon their theories even in light of conflicting evidence (Lederman & Abd-El-Khalick, 1998).

Pre-service teachers tend to view the elements of subjectivity as interfering with the otherwise supposed to be an objective endeavour. *That is Part of Life! Activity* was therefore meant to provide an opportunity for pre-service teachers to realize on their own the necessity of context in making sense of data. In this activity, students were required to read and interpret a text. To further emphasize the role of social and cultural context in making sense of observations, the story of evolution of man was narrated to students, where biosocial scientists postulated different theories to explain this evolution. In addition to these oral discussions, students were asked to read about the *mass extinction of dinosaurs* episode and were asked to write how it fits with the discussions that had already been done about NOS.

3.4.4 Self-regulatory strategies

Guided practice in metacognitive strategies was used to enhance participants' development of more informed views of NOS. This NOS instruction involved students in organizing their knowledge of NOS through concept mapping, and reflecting on their new NOS experiences through completing structured critical reflective journals (Kincannon, Gleber & Kim, 1999; Novak & Canas, 2008). Throughout the NOS instruction, participants were expected to revise their previous concept maps regularly so that they would reflect on and control their learning of the NOS concepts (Schraw & Denniso, 1994).

3.5 Data collecting Instruments

The major data collection instrument used in this study was a Views of the Nature of Science (VNOS-C), questionnaire originally designed by Abd-El-Khalick, Bell and Lederman (1998). The VNOS-C questionnaire is provided as Appendix B. Other instruments were an interview schedule, concept maps and document analysis. The open ended questionnaire was used to collect data that was used to assess the pre-service teachers' initial NOS and changes in their understanding of NOS after participating in the explicit reflective NOS intervention described in 3.3.2. Interviews, concept maps and reflective journals were meant for a smaller group that was selected from those who completed the questionnaire in order to gain more insights about teachers' NOS views and to explore the factors that enhance or hinder their development of more informed views.

3.5.1 The VNOS questionnaire

There are three original version of the VNOS questionnaire: VNOS-A, VNOS-B, and VNOS- C (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). Below is a description of the development of the VNOS instrument.

3.5.1.1 Development of the VNOS questionnaire

The VNOS A questionnaire

The first version of Views of Nature of Science (VNOS-A) questionnaire was developed by Lederman and O'Malley (1990) in response to general criticism levelled against traditional (e.g. multiple choice assessment) instruments (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Lederman, Wade & Bell, 1998). An open-ended questionnaire was seen as a better alternative as it reduces constraints on participants' responses allowing them to give honest detailed responses that result in a questionnaire that would provide richer data than closed questions (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Lederman, Wade & Bell, 1998). Such rich data is necessary to ensure deeper interpretations of participants' views (Vhurumuku & Mokeleche, 2009). This renders the open ended questionnaire a better instrument in assessing gains in NOS conceptions that arise from instructional interventions.

In order to validate the researcher's interpretations of participants' responses, administration of the questionnaire is followed up with individual semi-structured interviews. Interviews also enable the researcher to generate deeper profiles of participants' views, as a result of the opportunity to clarify and probe participants' responses (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002).

The VNOS-A questionnaire consists of seven items intended to assess different aspects of the tentative NOS (Lederman Wade & Bell, 1998; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002).

The VNOS-B questionnaire

Appraisal of the VNOS-A instrument revealed problems of validity with some of its items. Interviews revealed that three of the seven items did not assess the intended participants' beliefs (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Lederman, Wade & Bell, 1998). The instrument was therefore later revised by Abd-El-Khalick, Bell and Lederman (1998) which resulted into a second version of the instrument, VNOS-B that they used to assess pre-service "secondary science teachers' views of the empirical, inferential, creative, and theory laden NOS, and the functions of and relationship between theories and laws" (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002, p. 505). The VNOS-B questionnaire was subsequently used to investigate pre-service secondary teachers' (Bell, Lederman & Abd-El-Khalick, 2000) and pre-service elementary teachers' (Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick & Lederman, 2000) views of NOS.

The aforementioned studies provided evidence indicative of the validity of the instrument. Interpretations of participants' VNOS-B questionnaire responses were found to be more in agreement with views articulated by participants during interviews (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002).

The VNOS-C questionnaire

Abd-El-Khalick, Bell and Lederman (1998) further improved the VNOS-B instrument by altering four items, and adding five new items. This resulted in the VNOS-C instrument. The VNOS-C questionnaire is provided as Appendix B. Dekkers and Mnisi (2003) made use of a VNOS questionnaire that included items taken from both the VNOS B & C versions and adapted to the South African context. Their questionnaire included items that were aimed at investigating socio-culturally influenced conceptions of NOS.

3.5.1.2 The validity of the VNOS questionnaires

One way of establishing credibility of the findings is to ensure that the data collecting instrument is valid. Credibility refers to the adequacy by which the researcher represents the realities as revealed by the informants (Lincoln & Guba, 1985 in Krefting, 1991). The validity of an instrument is defined by Pietersen and Maree (2007, p.216) as the "degree to which an instrument measures what it is intended to measure". The VNOS-C instrument was scrutinized by a panel of five experts and its face and content validity was consequently established. The VNOS-B questionnaire, from which the VNOS-C instrument was expanded, was also tested for construct validity (Lederman, Abd-El-Khalick Bell & Schwartz, 2002). The instrument was administered to two groups of participants of nine each: an expert and an apprentice group. There was an apparent gap noted between the two groups with reference to their NOS views.

Moreover, three versions of the VNOS questionnaire (VNOS-A, B, and C) were used to assessalmost"2000 high school students, college undergraduates and graduates, and pre-service and in-service elementary and secondary science teachers across four continents. The questionnaires were coupled with 500 individual interviews" (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002, p.517). Dekkers and Mnisi (2003) used an adapted version of the VNOS questionnaire to assess NOS conceptions of South African teachers. Tan and Boo (2004) also investigated the NOS views of 125 Singaporean pre-service teachers using an adapted version of the same questionnaire. The results of the studies indicate that the VNOS instrument is highly valid for assessing NOS views of participants in many different contexts (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002).

The rich nature of VNOS responses as well as their ability to reveal slight differences in respondents' views makes the VNOS instruments particularly suitable for assessing even minor changes in participants' NOS views that could arise from instruction designed to augment participants' NOS views. It can also be useful in investigating the impression of different activities undertaken in the intervention on participants' conception of NOS (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002).

3.5.1.3 Reliability of the VNOS questionnaires

Pietersen and Maree (2007) state that an instrument is reliable if it yields similar findings when administered to different subjects from the same population or when administered to the same individuals at different times. All the VNOS versions have been shown to be reliable as they have been found to generate consistent findings in similar settings. Participants' conceptions of NOS as expressed in the VNOS-C questionnaire were found to closely match those revealed during interviews (Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick & Lederman, 2000; Kukuk, 2008; McDonald, 2010). Lederman, Abd-El-Khalick, Bell and Schwartz (2002) therefore argue that validation of an instrument is "an on-going process rather than a once off stance" (p.512).

Having discussed the strengths of the VNOS questionnaires in assessing pre-service teachers' NOS views, it is however worth mentioning that the questionnaire has also been shown to have some weakness. Alchin (2011) points out, for example, that the NOS conceptions assessed by these instruments are not relevant to the main reason for promoting a scientifically literate society. Alchin argues that rather than focusing on assessing recall or comprehension of a list of tenets, it is better to assess participants' understanding of science in the context of personal and social decision making. In spite of the criticisms, the VNOS questionnaire was used in this study because the researcher felt the questionnaire was relevant to the NOS ideas investigated and also because of its established validity and reliability in different contexts.

3.5.1.4 The VNOS questionnaire used in the current study

The current study employed an adapted version of the VNOS-C questionnaire (Appendix C). Most of the items used in this instrument were adapted and used by Dekkers and Mnisi (2003) to assess South African teachers' understanding of NOS. Based on the results of the pilot study, the questions used by Dekkers & Mnisi were evidently more relevant to the participants than the relatively more original versions of the instrument. The participants struggled to understand the questions asked in the context of species and dinosaurs. However, such a challenge was not observed when these items were replaced by the more familiar AIDS context used by Dekkers & Mnisi in assessing South African teachers' NOS views.

The questionnaire consisted of nine questions assessing participants' views of the tentative, empirical, inferential, creative, theory laden NOS, the social and cultural influences on the scientific enterprise, as well as the functions and relationships of theories and laws. Dekkers and Mnisi (2003) did not include the items (present in the VNOS-C) that investigated teachers' understanding of experiments and their role in science. The researcher in this study felt it was necessary that prospective teachers' understanding of the experimental NOS was ascertained as this is closely linked with the understanding of the inferential, creative as well as tentative NOS. Kukuk (2008) observed in his study that pre-service teachers' realist view of scientific models stemmed from their lack of understanding of the role played by experiments in science. Table 3.1 shows the items that assessed the different aspects of NOS in the current study.

Table 3.1 Questionnaire items assessing the target aspects of NOS

NOS aspect	Questionnaire Item
Empirical	1, 3, 4, 6
Tentative	1,2, 3, 4, 5, 6
Inferential and theoretical entities in science	1, 2, 3,5, 6,
Creative / imaginative	1, 2, 4,5, 6, 7
Theory laden NOS	8 & 9
Social and Cultural influences on scientific knowledge	8 &9
Functions of and relationship between laws and theories	4 &5

In line with Lederman, Abd-El-Khalick, Bell and Schwartz's (2002) recommendation, the questionnaire was administered during class time, under supervision. It was emphasized that there were no right or wrong answers to the questions. This was to ensure that the data collected was consistent with the pre-service teachers' views about NOS rather than getting the information from a relevant document. It also provided the researcher with an opportunity to assist with issues in the questionnaires which were not clear to the participants. The pre-service teachers were requested to be as elaborate as they could in response to each question; hence there was no time restriction (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002).

3.5.2 Interviews

The administration of pre- and post-instruction VNOS questionnaire was followed by individual interviews of three and seven participants respectively in order to gain more insights into the pre-service teachers' NOS views. Moreover, the interpretive stance of the study also made it crucial to ensure that participants' responses are not wrongly interpreted. Even though Lederman, Abd-El-Khalick, Bell and Schwartz (2002) recommend that a researcher who is using the VNOS instrument for the first time should interview more than 20% of the participants in order to better interpret respondents' views, this could not be done in this study. The number of participants interviewed was mainly determined by the number of participants who were willing to be interviewed. Although in response to the letter of consent all participants indicated a willingness to be interviewed, when they were approached following completion of the VNOS questionnaire, most of them were no longer confident enough to be interviewed prior to the intervention, in spite of having been assured that there were no wrong or correct responses. This drawback was hence made up for by disregarding responses that could not be interpreted by further help from the participants. These were categorized as 'cannot be categorized' responses similar to the categorization by Tan & Boo (2004).

During the interview sessions, participants were asked the same questions from the VNOS instrument (Appendix D). They were also asked to clarify, and give reasons for their views. Follow up questions were utilized to ascertain participants' sense of crucial terms and statements, and to follow up ideas raised in the questionnaire (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). Validity is established when the researcher's understanding of participants' conceptions being revealed by the VNOS questionnaire responses, closely match those explicated by respondents during interviewees. For example, one participant, in his VNOS post survey responses pointed out that scientists were certain about the structure of the atom. This was initially interpreted as an indication of the participants' absolutist view of scientific models. However, the follow up interview refuted this inference. It transpired that the participant did not mean scientists had shown the structure to be true beyond any doubt, rather that they had reasonable confidence on the structure as it is well supported by evidence.

Secondly, in order to ascertain participants' perceptions of their changes in NOS conceptions or lack of such change as well as other factors that have a bearing on their development of NOS, the researcher interviewed seven pre-service teachers who were selected based on their differential gains in their understanding of NOS and their willingness to be interviewed (Abd-El-Khalick & Akerson, 2004). Previous studies have revealed certain factors that impact on pre-service teachers' development of more informed NOS views (Abd-El-Khalick & Akerson, 2004; Kattoula, 2008; McDonald, 2010; Schwartz, Akom, Skjold, Hong, Kagumba & Huang, 2007). The interview schedule was therefore guided but not limited by these factors. The interview schedule (Appendix E) was semi structured and consisted of 12 questions. Among these were questions aimed at soliciting participants' perceptions of the course, including whether they felt their NOS views have changed as a result of the course, and what they felt contributed much in their changes, or lack of changes, whether they found learning about NOS important, as well as their perceptions about the best ways of learning and teaching science, and their views about science and religion. At the end, participants were also interviewed about their responses to the post-intervention VNOS questionnaire.

3.5.3 Concept maps

As part of the requirement of the programme, the pre-service teachers had to draw a concept map depicting their NOS views. Participants were given a list of key words to use in constructing the concept map. The participants made the concept maps prior to instruction and were expected to revise them after each session until the end of the study. The concept maps for the focus group were used to provide further evidence for these participants' understanding of NOS both prior and after instruction. According to Novak (1990 in Shavelson, Lang & Lewin, 1993), an understanding of a concept is represented by all propositional linkages that the student can create.

3.5.4 Document analysis

3.5.4.1 Structured critical reflection journals

Students kept structured critical reflective journals where they wrote down their reflection of each learning experience and how it impacts on their understanding of NOS. This was to be done after each session. Participants were given a list of questions to guide them in their reflection (Appendix F). Based on these daily reflections, student teachers wrote a final journal on their overall perceptions of the course and how they believed the knowledge gained was useful to them and their future teaching. The reflective journal as well as the post intervention interview transcripts of the selected group of participants served as a data source on participants' self-perceptions of changes in their NOS views, what brought about changes in their NOS views, as well as their reflection of the usefulness of the knowledge learnt.

3.5.4.2 Instructor's journal

The instructor also kept journal where she wrote down the NOS concepts covered in each lesson and the method used to address them. She also wrote down her own reflections of each session of the programme. This included reflective notes on her perception of the effectiveness of the various learning experiences in developing students' interest and understanding of the various NOS concepts. Students' difficulties, comments, questions raised, and elaborations of NOS issues were also noted. Such information was used to interpret student teachers' development or lack of development in their understanding of the different aspects of NOS addressed in the programme.

3.6 Data analysis

In order to ensure clarity, data analysis is discussed according to the guiding research questions.

3.6.1 Assessing initial and changes in participants' NOS views

3.6.1.1 Analysing participants' responses to the VNOS-C instrument

Analysis of participants' responses to the VNOS-C questionnaire occurred in three phases recommended by Lederman, Abd-El-Khalick, Bell & Schwartz (2002). The first phase was meant to establish the validity of participants' responses to the questionnaire. Each questionnaire of the interviewed students was searched for students' views of the empirical, inferential, tentative, theory laden, creative, the universal scientific method, and the social and cultural NOS. The information derived from this stage of analysis was used to create a profile of participants' views of NOS. The corresponding interview transcripts were similarly analysed. The system of using previously determined themes in the data is called prior coding and is used to provide direction of what to look for in the data (Nieuwenhuis, 2007). The two separately created summaries were subsequent compared to check if participants' conceptions of NOS as revealed by the questionnaire were matching those articulated during interviews. Lederman, Abd-El-Khalick, Bell and Schwartz (2002, p.517) emphasise that "even though the face and content validity of the VNOS instrument was established, its major source of validity is derived from the follow up interviews" which allows the researcher to directly check the respondent's meaning of each item in the questionnaire as well as his or her interpretation of these responses.

Secondly, all students' questionnaires were similarly analysed to create a profile of each student's NOS views regarding the target NOS aspects. Each profile was subsequently categorized as: informed, partially informed or inadequate. A participant's view was categorized as partially informed if it was in line with the generally accepted current view of NOS. For example, a student's response that either clearly pointed out that scientific knowledge change as a result of newly collected evidence, or reinterpretation of old evidence, was categorized as having an informed view. However, a student who stated that scientific knowledge is tentative because of its empirical, creative or subjective character, without further pointing out what could cause the change was categorized as having a partially informed view of the tentative NOS. A student who stated that "theories will never change" was classified as having an inadequate view of the tentativeness of science.

A response that point out that theories change but with a reason that is inconsistent with the basic premise of science such as “theories change because the world is also changing”(Abd-El-Khalick & Akerson, 2009, p. 2171) or one that reveals a misconception of the nature of theories, was also classified as inadequate (Elby & Hammer, 2001). Similarly, a student who stated that theories change because they are generalized opinions, not supported by data or evidence, was classified as having an inadequate view of the tentative NOS (Abd-El-Khalick, 2001). Such a method of categorization is similar to the one used by Akerson, McDuffie and Morrison (2006) and Abd-El-Khalick and Akerson (2009) when they studied pre-service elementary teachers' development of NOS understanding. A table showing the coding method of categorizing participants' views as informed, partially informed and naive is included as Appendix G.

Participants' responses to different items in the questionnaire were scrutinized for any evidence that would confirm or negate the generated categories and modifications were made accordingly. For example, a participant who states in response to item 7 of the questionnaire that interpretation of data is subjective due to prior knowledge or ideas, while in response to item, 8, he or she points out that science is free of social and cultural influences was ultimately categorized as having a partially informed view of the role of subjectivity in science.

Thirdly, numbers and percentages of pre-service teachers with different categories for each NOS aspect were calculated. The same procedure done for the pre-instruction data was repeated for the post-instruction data at the conclusion of the study. The obtained data was used to obtain frequency distribution tables representing the numbers and percentages of pre-service teachers with the different categorized views for each NOS aspect before and after instruction. In order to compare the development of participants' understanding of the various aspects of NOS as a result of the intervention, the percentage difference in the number of participants having informed views prior and after instruction was calculated and tabulated.

Lastly, in order to ascertain how the pre-service teachers' views of NOS develop from pre- to post-instruction, the obtained numbers of participants with the different categorized views before and after the NOS intervention was entered into a computer and analysed to obtain bar charts. To establish if there were statistically significant changes in participants' understanding of NOS from pre- to post-instruction., a Chi-square test was used to compare percentages of participants with inadequate, informed and uncategorized for & Arslan, 2011; Khisfe, 2008). The test was carried out at 5% level of significance. The Chi-square test was chosen because the study sample was not randomly selected (Mthethwa, 2007).

3.6.1.2 Analysing concept maps for NOS conceptions

A qualitative approach was used to analyse the pre- and post-instructional concept maps for the focus group in order to get deeper insights into changes in students' NOS understandings. Each student's set of concept maps was searched for propositions that indicate the following:

- Correct conceptions of NOS.
- Gaps or missing connections in student's knowledge.
- Misconceptions.

Changes in NOS views were searched by directly comparing the pre- and post-instruction students' summaries. The observed changes in NOS views were described qualitatively to provide the quality and extent of students' changes in NOS views. Qualitative descriptions of new correct conceptions that students were able to make after instruction provided further indication of the effects of the intervention on students' conceptions of NOS (Rye & Rubba, 2002).

3.6.2 Analysing data for participants' perceptions of the elements of the course that influenced their development of NOS understanding

Students' responses to exit interviews and students' reflective journals were analysed using an emergent coding technique (Miles & Huberman, 1994 in Quigley, Pungsanon & Akerson, 2010). Firstly, the exit interview data and students' journal were searched for statements that indicate the pre-service teacher's reasons for changes or lack of changes in their NOS views. A statement would be a paragraph, sentence, a group of sentences, or a phrase. Secondly, each of the highlighted portions was grouped into categories according to the type of reasons for changes in NOS views. The numbers of students, falling into each category of reasons were then counted, to get an indication of participants' self-perceptions of the influence of the various course elements, as well as other factors impacting on the development of their NOS understanding.

3.6.3 Analysing data for factors impacting on participants' development of more informed NOS views

The analysis was done by searching for themes that helped to explain the observed differential gains in NOS conceptions. It involved contrasting analysed data from concept maps, reflective journals, reflection papers, interviews transcripts, and other artefacts of participants with significant gains in NOS views with those who made comparatively minor gains. Themes that were found to be common among the students who gained more informed views, and absent in the case of the other group, with less gains in such views, were assumed to be the factors affecting participants' development of more informed NOS views. On the other hand, themes that were found to be common among the less successful group in terms of developments of more informed views were taken to be factors that inhibited such developments. The analysis venture was guided but not limited by the conceptual framework of the study. A similar method of analysis was used successfully by Abd-El-Khalick and Akerson (2004) when they assessed factors affecting conceptual change among elementary pre-service teachers.

3.7 Methodological Norms

The merit of a qualitative study depends upon its trustworthiness (Nieuwenhuis, 2007). By a qualitative study, the researcher refers to a study that seeks to understand a phenomenon from its natural, context-specific setting (Golafshani, 2003). The trustworthiness of study is an assessment of its worth as evaluated by peers, reviewers and readers (Krefting, 1991). Guba provides one conceptual model that can be used to ensure the trustworthiness of study findings (Shenton, 2004). Guba's conceptual model proposes that a qualitative researcher should guarantee that his or her study findings are credible, confirmable and dependable as well as transferable (Shenton, 2004).

3.7.1 Credibility

Credibility, which is similar to internal validity in quantitative research, is one of the most important criteria for ensuring trustworthiness (Guba & Lincoln in Shenton, 2004). Jansen (2007) asserts that the credibility of a qualitative study is established when researcher's explanation of a phenomenon matches reality. Shenton (2004) points out one way of making sure that your study findings are credible is to use data collecting methods that are appropriate for assessing the construct under consideration (Shenton, 2004). For that reason, the main data collecting instrument used to assess the participants' NOS views in this study was adapted from the VNOS-C questionnaire designed by Abd-El-Khalick, Bell & Lederman (1998). According to Lederman, Abd-El-Khalick, Bell and Schwartz (2002), the VNOS-C was scrutinized by a panel of five experts and its face and content validity was consequently established. The VNOS-C instrument, the interview schedule, and the reflective journal questions were also assessed by the supervisor and independent critical readers; themselves experienced researchers, in order to ensure their face and content validity.

3.7.2 Transferability across contexts

Shenton (2004) further asserts that in order for study findings to be credible, the researcher must ensure that the data collecting and analysis methods stem from those that have been used in similar earlier studies. The VNOS instrument, the concept maps, interviews, document used to collect data in this study have been previously used by several studies in assessing participants' NOS views or reasons for changes in their NOS understanding. The major research instrument, the VNOS-C instrument has been used by many different studies in different context to assess pre-service teachers' and teachers' NOS views Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick & Lederman, 2000; Kukuk, 2008; McDonald, 2010; Tan & Boo, 2004). According to Lederman, Abd-El-Khalick, Bell and Schwartz (2002), the results of the studies indicate that the VNOS questionnaire is highly valid for assessing NOS conceptions of participants in many different contexts.

The validity of the VNOS instrument in this study was also checked by administering the instrument to a smaller sample before carrying out the main study. Firstly the original VNOS-C instrument by Lederman, Abd-El-Khalick, Bell and Schwartz (2002) was given to a group of four pre-service teachers who were not among participants of the main study. The main purpose of this pilot study was to test the clarity of questionnaire items to the pre-service teachers. Items 7 and 8 were either unanswered or the responses were ambiguous. The participants pointed out that they did not understand these two items. The students struggled in understanding the concepts (species and dinosaurs) used as context in the two items. It was therefore concluded that these questions were inadequate in ascertaining the current study participants' understanding of the role of creativity and imagination in the development of scientific constructs. For that reason, the researcher replaced Q7 with the item from the version of the VNOS used and validated by Dekkers and Mnisi (2005) in the South African context.

Even though Dekkers and Mnisi (2003) point out that the use of the HIV/AIDS controversy did not necessarily lead to clearer responses from the participants in their study, the researcher opted for it as the HIV controversy was believed to be more meaningful to the Swaziland pre-service teachers than the dinosaur extinction controversy. Also, similar to Dekkers and Mnisi, the question on species was excluded as all of the four participants could not understand it; hence it could not serve the desired purpose.

The researcher believed that the pre-service teachers' conceptions of the empirical, tentative, inferential, imaginative and creative nature of scientific knowledge could be established in the context of the atomic theory which seemed to be familiar to all the students. In line with this belief, Abd-El-Khalick (2001) noted that pre-service teachers who participated in his study were more able to explicate clearer conceptions of these various targeted conceptions of NOS within the familiar atomic theory context than in the relatively less familiar dinosaurs' context. Also, students' responses indicated that they did not hold the common naive notion that theories were lesser supported by empirical evidence compared to other aspects of scientific knowledge. Thus their responses to this question could be used to make a generalization of whether they understood scientific knowledge as tentative or not. Moreover, participants' views of the differences between laws and theories were also used to ascertain the validity of this assertion.

The questionnaire was further piloted with a group of 10 students who were doing either doing their first or second year of the three year teacher training programme, and were therefore not part of the main study. The pre-service teachers were asked to mention questions that did not make sense to them. All students were able to answer all the questions, and did not point out any problems in interpreting them. It was hence concluded that the questionnaire was acceptably valid in assessing the participant pre-service teachers' views of NOS. The pilot group's responses were however not included in the results of this study.

3.7.3 Dependability

Another way of establishing the trustworthiness of a study is to ensure its dependability. Dependability is a construct that is similar to reliability in quantitative research (Golafshan, 2003; Shenton, 2007). Durrheim and Wassenaar (2002, p. 64) define dependability as the degree to which the reader can be convinced that the study findings represent what really occurred.

One way of ensuring the dependability of study findings is to make use of triangulation in the collecting and analysis of data. Stake (2000, p.443) defines triangulation as a process of using a variety of perceptions in order to gain insights into a phenomenon or to test the repeatability of an observation or interpretation of data. "One form of triangulating is to make use of different data collection methods in order to compensate for their individual limitations and exploit their respective strengths" (Shenton, 2004, p.65).

In this study, triangulation was applied by following up the administration of the survey questionnaire with an in-depth, one- to- one interview with some of the participants. This was done in order to ensure that the researcher's interpretations of participants' responses to the VNOS questionnaires were accurate and dependable. After separate analysis of the questionnaire and interview transcripts was done, the two profiles were compared to see the extent to which they agreed with each other. In cases where a satisfactory agreement between the profiles was not initially met, the researcher modified her interpretations of the VNOS questionnaire responses such that they match those articulated by participants during interviews (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). Lederman, Abd-El-Khalick, Bell and Schwartz (2002) assert that construct validity is established when the two profiles match. As it was not possible to interview all participants, questionnaire responses that could not be interpreted without the help from the participants were disregarded.

In the case of the focus group, the analysed data from interview transcripts, reflective journals, VNOS-C responses and concept maps, were triangulated to develop a single profile of changes and reasons for changes in views of NOS for each of the seven participants. In case of disparities between perceived changes, and those identified through the analysis of pre- and post-intervention VNOS responses and concept maps, all data was reviewed again for confirmatory and contradictory evidence. Students' perceptions of their changes in NOS views took precedence in cases where disparities were not resolved (Schwartz, Lederman & Crawford, 2004).

3.7.4 Confirmability

Confirmability or neutrality refers to the degree to which "findings emerge from the data and not the researcher's own predispositions" (Shenton, 2007, p.63). Confirmability in this study was ensured by fully transcribing all interviews, and by also including some of the raw data as direct quotes from the transcripts in addition to the researcher's interpretation (McDonald, 2010). Furthermore, scrutiny of the project by the supervisor as experienced researcher helped the researcher to improve her data collecting methods as well as her inferences (Shenton, 2007). Transferability or external validity of the study findings was established by providing a rich description of the participants, the context of the study, the NOS intervention as well as explanations of why it worked in this particular context (Maree & Westhuizen, 2007, p.37). The context-bound nature of this research does not however, allow context free generalizations of its findings (Van der Akker, Gravemeijer, McKenney, & Nieveen, 2009).

3.8 Ethical considerations

The University of Pretoria, Faculty of Education, demands high standards of ethical practice during the conduct of educational research. One of main responsibilities of the Faculty's Research Ethics Committee is to ensure that the human rights and dignity of all human respondents are respected in the whole research process. In line with this point of view, Cohen, Manion and Morrison (2008) assert that researchers must treat all study participants with respect rather than simply as means to an end. In order to ensure this respect of human respondents, the Research Ethics Committee has prescribed certain principles of ethical practice that all researchers need to adhere when carrying out their investigations.

First and foremost, it is ethically imperative that the researcher ensures that participation in the research is voluntary and that participants are always free to withdraw at any stage of the research process. To ensure voluntary participation in this study, letters were written, first to the relevant authorities (Appendices H and I) seeking permission to carry out the study in the institution. The letters were accompanied by a form that afforded the authorities the freedom to either decline or consent that the study be conducted at the institution. After permission was afforded, letters (Appendices J and K) were written to all pre-service teachers that were within the purposively selected sample, inviting them to participate in the study. A letter was also written to the instructor (Appendix L), requesting permission to make use of her teaching journal. The letters were also accompanied with a letter of consent in which it was clearly stated that their participation was voluntary and that they could withdraw from the research at any time. As a result of this voluntary participation, 24 out of a total of 26 pre-service teachers participated in the study.

Although it was emphasized to students that their participation was voluntary and that they could withdraw at any time, some pre-service teachers could have felt coerced to participate because of the relationship they had with the researcher as their educator and because of the power the researcher's position as an educator has over them (Anderson, 1998). They might have also felt that their consent or failure to do so would have consequences for them, such as impacting on the appraisal of their academic performance (Anderson, 1998; Kubanyiova, 2008). The researcher therefore did not participate in the teaching and assessment of the group's academic performance. In addition, the researcher made every effort to be responsive to participants' nonverbal indications of a desire to discontinue if the person seemed to have a problem with communicating such a desire (Kubanyiova, 2008).Consequently, participants who had initially indicated a willingness to participate in the follow up interviews were not compelled to do so when they later showed signs of discomfort.

Secondly, the ethics of research requires that the researcher obtains informed consent from the participants of the study, including the authorities of the institution where the research is taking place. Informed consent refers to the "procedures that a researcher needs to follow in order to ensure that participants are well informed of all facts necessary to enable them to make a decision about whether or not to participate in a study" (Cohen, Manion & Morrison, 2008, p. 52). In order for adhere to this code of ethics, all request letters clearly stated the purpose of the research and the time of the year it was to take place. The letters were accompanied by a form that afforded the authorities the freedom to either decline or consent that the study be conducted at the institution. The participant pre-service teachers were also informed about all aspects of the study, including its purpose, how it would benefit them, as well as how they would be involved. An opportunity for participants to ask questions was also afforded so that they could be able to make an informed choice of whether or not to participate. Each of the prospective teachers who were willing to participate in the study then completed a letter of consent.

Thirdly, researchers are ethically obliged to ensure participants' right to privacy (Cohen, Manion & Morrison, 2008). The participants' confidentiality and anonymity was safeguarded at all times in this study. None of participants' names were made known publicly. In the case of the focus group of students selected for an in-depth study, pseudonyms were used. The name of the institution was also not made known publicly, only the name of the country. As a result, any information in the letters of consent that could reveal the identity of the institution was deleted.

Fourthly, it is the duty of the researcher that participants are not harmed or exposed to any form of danger as a result of the investigation. In this study chances of participants being harmed were minimal. However, in order to prevent participant pre-service teachers from feeling distressed on noticing that their NOS views were inadequate, they were assured that the research information will only be used for research purposes. They were also informed that they were free to contact the researcher in order to improve their knowledge. Additionally, in order to prevent participants being hurt as a result of their artefacts (assignments) or questionnaires or interviews being seen by a third party, these sources of data were kept safe in a locked cabinet. The researcher also ensured that participants' views of NOS were not discussed with anyone else, not even the instructor of the NOS programme.

Lastly, it is also ethically necessary that researchers are honest and do not deceive participants in any way during the course of the study. The researcher therefore made every effort to be always truthful to participants. Debriefing after an interview was afforded to all interested participants (Maree &van der Westhuizen, 2007).

3.9 Summary

This study made use of a pretest-posttest design to investigate the effects of an explicit NOS approach on an individual science classroom of Swaziland elementary pre-service teachers. It made use of an adapted version of the VNOS-C questionnaire in concurrence with individual interview to assess the pre-service teachers' understanding of NOS before and after participating in a NOS intervention. At the end of the NOS intervention, 7 participants who had achieved different gains in NOS understanding participated in an exit interview. The selected group's concept maps and reflective journals and assignments were also collected for analysis. These sources of data were used to ascertain factors that have a bearing on their growth in NOS understanding. The subsequent chapter presents the results of the study from the analysis of both qualitative and quantitative data.

CHAPTER FOUR

THE RESULTS OF THE STUDY

4.0 Introduction

This chapter provides the findings of the study. Both qualitative and quantitative aspects strategies were used to analyse data. The results are described according to the research questions and are presented in the following sequence:

- Pre-instruction NOS views,
- Post-instruction NOS views,
- Pre-service teachers' report of the influence of course components on their NOS views, and
- Factors mediating pre-service teachers' NOS views.

Instead of the real names of participants codes will be used. The code 'P' is used to refer to the participants and the number following the code refers to a specific participant.

4.1 Pre-instruction NOS views

This section presents the pre-service teachers' pre-instruction NOS views. The views are based on the quantitative and qualitative analysis of the participants' responses to the questionnaire and follow up individual interviews. The quantitative data is presented first.

4.1.1 Numbers and percentages of pre-service teachers with informed, partially informed and inadequate conceptions of the highlighted aspects of NOS

A total of 24 pre-service teachers completed the VNOS questionnaire. Participants' views were categorized as informed, partially informed or inadequate. A participant's view was categorized as 'adequate' if it was in line with the generally accepted current view of NOS, while a view that contradicted current conceptions of NOS was categorized as 'inadequate'. However, a participant who displayed an incomplete understanding of the target aspect of NOS was categorized as being 'partially informed' (Abd-El-Khalick & Akerson, 2009; Akerson, McDuffie & Morrison, 2006). Participants' views that could not be interpreted were categorized as 'cannot be categorized' (Tan & Boo, 2004). The categorized views of each aspect of NOS and illustrative examples are provided as Appendix F. Table 4.1 shows the number and percentage of participants categorized as having 'informed', 'partially informed', 'inadequate' and 'cannot be categorized' views of the different target aspects of NOS.

Table 4.1 Number and percentage of participants with informed, partially informed, inadequate and uncategorized views of emphasized aspects of NOS

NOS Aspect	Number of Students				TOTAL
	Informed	Partially Informed	Inadequate	Cannot be categorized	
Empirical NOS	4(16.7%)	5(20.8%)	15(62.5%)	0 (0%)	24
Observations versus inferences	0 (0%)	4 (16.7%)	19 (83.3%)	0 (0%)	24
Scientific laws versus theories	0 (0%)	4 (16.7%)	20 (83.3%)	0 (0%)	24
Universal scientific method	9 (37.5%)	8 (33.3%)	7(29.2%)	0 (0%)	24
Creativity and imagination in the development of theoretical constructs	1 (4.1%)	2 (8.3%)	21(87.5%)	0 (0%)	24
Subjectivity	1(4. 2%)	7 (29.2%)	15(62.5%)	1(4.2%)	24
Social and cultural Influence	1 (4.2%)	1(4.2%)	21 (93.3%)	1 (4.2%)	24
Tentative NOS	0 (0%)	0 (0%)	24 (100%)	0(0%)	24

As revealed in the table, a high percentage of pre-service educators held inadequate views of most of the explored NOS aspects exclusive of the role of 'creativity and imagination in the design and collection of data'. In the main, the pre-service teachers held the traditional positivist view of NOS. Science was viewed as an objective endeavour that is solely based on observable facts without the involvement of human inference, creativity and imagination. This explains why most participants held a realist view of scientific knowledge. They believed that scientific theories and models were actual representations of reality and are therefore not subject to change as indicated by the illustration below:

"Because science is nature, and the theories are there in nature, and I think that is why these theories do not change easily because it is something that is there and they just discover them"(P 1, pre-interview*).*

4.1.2 A description of the pre-service teachers' views of each aspect of NOS prior to the intervention

The next section is an account of participants' conceptions of each emphasized NOS aspect ahead of the NOS intervention.

4.1.2.1 Empirical NOS

Only four (16.7%) of the participants articulated informed views of the empirical NOS. These prospective teachers correctly pointed out that what sets science apart from other ways of knowing such as religion and philosophy was that scientific claims are supported by empirical evidence as illustrated below:

"In most cases science come into conclusions after having conducted a research or an experiment in anything they do. This research can come in a form of observation some time" (P3, pre-questionnaire).

A large percentage (62.5 %) of the participants however held views that were categorized as inadequate. Most of them stated that scientific knowledge is a body of proven facts or truths as demonstrated by the following response:

"I think science is different because we have got some facts while other enquiries consist of non-proven facts" (P1, pre-interview).

Consistent with this view of scientific knowledge, experiments were inadequately regarded by 67% of the participants as activities aimed at verifying already known facts rather than an inquiry method aimed at finding evidence that may support or falsify scientific claims.

"An experiment is a practical activity carried out by an experimenter to prove some well-known facts. The facts are already known before you carry out the experiment" (P2, pre-questionnaire).

> *"Yes, it is a matter of proving; like when you are conducting an experiment to prove that sunlight is necessary for photosynthesis, you already know that sunlight is required for photosynthesis, but you just want to prove that fact"* (P2, pre-interview).

This inadequate conception of the experimental NOS is also indicated by one participant who could not explain the role of empirical evidence in cases where the phenomenon cannot be directly investigated.

> "*The fact that we cannot see the protons makes us not to be sure if scientists really had that evidence about the atom or it was their creativity and imagination which led to the formation of the structure of the atom"* (P19, pre-questionnaire).

Some participants held a partially informed view of the empirical NOS as they noted that scientific knowledge develops by means of carrying out processes such as formulating hypotheses, experimenting, observing, and inferring. These participants, however, did not point out that the demand for empirical evidence is what sets science apart from other ways of knowing.

> "*Scientists gain scientific knowledge by using different ways of thinking such as formulating hypothesis, experimenting (observing) and inferring*" (P12, pre-questionnaire).

4.1.2.2 Observations versus inferences

In line with the participants' view of science as representing facts about natural phenomena, none of the participants held an informed conception of the role of inference in the generating scientific claims. A large percentage (79.2%) of the participants inadequately believed that theoretical models are exact copies of natural phenomena discovered through experimentation or direct observations rather than human interpretations of indirect experimental evidence. As a result of this "seeing is knowing view" (Akerson, Abd-El-Khalick & Lederman, 2000, p.306), they believed scientists were sure of the structure of an atom as illustrated by the following responses:

> "*Scientists are sure about how an atom looks like because they took their time investigating, analysing, and experimenting about it, and as a result they discovered its structure*"(P7, pre-questionnaire).

> "*Scientists used microscopes to determine how an atom looks like*" (P8, pre-questionnaire).

4.1.2.3 Functions of and relationships between scientific theories and laws

As in most studies on pre-service teachers' views (Akerson, Abd-El-Khalick & Lederman, 2000; Kukuk, 2008; Yalvac, Tekkaya, Cakiroglu & Kahyaoglu, 2007), participants were ignorant of the functions of and the relationship between scientific laws and theories. Only four (16.7%) of the participants held partially informed conceptions of this NOS aspect as illustrated by the following responses:

> "*A scientific law is a description of an observed phenomenon. The law of the planetary motion is one of the good examples. The law describes the motion of the planetary motion but does do not explain why the motion is there. On the other hand, a scientific theory is an explanation of an observed phenomenon"* (P5, pre-questionnaire).

> *"A law is a description of a phenomenon observed, without giving much details why this occurs, while a scientific theory describes the phenomenon and explains why this is so. One example of a scientific law, is Kebler's law of motion, he only describes the motion without giving much detail"* (P2, pre-interview).

The rest of the participants seemingly were unaware of the different roles of the two constructs and how they relate to each other. Consequently, they expressed many different inadequate or partially informed views. Thirty three percent of the participants believed that laws are unchanging truths about natural phenomena. They however viewed theories either as facts that scientists have discovered through carrying out investigations or as scientists' mental constructions of natural phenomena which are however well supported by empirical evidence. It is however worth noting that even though these two groups of participants held different views about the role of theories; some believing theories area representation of reality while others viewed them as scientists' construction of reality, they all commonly believed that theories are subject to change. Such an outlook of theories and laws is demonstrated in the following participants' VNOS responses, categorized as inadequate views of the functions of and relationship between theories and laws.

> "*I think there is a difference. A law is what science cannot change while a theory is what they have tested; different answers are possible depending on conditions*" (P9, pre-questionnaire).

> *"A scientific theory can be changed by what is researched and investigated which is also thought to be true about something. Scientific theories can be many about something whereas a scientific law is there and cannot be changed. For example, the law of gravity is there for generations and generations. It is not easy to change this law, because it is nature"* (P16, pre-questionnaire).

Some participants inadequately believed that laws are made by God or nature and are therefore certain whereas theories are believed to be discovered by man, and are therefore fallible as demonstrated by the following responses:

> *When you talk of a law you mean something that is stated and never change like the law of gravity. Laws are made by God"* (P20 pre-questionnaire).

> "*Scientific theories because they are discovered by man who might have errors and may not have some information, however, a scientific law cannot change because nature obeys that law. A scientific law is always respected"* (P6, pre-questionnaire).

Contrary to other previous studies (Akerson, Abd-El-Khalick & Lederman, 2000; Buaraphan, 2011; Dekkers & Mnisi, 2003; Tan & Boo, 2004) only two of the participants held the misconception that theories are just someone's opinion about some phenomenon. Participants who pointed out that scientists develop laws from theories did not hold the common hierarchical view that theories once proven become laws rather believed that laws were scientists' inferences or interpretations of theories, where theories are viewed as actual observations of natural phenomena. These participants consequently believed laws, as human interpretation of observations, are more subject to change than theories. This view of the relationship between laws and theories is pointed out by the following responses that were also considered inadequate.

"They use the theory, to develop their own laws. Theories are some facts about a certain idea or a topic. For example, the atomic theory, those are facts about atoms and elements" (P1, interview data).

"Theories are the facts or the data that is collected while a law is derived from the facts" (P22, pre-questionnaire).

"*Laws are derived from theories*" (P21, pre-questionnaire).

Those participants, who did not point out any relationship between theories and laws, did not view laws as one form of scientific knowledge. These participants either believed laws were principles which scientists need to adhere to when searching for information or rules made by scientists in order to protect life.

A scientific law is somehow a principle which scientists should follow when investigating information. For example, 'do not touch chemicals with bear hands' (P12, pre-questionnaire)

"*Example of a scientific law is 'do not smoke in a garage where cars are loaded with petrol"* (P8, Pre-questionnaire).

4.1.2.4 Creative and imaginative NOS

The pre-service teachers who held informed views of the role of creativity and imagination when designing an investigation constituted 37.5% of the total number of participants. They believed that scientists do not follow a single method, but make use of creativity and imagination in designing and planning their investigation, in collecting data as well as in predicting the outcome of an investigation. These pre-service teachers had this to say regarding creativity and imagination in science:

"Scientists use their own creativity in coming up with the strategies to undertake when carrying out an investigation" (P14, pre-questionnaire).

> *"Imagination is involved in formulating the question to guide the experiment. Creativity comes in when picking up the steps to follow when carrying out the investigation, also when predicting the outcome of the experiment (*P7, pre-questionnaire*)*

> *"When collecting data, the scientist has to know what information is needed and use creative ways of getting the information and "use different methods or systems to reach their conclusions"* (P6, pre-questionnaire).

A smaller percentage (29.2%) of the pre-service teachers however inadequately believed that scientists need to follow a certain prescribed procedure when carrying out investigations in order to ensure that they get the correct answer. The participants were evidently unaware of the tentative NOS as they believed scientific investigations provide definite answers to questions put forth about natural phenomena. For example, two teachers holding this view had this to say regarding creativity and imagination in science:

> *"If they use imagination and creativity, theories would clash because we were not given the same imagination and creativity, but because they experiment scientifically they all come up with one thing. For example, the speed of light was discovered by many scientists; they did not imagine it but they measured it*" (P7, pre-questionnaire).

> *"Scientists have to follow a certain procedure when carrying out experiments." "If one uses creativity and imagination the end results may be incorrect because they were not done according to the way they were supposed to be performed"* (P4, pre-questionnaire).

Participant (P4) also views science as authoritative. She believes that in science one is obliged to follow a particular procedure of carrying out an investigation. The view of science as being about following a single route that leads to a definite body of knowledge is most likely perpetrated by the cookbook nature of laboratory activities aimed at verifying already known facts (Buaraphan, 2010; Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2009; McComas, 1998; Park & Lee, 2009). In such investigations, students are usually given instructions on how to go about carrying out an investigation instead of being involved in carrying out their own.

Similar to many previous studies (Abd-El-Khalick, 2001, 2005; Adams, Macklin & Ebenezer, 2009; Dekkers & Mnisi, 2003; Liang, Chen, Kaya, Adams Macklin & Ebenezer, 2009), an overwhelming majority (87.5%) of the participants was not aware of the role of creativity and imagination in making sense of collected data. These participants inadequately believed scientific knowledge is solely derived from empirical evidence as exemplified by the following responses:

> *"Scientists do not use imaginations and creativity, because to come up with theories and laws, experiments or investigations are carried out" (*P10, pre-questionnaire).
> "*Using the same set of data and each group base its findings on that same data they can draw conclusions in one accord" (*P24, pre-questionnaire).

These pre-service teachers were not aware that scientific theories are ideas created by scientists to give explanation for observable phenomena. They instead believed that theories exist independent of the scientists' awareness of it and the role of scientists is to discover them. As an example of this inadequate view, one participant had this to say about a theory:

> "*A theory is something that is out there in nature and scientists just discover it*" (P1, pre questionnaire).

One participant who seemed to strongly hold a "seeing is knowing" view of knowledge, inadequately believed that since atoms cannot be seen, the atomic structure was merely a product of scientists' imagination and creativity.

> *"I think scientists used their imagination and sat down to design the structure of the atom. I think they tried to investigate it but could not come up with facts about the structure*" (P19, pre questionnaire).

Only one participant held an informed view of the role of creativity and imagination in the development of scientific constructs; the participant believed that theories are invented by scientist rather than discovered. He also revealed an awareness of the fact that these ideas must be supported by empirical evidence.

> "*You formulate an idea, you observe a lot of things or manipulate variables to get something that appears to be supporting your idea, and then after that you can formulate your own theory"* (P3, pre-questionnaire).

Like in some other studies (Dekkers & Mnisi, 2003; Kukuk, 2008) some participants articulated different inadequate conceptions of the meaning of creativity. One participant viewed creativity in science as referring to improvisation. She said that:

> "*Scientists imagine what is needed in their experiments/investigations. If the required equipment is not available they have to be creative"* (P15, pre-questionnaire).

Others viewed creativity as being about creating the best strategy of communicating your data rather than as another strategy involved in making sense of natural phenomena as demonstrated by one participant's response:

> "*Creativity is involved even after data collection. It is about how you are going to communicate or present your data to other people"* (P1, pre-questionnaire).

4.1.2.5 Subjective NOS

A sizeable proportion (62.5%) of the participants held inadequate views of the role of subjectivity in the development of scientific knowledge. The participants did not believe that there may be more than one explanation put forth to account for the same phenomenon. They were seemingly oblivious of the influence of "scientists' backgrounds, training, assumptions, disciplinary and theoretical commitments, and beliefs" on the work scientists do (Lederman & Abd-El-Khalick, 1998, p. 23). Some participants argued that this objectivity is ensured by following a single method of carrying out an investigation as demonstrated by the following responses:

> "*If two scientists follow the same method and interpret the data correctly, they will come up with same conclusions"* (P4, pre-questionnaire).

> "*It is possible to come with different conclusions if the groups do not follow the same correct instructions*" (P9, pre-questionnaire).

According to Clough and Olson (2004), the belief in a single method of carrying out investigation is perpetuated by the cook-book nature of most classroom investigations, where students follow a prescribed procedure of carrying out an investigation aimed at verifying already known facts or observations. These activities also promote a belief in a single correct external reality that can be discovered by means of the processes of science. This assertion is supported by one participant who clearly stated that:

> "*Because science is nature, and the theories are there in nature. I think it something that is there and that is why these theories do not change easily because it something that is there and they just discovered it"* (P1, pre-interview).

The processes of discovering this external reality are inadequately viewed as completely objective. For, example, one participant alleged that:

> *"Scientists are people who are not influenced by their beliefs; they find facts by collecting data, experimenting and observing"* (P 15, pre-questionnaire).

Theories are therefore viewed as actual representations of reality rather than scientists' perception of reality.

4.1.2.6 Social and cultural influence

Except for one, all participants held inadequate views of the role of social and cultural contexts on science. The participants pointed out that science is universal and not influenced by the social and philosophical values and intellectual norms of the culture in which it is practiced. One interviewee who was categorized as holding an inadequate view of NOS, when asked whether the social and cultural context has an impact on ideas that scientists are likely to have, argued that:

> "*Although people normally do not have the same ideas, scientists are different from other people because though they are human they have a different or a special way of perceiving or dealing with things. Yes, I think they are more objective and not influenced by their social and cultural values"* (P1, pre-interview).

The participants gave three arguments for their belief in the universality of scientific knowledge. The majority of them contended that science is about discovering the principles of nature which apply everywhere. The participants were seemingly unaware of the influence of scientists' backgrounds on the way they perceive observable phenomena, the manner in which they carry out their investigations, as well as the way they collect and interpret results (Lederman, 2006; Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2009).

> *"The same gravitational force that applies in Swaziland is the same law in America" (*P6, pre-questionnaire).

> *"If an African can have sexual relationship with a European, scientifically, that European can be pregnant depending on the fertility of the two*" (P12, pre-questionnaire).

Four of the participants based their belief in the universality of science on their observation that the body of scientific knowledge taught in one country is the same as in another country. This evidence supports the claim that students develop their views of NOS based on their classroom science (Iqbal, Azam & Rana, 2009). This calls attention to the necessity of an explicit discussion of how scientific claims are developed and how science done in the classroom is different or similar to professional science.

4.1.2.7 Tentative NOS

All of the participants held inadequate views of the tentative NOS. Many of these participants pointed out that a law is an actual representation of reality and is therefore not subject to change.

> *"When you talk of a law you mean something that is stated and never change like the law of gravity. Laws are made by God"* (P20, pre-questionnaire).

Many participants believed theories can change, but because they believed theories can be proven through experiments, they viewed the change as only evolutionary rather than revolutionary. The participants inadequately believed that theories can only be modified or expanded as more information is discovered as illustrated by following quotations:

"Scientific theories do not change simply because before scientific theories are publicly confirmed, experiments are conducted to determine the truth" (P2 pre-questionnaire).

"*Theories do not change because what we learn from primary, secondary, and high schools is still the same, instead more information is added to the theory*" (P8, pre-questionnaire).

"*Scientific theories do not change; they would rather be developed after thorough investigation and experimentations, but as far I know, it takes more than a thousand years for this to happen. My point is they never change*" (P24, pre-questionnaire).

"In science a theory does not change but it can be edited, that is something can be added positively to that theory as more and more discoveries are added on it" (P23, pre questionnaire).

4.2 Post-instruction NOS views

The pre-service teachers' post-instruction NOS views are presented next. The views are based on the quantitative and qualitative analysis of the participants' responses to the questionnaire and follow up individual interviews. Firstly, a comparison of the numbers and percentages of participants categorized as having inadequate, partially informed, and informed views of each emphasized aspect of NOS is presented. This is then followed by a description and discussion of changes in the pre-service teachers' understanding of each of the selected aspects of NOS.

4.2.1 Numbers and percentages of pre-service teachers with informed, partially informed and inadequate views of the emphasized aspects of NOS after instruction

All the 24 pre-service teachers who completed the VNOS questionnaire prior to the NOS instruction also participated in completing the same questionnaire at the end of the intervention. Table 4.2 shows the number and percentage of pre-service teachers categorized as having informed, partially informed, and inadequate views of the different target aspects of NOS.

Table 4.2 Number and percentage of participants with informed, partially informed and inadequate views of emphasized aspects of NOS

NOS Aspect	Number of Students				TOTAL
	Informed	Partially informed	Inadequate	Cannot be categorized	
Empirical NOS	14 (58.3%)	7 (29.2%)	3 (12.5%)	0 (0%)	24
Observations and inferences	13 (54.2%)	5(20.8%)	6 (25.0%)	0 (0%)	24
Laws versus theories	16 (66.7%)	6 (25%)	2(8.3%)	0 (0%)	24
Creativity in the design of an investigation	13 (54.1%)	7 (29.2%)	4 9 16.7%)	0 (0%)	24
Creativity and imagination in the development of scientific constructs	9 (37.5%)	8 (33.3%)	7 (29.2%)	0 (0%)	24
Subjectivity in science	13 (54.2%)	10 (41.7%)	1 (4.2%)	0 (0%)	24
Social and cultural influence	14 (58.3%)	4 (16.7%)	6 (25%)	0 (0%)	24
Tentativeness of scientific knowledge	15 (62.5%)	6 (25%)	3 (12.5%)	0 (0%)	24

Table 4.2 indicates that at the end of instruction most participants had developed at least partially informed views of almost all the target NOS aspects. Very few pre-service teachers still possessed misconceptions of NOS at the end of the intervention.

4.2.2 Changes in pre-service teachers' views of each emphasized aspect of NOS

As part of ascertaining the effects of the NOS intervention on the pre-service teachers' understanding of the different aspects of NOS, the percentage change in participants' understanding of each aspect of NOS was estimated. The estimation was done by computing the difference between the percentages of participants categorized as having informed views of each aspect of NOS prior and after the intervention. The data is presented in Table 4.3. The table is followed by a description and explanation of the participants' changes in their views of each selected aspect of NOS. For each aspect of NOS, a bar chart is included to depict changes in the number of pre-service teachers' having the different categorized views from pre- to post-instruction. A Chi-square test was used to find out whether or not such changes in NOS views were statistically significant.

Table 4.3 Percentage change in participants' view of NOS

NOS Aspect	Pre-instruction (%)	Post-instruction (%)	Percentage change
Empirical NOS	16.7	58.3	+41.6
Observations and inferences	0	54.2	+54.2
Scientific laws and theories	0	66.7	+66.7
Creativity in the design of an investigation	37.5	54.1	+16.6
Creativity and imagination in the development of scientific constructs	4.2	54.2	+50
Subjectivity in science	4.2	58.3	+54.1
Social and cultural influence	4.2	58.3	+54.1
Tentativeness of scientific knowledge	0	62.5	+62.5

From Table 4.3 it is evident that there was a considerable increase in the number of participants who held informed views of the targeted NOS views at the end of the programme as compared to prior to the programme. It is however worth noting that the observed changes were not uniform across the investigated NOS aspects. Gains in participants' NOS views were more prominent with regards to functions of and relationship between laws and theories, tentative NOS, subjectivity and social and cultural embeddedness of science. An increase in the number of pre-service teachers with informed views of the distinction between observation and inference, creativity and imagination in the development of scientific constructs as well as empirical NOS was also evident though less pronounced. There was a very minor improvement (16.7%) in the number of pre-service teachers embracing informed views of the role of creativity in the stages prior to data interpretation.

Following is a description and discussion of participants' views of each NOS aspect at the end of the intervention. Even though some participants were observed to still hold inadequate views even at the end of the study, this section is focused more on describing the pre-service teachers' informed views. The code 'P' refers to the participants and the number following the code refers to a specific participant.

4.2.2.1 Empirical NOS

In response to the question "how is science different from other ways of knowing, such as philosophy or religion" only 16.7% of the pre-service teachers were able to express an informed view of the empirical NOS, prior to the programme. However at the end of the study, 58.3% of the participants adequately pointed out that scientific claims are supported by empirical evidence. For example one pre-service teacher stated that:

> *"Unlike other disciplines like religion, scientific claims have to be supported by empirical evidence*" (P3, post-questionnaire).

Of note, these participants did not view scientific claims as solely based on observations, but were also fully aware of the role of inference, creativity and imagination as well as subjectivity in the development of such claims. This is evident, for example, in the following pre-service teachers' response to the aforementioned question:

> *"Science involves a lot of creativity and imagination and this goes together with empirical evidence, whereas discipline like philosophy, creativity and imagination alone is used as a tool of developing knowledge"* (P17, post-questionnaire).

Figure 4.1 illustrates the development in the percentage of pre-service teachers' views with inadequate, partially informed and informed views of the empirical NOS from pre- to post-instruction. The percentage of pre-service teachers with inadequate views declined considerably from (62.5%) to 16.7% while the number of participants with informed views increased considerably from 12.5% to 58.3% from pre- to post instruction. There was a relatively smaller increase in the percentage of participants with partially informed views (20.8 to 29.2%).

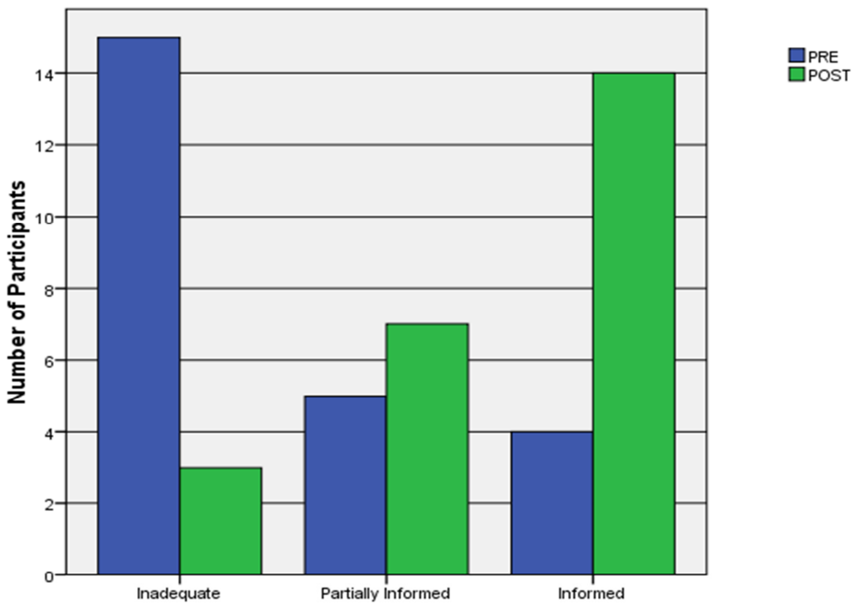

Figure 4.1 Number of pre-service teachers with inadequate, partially informed and informed views of the empirical aspect of NOS during pre- and post-instruction

Table 4.4 shows the Chi-square test result as it relates to NOS instruction and categorized views of the empirical NOS.

Table 4.4 Chi-square test results- NOS instruction and categorized views of the empirical NOS

Empirical NOS	**Inadequate**	**Partially informed**	**Informed**	**Chi- square (χ^2)**	**p**
Pre-instruction	15(62.5%)	5 (20.8%)	4 (16.7%)		
Post-instruction	3 (16.7%)	7 (29.2%)	14(58.3%)		
χ^2(2, N=24)				13.889	0.001

Table 4.4 indicates that the probability of the observed Chi-square (χ^2 = 13. 889) is 0.001. The probability for the obtained Chi-square was less than the significance level set, $\alpha = 0.05$ ($0.001 < 0.05$). The null hypothesis was therefore rejected at the 5% level of significance. The conclusion was that there were statistically significant changes from pre- to post-instruction in the pre-service teachers' views of the empirical NOS.

4.2.2.2 Observation versus inference

None of the participating pre-service teachers articulated informed views of the differences between observations and inferences prior to the intervention. However, 50% expressed informed views of this aspect at the end of the study. The participants, who initially incorrectly thought the atomic model was an actual representation of reality, adopted the new informed view that the atomic model is a scientists' interpretation of experimental evidence. For example, two teachers had this to say regarding the development of the atomic theory:

> "*Based on Rutherford's experiment, scientists inferred that they might be a nucleus that deflects the alpha particles." "Scientists are not sure about the structure of an atom, but that was their representation of their thought. You might find that in reality an atom is not like that"* (P20, post-questionnaire).

> *"The atomic theory was not exactly derived from visible atoms, protons, neutrons, or electrons. To come up with the theory, the scientists conducted experiments where then, from the data collected, analysis and inferences were made to come up with the atomic theory"* (P19, post-questionnaire).

It is however worth noting that some participants (16.7%) exited the NOS instruction with an incoherent understanding of the inferential nature of scientific constructs. As much as these participants pointed out that the atomic model was an inference rather than an observation, they however believed scientists were certain about the proposed structure as it is supported by experimental evidence. These participants were seemingly unaware that experiments only provide scientists with clues, which they interpret to come up with a model (Kukuk, 2008). This observation further supports Kukuk's belief that participant's assertion that scientists perform experiments, does not necessarily mean they understand the experimental NOS. This evidence is however not conclusive as participants meaning of the word certain was not confirmed with all participants.

Figure 4.2 demonstrates the development in the number of pre-service teachers' views with inadequate, partially informed and informed views of the inferential aspect of NOS, from pre- to post-instruction. The number of pre-service teachers with inadequate views had greatly declined at the end of the NOS instruction. Whereas none of the participants held informed views of this aspect of NOS prior to the intervention, 54.2% of them had developed informed views of NOS at the end. The number of pre-service teachers with partially informed views remained the same from pre- to post instruction.

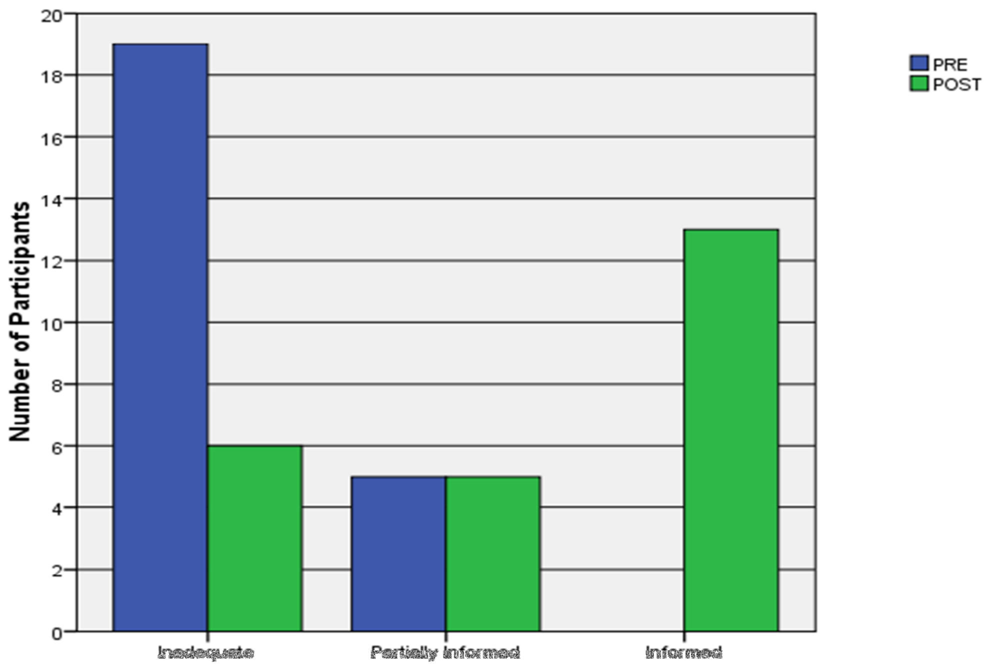

Figure 4.2 Number of pre-service teachers with inadequate, partially informed and informed views of the inferential aspect of NOS during pre- and post-instruction

Table 4.5 shows the Chi-square test result as it relates to NOS instruction and categorized views of the difference between observation and inference.

Table 4.5 Chi-square test results-NOS instruction and categorized views of the difference between observation and inference

Observation versus Inference	Inadequate	Partially informed	Informed	Chi- square (χ^2)	p
Pre-instruction	19 (79.2%)	5 (20.8%)	0 (0%)		
Post-instruction	6 (25.0%)	5 (20.8%)	13(54.2%)		
χ^2 (2, N=24)				19.760	0.00

Table 4.5 indicates that the probability of the observed Chi-square (χ^2 = 19.760) is .0.00. The probability for the obtained Chi-square was less the significance level set, $\alpha = 0.05$ ($0.00 < 0.05$).

The null hypothesis was therefore rejected at the 5% level of significance. The conclusion was that there were statistically significant changes from pre- to post-instruction in the pre-service teachers' views of the difference between observation and inference.

4.2.2.3 Functions of and relationship between scientific theories and laws

At the beginning of the study, a majority of the participants were not aware of the different roles of the two constructs. The participants stated many different inadequate views of the roles of, and relationships between, scientific theories and laws. In line with many previous studies, some elucidated a hierarchical view between theories and laws. Even though participants did not explicitly point out that a theory develops into a law, they believed that the difference between the two constructs was in their certainty. Laws were viewed as not subject to change, while theories were either viewed as facts or empirically tested ideas that are however subject to change. On the other hand, at the conclusion of the study, 66.7% of the participants were aware that scientific theories and laws were different kinds of scientific knowledge. They correctly pointed out that scientific laws describe regularities as observed in nature without offering explanations while theories explain such observed regularities. Examples of pre-service teachers' responses demonstrating such an understanding are presented below:

> "*Laws describe regularities in nature, for example, the law of conservation of mass which states that the mass of reactants will be equal to the mass that you will end up with. The law on its own has no explanation, therefore there has to be a theory that will explain the law. Like Dalton's atomic theory which states that atoms are neither destroyed nor created; this explains the law of conservation of mass*" (P3, post-questionnaire).

> *"For example, the law of segregation states that the characteristic of a diploid organism are controlled by alleles that occur in pairs. Scientific theories, on the other hand, explain why things happen in a certain way"* (P5, post-questionnaire).

Figure 4.3 below is a depiction of the development in the number of the pre-service teachers with inadequate, partially informed and informed views of the functions of scientific laws and theories and from pre- to post-instruction. There was a significant decrease in number of pre-service teachers with inadequate views of this aspect of NOS at the end of the NOS instruction.

Very few participants held informed views at the beginning of the instruction, but at the end the percentage of participants with informed views had increased considerably. The number of participants with partially informed views also increased slightly from pre- to post-instruction.

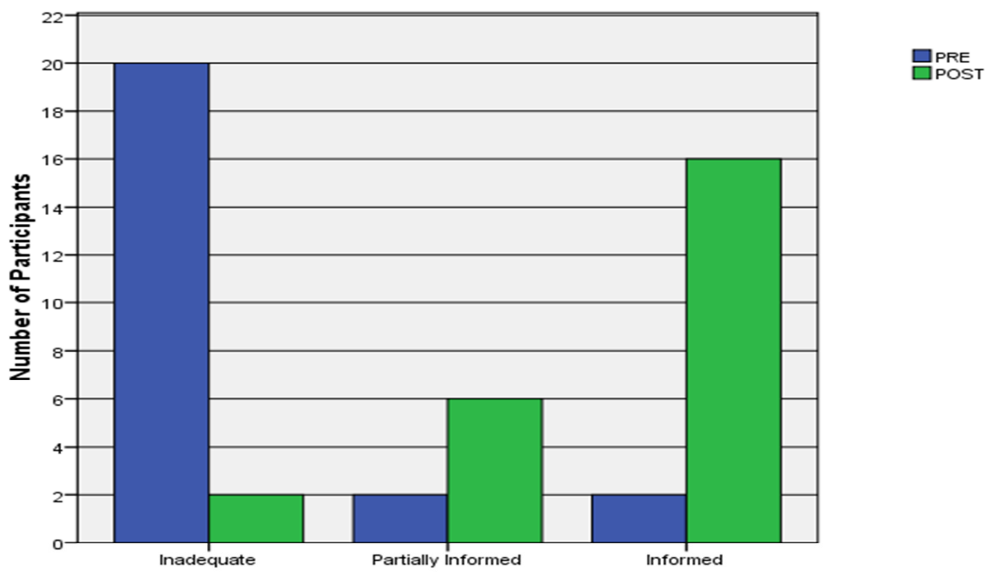

Figure 4.3 Number of pre-service teachers with inadequate, partially informed and informed views of the functions of scientific laws and theories during pre- and post-instruction

Table 4.6 shows the Chi-square test result as it relates to NOS instruction and categorized views of the functions of scientific theories and laws. The Chi-square test results of this relationship indicated that two cells (33%) had an expected count of less than 5. According to Pietersen and Maree, 2007, the Chi-square test is valid only in cases where none of the cells has an expected cell frequency of less than 5. The pre-service categorized views were consequently dichotomized by fusing the partially informed and informed views into at least partially informed views. This enabled the researcher to at least test statistically if the changes in participants' views of the functions of scientific theories and laws were significant.

Table 4.6 Chi-square test results- NOS instruction and categorized views of the functions of scientific theories and laws

Scientific laws versus theories	Inadequate	Partially informed	Informed	Chi- square (χ^2)	p
Pre-instruction	20 (83.3%)	4(16.7%)	0(0%)		
Post-instruction	2 (8.3%)	22 (91.7%)			
χ^2 (2, N=24)				31.127	0.00

Table 4.6 indicates that the probability of the observed Chi-square (χ^2 = 31.127) is 0.00. The probability for the obtained Chi-square was less than the significance level set, $\alpha = 0.05$ ($0.00 < 0.05$). The null hypothesis was therefore rejected at the 5% level of significance. The conclusion was that there were statistically significant changes from pre- to post-instruction in the pre-service teachers' views of the functions of scientific laws and theories as well as the relationship between them.

4.2.2.4 Creativity and imagination in designing an investigation and in data collection

As evident in the table, little change was observed in participants' views of a universal scientific method. At the end of the programme, 54.2% held informed views of the role of creativity and imagination in the design of an investigation (an increase of only 16.7%). A relatively bigger number of participants compared to the other NOS aspects were well informed of this aspect of NOS even before instruction. Comparison of participants' pre- and post NOS views indicates that some of them who started with informed views of this aspect, ended up adopting an inadequate or a partially informed view at the end of instruction. For an example, one pre-service teacher correctly pointed out prior to instruction that scientists do not use a single method of carrying out investigation, as indicated by his direct words below:

> *"When collecting data, the scientist has to know what information is needed and use creative ways of getting the information"* (P6, pre-questionnaire).

However, at the end of instruction, this very same participant stated that scientists use the same method when carrying out investigations and only use their creativity and imagination after data collection. Some participants stated that there is less creativity and imagination involved at the stages prior to the data interpretation stage.

A possible explanation for this could be the prominence of the role of creativity and imagination in the interpretation stage of data in the NOS instruction. Information from the instructor's journal shows that the focus of the intervention was more on creativity and imagination in data interpretation than on the design of an investigation. Emphasizing this aspect of creativity could have created an impression that creativity is either not involved or not an important element in the design and collection of data.

Figure 4.4 is an illustration of the changes in the numbers of pre-service teachers with inadequate, partially informed, and informed views of the involvement of creativity and imagination in the design of an investigation as well as in data collection. There was a minor decrease in the number of pre-service teachers with inadequate views and a slight improvement in the number of participants with informed views of this aspect from prior to after the NOS instruction. The number of participants having partially informed views slightly decreased subsequent to the NOS instruction.

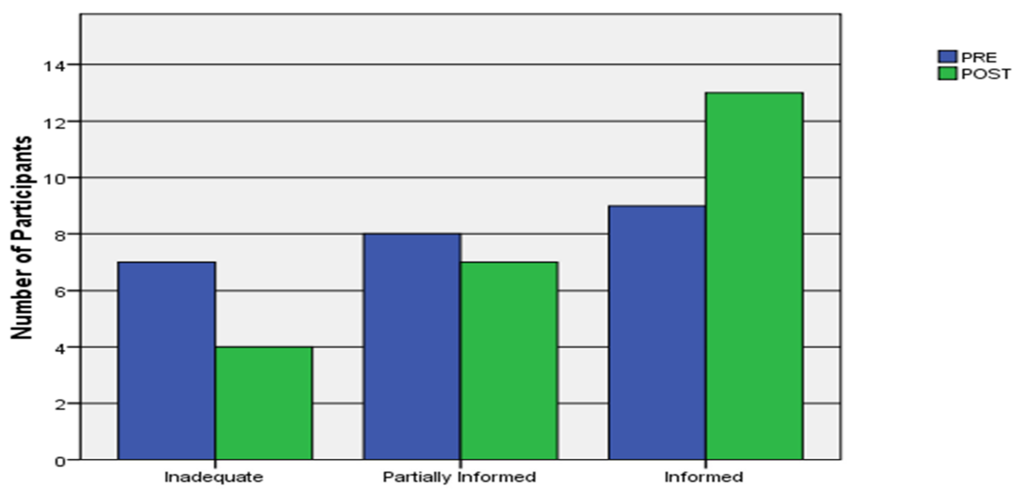

Figure 4.4 Number of pre-service teachers with inadequate, partially informed and informed views of the role of creativity and imagination at the stages prior to data interpretation

The next table (Table 4.7) shows the Chi-square test result as it relates to NOS instruction and categorized views of the role of creativity at the stages of an investigation prior to data interpretation.

Table 4.7 Chi-square test results- NOS instruction and views of the role of creativity at the stages of an investigation prior to data interpretation

Data interpretation in the design and collection of data	**Inadequate**	**Partially informed**	**Informed**	**Chi- square(χ^2)**	p
Pre-instruction	7 (29.2%)	8 (33.3%)	9 (37.5%)		
Post-instruction	4 (16.7%)	7 (29.2%)	13(54.2%)		
χ^2 (2, N=24)				1.612	0.447

Table 4.7 indicates that the probability of the observed Chi-square (χ^2 = 1.612) is 0.0.447. The probability for the obtained Chi-square was less than the significance level set, $\alpha = 0.05$ ($0.447 > 0.05$). The null hypothesis was therefore not rejected at the 5% level of significance. The conclusion was that there were no statistically significant changes from pre- to post-instruction in the pre-service teachers' views of the role of creativity and imagination prior to the data interpretation stage of an investigation.

4.2.2.5 Creativity and imagination in interpreting data

Thirty eight percent compared to 4.2 % of participants at the onset of the study, held informed views of the role of creativity and imagination in development of scientific knowledge at the conclusion of the study. These participants pointed out that interpreting data involves creativity and imagination. The participants also viewed scientific constructs' (theories and models) as human constructed ideas used to explain observations rather than discovered facts about natural phenomena. Such an understanding of science is illustrated by the following pre-service teachers' responses to the VNOS-questionnaire:

> *"Mendel inferred that there are factors that are transferred from parent to offspring, and postulated that these factors are the ones that carry the genetic information and in that statement there is a lot of creativity and imagination*"(P3, post-questionnaire).

"*Science is a systematic way of knowing that involves creating ideas; it is not solely based on observations*" (P17, post-questionnaire).

"Rutherford used his gold leaf experiment as well as his own creativity and imagination in coming up with the structure of an atom (P23, post-questionnaire, informed).

"A theory, such as the atomic theory, is a human constructed idea used to explain observations and it requires a great deal of creativity and imagination" (P8, post-questionnaire).

Figure 4.5 demonstrates the progression in the numbers of pre-service teachers' views of the involvement of creativity and imagination in the development of scientific constructs. There was a noteworthy decrease in the number of pre-service teachers with inadequate views and an improvement in the number of participants with informed and partially informed views of this aspect from pre- to post-instruction.

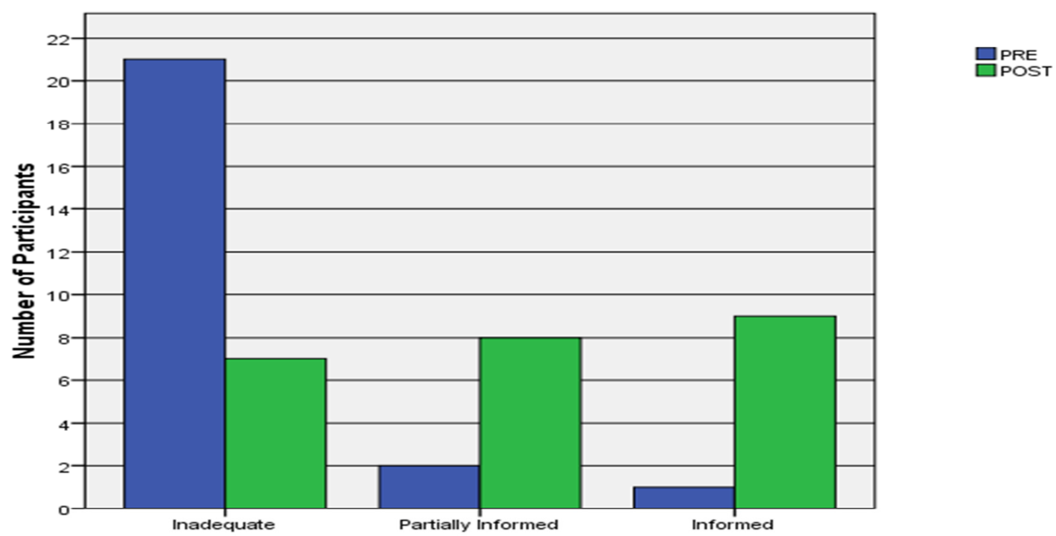

Figure 4.5 Number of pre-service teachers with inadequate, partially informed and informed views of the role of creativity and imagination in the development of scientific constructs

Table 4.8 shows the Chi-square test result as it relates to NOS instruction and categorized views of the role of creativity in the development of scientific constructs.

Table 4.8 Chi-square test results- NOS instruction and categorized views of the role of creativity in the development of scientific constructs

Creativity and imagination in data interpretation	**Inadequate**	**Partial Informed**	**Informed**	**Chi- square (χ^2)**	**p**
Pre-instruction	21(87.5%)	2 (8.3%)	1(4.2%)		
Post-instruction	7(29.2%)	8 (33.3%)	9 (37.5%)		
χ^2 (2, N=24)				17.00	0.00

Table 4.8 indicates that the probability of the observed Chi-square ($\chi^2 = 17.00$) is .0.00. The probability for the obtained Chi-square was less the significance level set, $\alpha = 0.05$ (0.00 < 0. 05). The null hypothesis was therefore rejected at the 5% level of significance. The conclusion was that there were statistically significant changes from pre- to post-instruction in the pre-service teachers' views of the role of creativity and imagination in the development of scientific constructs.

4.2.2.6 Subjective NOS

Compared to 4.3% at the commencement of the study, 54.2% of the participants exited the NOS programme with more informed views of the subjective NOS. The pre-service teachers contended that many factors such as cultural and social factors, prior knowledge, prior expectations and different ways of thinking impact on data interpretation which therefore makes it possible for two scientists to come up with different interpretations of the same data. Such an understanding is demonstrated in the following responses:

> "*When you look at something, you usually see that thing in relation to what you know. It is therefore possible to have different conclusions if they have different prior knowledge and experiences*" (P6, post-questionnaire).

> *"Different conclusions are possible because interpreting data or making inferences is influenced by a number of factors which will lead to different conclusions. These factors may include other ways of knowing such as religion, philosophy, social and cultural factors"* (P5, post-questionnaire).

Figure 4.6 shows the development in the numbers of pre-service teachers' views of the involvement of subjectivity in science. There was a striking decrease in the number of pre-service teachers with inadequate views and an improvement in the number of participants with informed and partially informed views of this aspect from pre- to post instruction.

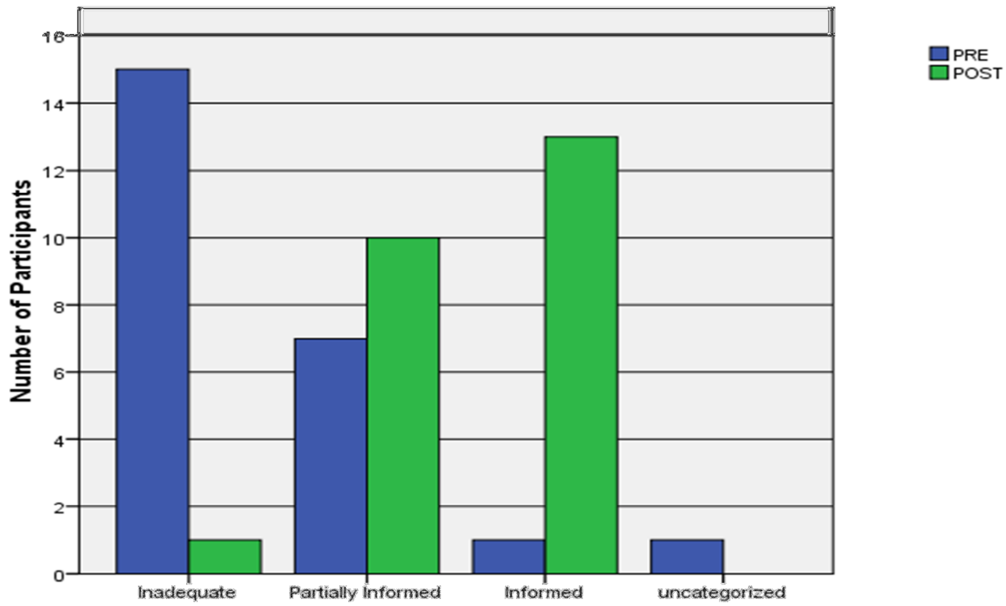

Figure 4.6 Number of pre-service teachers with inadequate, partially informed and informed views of the subjective NOS

Table 4.9 shows the Chi-square test result as it relates to NOS instruction and categorized views of the subjective NOS. Since the aim of the Chi-square test was to find out whether there were significant changes in the numbers of participants having inadequate, partially informed, and informed view of NOS, the participant who started out with an uncategorized view of this aspect of NOS was excluded. Hence, for this particular test, the sample size is 23 (N = 23).

Table 4.9 Chi-square test results- NOS instruction and categorized views of the subjective NOS

Subjective NOS	**Inadequate**	**Partial Informed**	**Informed**	**Chi- square(χ^2)**	p
Pre-instruction	15 (65.2%)	7 (30.4%)	1 (4.3%)		
Post-instruction	1(4.3%)	10 (43.5%)	12 (52.2%)		
χ^2 (2, N=23)				22.087	0.00

Table 4.9 indicates that the probability of the observed chi-square (χ^2 = 22.087) is .0.00. The probability for the obtained Chi-square was less the significance level set, $\alpha = 0.05$ ($0.00 < 0.05$. The null hypothesis was therefore rejected at the 5% level of significance. The conclusion was that there were statistically significant changes from pre- to post-instruction in the pre-service teachers' views of the element of subjectivity in science.

4.2.2.7 Social and cultural Influence

At the end of the NOS instruction, 62.5% of the participants articulated informed views of the social and cultural influence on science as opposed to only 1% at the commencement of the study. The participants noted that the scientists' social, political, and philosophical assumptions have an influence on the way they interpret or make sense of data. These contexts influence the scientists' mind-set which in turn influences how they approach any given data.

> *"The evolution theory originally talked about 'the man hunter' before women was accepted in the scientific realm. After being accepted, it talked also about the 'woman gatherer' which shows an influence of cultural and social belief"* (P17, post-questionnaire).

> *"For example, two hypotheses were put forth to explain the mass extinction of dinosaurs indicating the influence of different philosophical assumptions on science"* (P5, post-questionnaire).

Figure 4.7 gives a picture of the progression in the number of pre service teachers having inadequate partially informed and informed views of social and cultural influence on science from pre- to post-instruction. There was a noticeable decrease in the number of pre-service teachers with inadequate views and also a marked improvement in the number of participants with informed views of this aspect from pre- to post instruction.

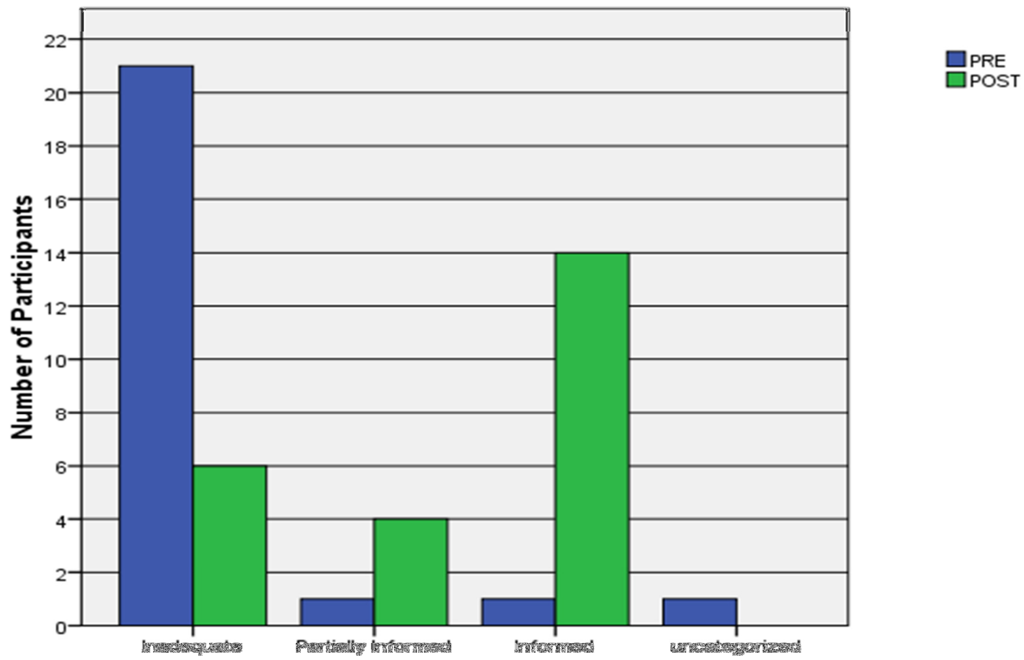

Figure 4.7 Number of pre-service teachers with inadequate, partially informed and informed views of the social and cultural influence on science

Table 4.10 shows the Chi-square results as it relates to NOS instruction and categorized views of the social and cultural influence of science. The Chi-square test results of this relationship, when using three categories (inadequate, partially informed, informed views) indicated that two cells (33%) had an expected count of less than 5. According to Pietersen and Maree (2007), the Chi-square test is valid only in cases where none of the cells has an expected cell frequency of less than 5. The pre-service categorized views were consequently dichotomized by fusing the partially informed and informed views into at least partially informed views. This enabled the researcher to at least statistically test whether the changes in participants' views of the subjective NOS were significant. Since the aim of the Chi-square test was to find out whether there were significant changes in the numbers of participants having naive and at least partially informed view of NOS, the single participant who started out with an uncategorized view of this aspect of NOS was excluded. Hence, for this particular test, the sample size is 23 (N = 23).

Table 4.10 Chi-square test results- NOS instruction and categorized views of the social and cultural embeddedness of science

Social & Cultural Influence	Inadequate	At least partially informed	Chi- square (χ^2)	p
Pre-instruction	21 (91.3%)	2 (8.7%)		
Post-instruction	5(21.7%)	18 (78.3%)		
χ^2 (1, N=24)			22.646	0.00

Table 4.10 shows that the probability of the observed Chi-square (Chi-square = 22.646) is 0.00. That is the probability for the obtained Chi-square was less than the significance level set, α = 0.05 (0.00 < 0.05). The null hypothesis was therefore rejected at the 5% level of significance. The conclusion was that there were statistically significant changes from pre- to post-instruction in the pre-service teachers' views of the social and cultural embeddedness of science.

4.2.2.8 Tentative NOS

There was a significant positive change in participants' views of the tentative NOS. At the commencement of the study, none of the participants held informed views of this aspect of NOS. However, at the end of the study, 62.5% of participants pointed out that all scientific knowledge is subject to change. They believed that this change could both be evolutionary and revolutionary, whereas prior to the programme participants who stated that theories can change believed that they can only be developed or modified in light of new evidence. As an example, one participant stated that:

> "*Scientific knowledge is open to falsification and modification. For example, the atomic theory started with Thompson's who discovered that an atom consist of protons and electrons which were uniformly distributed throughout the atom. Later Rutherford discarded Thompson's plum pudding model and developed a planetary model of the atom which put all the protons in the nucleus and the electrons orbiting the nucleus like planets around the sun*" (P17, post-questionnaire).

> *"In light of new evidence, some theories do change, and when there is a new theory that will explain a certain phenomenon better than the existing one, the existing one is put aside and the new theory is then used" (*P3, post-questionnaire).

A significant percentage (62.5%) of the participants who expressed an informed view of the lack of certainty of scientific theories attributed theory change solely to the discovery of new evidence. However, 37.5% were also aware that theories also change as a result of a new perspective in interpreting existing data. This was a great improvement as almost all participants at the onset of the study believed scientific knowledge represented truth about nature that is exposed objectively by the processes of science. Very few viewed science as a way of understanding natural phenomena, which therefore renders scientific constructs tentative. At the end of the study, participants were aware of the influence of human elements in the development of scientific knowledge. For example, one participant had this to say concerning the tentative nature of theories:

> *"Theories change because they involve a lot of imagination and creativity other than observable facts*" (P12, post-questionnaire).

Some participants also pointed out that the higher involvement of creativity and imagination in the development of theories, made them more tentative than laws as illustrated by the following response:

> *"A Scientific theory is more tentative than a scientific law because it involves more imagination and creativity*" (P16, post-questionnaire).

Figure 4.8 depicts the development in number of pre-service teachers harbouring inadequate, partially informed, and fully informed views of the tentative NOS from pre- to post-instruction. All the participants started with inadequate views of NOS, but at the end of instruction, most of them had developed a fully informed view of the tentative NOS believing that all scientific claims are subject to both refutation and modification.

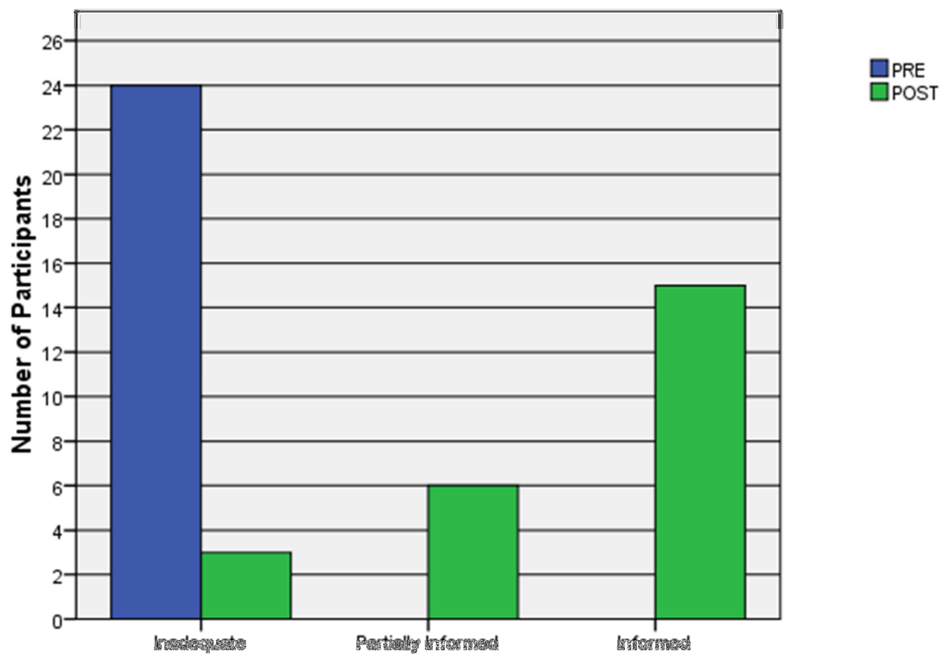

Figure 4.8 Number of pre-service teachers with inadequate, partially informed and informed views of the tentative NOS

Table 4.11 shows the Chi-square test result as it relates to NOS instruction and categorized views of the functions of scientific theories and laws. The Chi-square test results of this relationship, when using four categories (inadequate, partially informed, informed, and uncategorized views) indicated that two cells (33%) had an expected count of less than 5. According to Pietersen and Maree (2007), the Chi-square test is valid only in cases where none of the cells has an expected cell frequency of less than 5. The pre-service teachers' categorized views were consequently dichotomized by fusing the partially informed and informed views into at least partially informed views. This enabled the researcher to at least statistically test if the changes in participants' views of the tentative NOS were significant.

Table 4.11 Chi-square test results- NOS instruction and categorized views of the tentative NOS

Tentative NOS	Inadequate	At least partially informed	Chi- square (χ^2)	p
Pre-instruction	24 (100%)	3 (12.5%)		
Post-instruction	0 (0%)	21 (87.5%)		
χ^2 (1, N=24)			37.33	0.00

Table 4.11 shows that the probability of the observed Chi-square (Chi-square = 37.33) is .000. That is the probability for the obtained Chi-square was less than the significance level set, α = 0.05 (0.00 < .05). The null hypothesis was therefore rejected at the 5% level of significance. The conclusion was therefore that there were statistically significant changes from pre- to post-instruction in the pre-service teachers' views of the social and cultural embeddedness of science.

4.3 Pre-service teachers' report of the influence of course components

Similar to McDonald's (2010) study, the current study did not make use of a comparison group and therefore assertions regarding the impact of different course elements on the pre-service teachers' conceptions of NOS are not causative. Also, the influence of the course elements is based on the selected group participants' reports made in their reflective journals and during post-interviews. The selected group participants' perceptions were therefore only used to explain the pre-service teachers gain or lack of gain in NOS conceptions

The group was selected based on their differential gains in their understanding of NOS. For ethical reasons, the names used below and throughout the rest of this report are pseudonyms.

4.3.1 Explicit discussion of NOS in the context of activities and learning science content

Four out of the seven selected group participants pointed out during exit interviews that the guided discussion of NOS in the context of learning activities as having had an impact in their development of NOS views. When Muzi was asked about what he believed contributed most to his understanding of NOS, he stated that the activities played a big role in influencing his views as indicated by his direct words below:

> *"Actually, it is learning about NOS. I could make an example of some activities. We had some couple of activities; that one when we shot into the box, we all made the same observations and came up with different interpretations. And also where there we read a passage where each and every one came up with a different aspect of what he or she thought the passage was about. It then clicked to me that, ey, but we are looking at the same passage but we also interpret it differently" (*Muzi, exit interview).

In his daily reflective journal Muzi also indicated that the explicit reflective discussion of the relationship between laws and theories in the context of learning of Genetics enabled him to understand the difference and the relationship between the two constructs.

> *"After today's lesson, when learning about the chromosome theory, I understand that it came after the law of segregation and the law of independent assortment. This is because a theory explains a law. That is why we first have a law, and then a theory explains the law that has been earlier put forth" (*Muzi, daily reflective journal).

Muzi's assertion indicates that the explicit reflective discussion caused him to view science as being about establishing "generalizations, principles or patterns in nature (laws) and subsequently creating explanations (theories) of these generalizations" (McComas, 1998, p.2).In line with this view of laws and theories, when Muzi was asked to state his definition of science, he revealed a belief in both the empirical and creative aspects of NOS.

> *"Actually, science, I believe, is an intrinsic curiosity of a human being to discover and understand the behaviour of natural phenomena".*

Muzi's assertion that a law comes before theories could however indicate that the historical account of the development of laws and theories might have caused Muzi to believe that laws are only developed from "facts or empirical evidence' (McComas, 1998, p.18). Muzi may not be aware that an existing theory can be used to propose additional laws that were not initially involved in formulating that theory. The use of other historical narratives that illustrate the use of theories to predict further relationships may be useful in enhancing participants' understanding both the explanatory and predictive role of theories, and hence understand the role of theories in guiding further research.

Futhi, also stated in her final reflective journal that learning the history of the theories of matter helped her to develop a balanced view of the creative nature and instrumental role of theories as shown by the illustration below:

> *"By learning about the theories of matter, I came to conclude that science needs empirical evidence to support theories, and that not every theory is accepted in the scientific realm." I also learnt that theories guide further research leading to the development of knowledge"* (Futhi, reflective journal).

During exit interviews, Futhi clearly pointed out that it was the explicit discussion of the meanings of terms such as theories, laws, as they learnt the science subject matter that helped her a lot in understanding the nature of scientific knowledge. She pointed out that it was the lack of understanding of the meaning of such terms that was responsible for her prior erroneous beliefs about NOS:

> *"What really helped me is learning about it in class, trying to unpack these terms to me and trying to explain some of the theories and laws that I have learnt before. So it helped me a lot. My NOS views have changed a lot, because at first, I think what made me not to understand clearly was that may be I had a misunderstanding of some of the terms. So, I think understanding the meaning of these terms, such as a theory has helped me in understanding NOS"* (Futhi, exit interview).

These findings support the assertion that an explicit reflective instruction to NOS does play a positive role in influencing pre-service teachers' understanding of NOS.

4.3.2 Pre-service teachers' discussion of their ideas about the target aspects of NOS

As part of the intervention, students were from time to time given an opportunity to discuss their conceptions about NOS in order to enable them to reflect and be challenged about their conceptions of NOS. During exit interviews, only two of the participants explicitly stated that discussions of their NOS with their colleagues played a pivotal role in developing their NOS views. Hlobi, for example, pointed out that group debates on issues was one of the experiences that helped a lot in enhancing her NOS understanding:

> *"Working with a group which is cooperative sometimes really has played a big role, because you sometimes sit as a group; debate until you come with one understanding which you most think is correct"* (Hlobi, exit interview).

Though this strategy of enhancing participants' views of NOS was cited by a smaller proportion of the focus group participants, it does however provide support of the claim that such a learning strategy may be useful in enhancing participants'' understanding of NOS. It is worth noting that most of the students pointed out they had never had an opportunity to think critically about NOS, as one participant points out:

> *"But I think, we have learnt about science, but talking about NOS, it was my first time, and I had a problem understanding what it was all about."* (Sizakele, exit interview).

In line with Hammrich's (1997) assertion, engaging students in discussions of their NOS conceptions could afford them an opportunity to express, reflect and be challenged about their conceptions of NOS.

4.3.3 Metacognitive strategies

In this study concept maps and reflective journals were used as means to stimulate the pre-service teachers to think deeply about their understanding the nature of the scientific enterprise. Two of the seven focus group participants reported the strategies as having played a primary role in enhancing their NOS views. For example, when Hlobi was asked about what she felt contributed most to her development in NOS views, she pointed out the concept map and the reflective journal played a big role.

> *"The reflective journal, the concept map really played a big role, because I was able to see where I did not understand and make a follow up or consult through using what I had written on the reflective journal" (Hlobi, exit interview).*

Indeed, Hlobi's personal diary indicates that she did a lot of reflection about her learning of NOS. Some extracts from Hlobi's reflective journal are given as part of Appendix M.

Since this was a new learning strategy that participants had not used before, the researcher was interested in finding out participants' perceptions about the usefulness of such strategies. Hence, even in cases where it was not reported as having played a crucial role in their development in NOS views, participants' perception of the usefulness of the strategy was probed during interviews. Two of the five participants who did not classify concept maps as having played the most important role in developing their NOS views recognized the concept mapping learning strategy as being part of the cause of their development in their NOS views. For example, Muzi stated that:

> *"The concept map really had an impact on developing my understanding. It really enlightened my mind about how certain concepts relate to each other"* (Muzi, exit interview).

Muzi's concept map indeed consisted of a relatively high number of propositions substantiating his deeper reflection on the NOS concepts. Muzi's concept map forms part of Appendix N.
Two of the seven selected participants, Themba and Londiwe expressed negative feelings about the reflective journal, pointing out that they were not used to this strategy of learning. Themba who reported a very positive attitude towards the concept map pointed out time constraints as another factor that prevented him from adopting the reflective journal. Londiwe, on the other hand, reported that she had difficulties in using both the concept map and reflective journal. She attributed her difficulty to her perceived incapability to reflect on her learning.

> *"I tried to use them, but, esh…me, I am not used to reflecting about what I have been doing. So it makes it difficult for me to retrieve what I have been doing. I am not used to it, and I don't think it is useful. I don't sit down to think about what I have learnt and I don't think it is useful"* Londiwe, exit interview).

It is worth noting that those pre-service teachers who reported problems with the reflective learning strategies also did not develop much in their understanding of NOS. These results provide further evidence that adequate reflection is necessary to bring about conceptual change.

4.4 Factors mediating the development of NOS conceptions

A comparative in-depth study of a smaller group of seven pre-service teachers, of which three of them held relatively more informed views of the target NOS aspects at the end of the intervention, was used to ascertain the characteristics that had a bearing on the pre-service teachers' understanding of NOS. The focus group was similar to the rest of the participants in that they all held more or less identical inadequate views of the target NOS aspects at the onset of the intervention. Almost all the participants, with only a few exceptions, held the traditional positivist view of NOS, believing that scientific knowledge (theories, models and laws) is an actual representation of realty that is uncovered through carrying out the objective processes of science. The participants were generally uninformed of the role of human imagination, creativity and subjectivity in the development of scientific knowledge.

Table 4.12 shows the major inadequate conceptions of the focus group participants prior to the NOS instruction as revealed by their VNOS responses.

Table 4.12 Major inadequate conceptions held by focus group participants prior to NOS instruction

NOS aspect	Inadequate conceptions	Representative Quotes
Empirical	Science deals with facts about natural phenomena that are proven. The participants were not aware that what distinguishes science from other ways of knowing is that scientific claims are supported with empirical evidence.	"Yes, it is a matter of proving; like when you are conducting an experiment to prove that sunlight is necessary for photosynthesis, you already know that sunlight is required for photosynthesis, but you just want to prove that fact" (Themba)
Inferential	Scientific theories and models represent facts discovered through direct observations or experimentation rather than human interpretations of empirical evidence	"It was easy for scientists to determine the structure of an atom because they had seen them during their experiments." (Hlobi) "I think they actually saw the particles. I think they used a microscope, and they then conducted experiments such that they came up with the idea of that an atom consists of these different

NOS aspect	Inadequate conceptions	Representative Quotes
		particles.” (Themba)
Creativity and imagination in the interpretation of data.	Scientific claims (theories and laws) are solely based on empirical evidence, without the involvement of creativity and imagination. Scientific theories are discovered rather than created to make sense of observable phenomena.	“Scientists do not use imaginations and creativity, because to come up with theories and laws; experiments or investigations were carried out” (Sizakele). “Scientists are certain about the structure of the atom because different scientists discovered almost the same thing about the structure of an atom (Futhi).
Creativity in the planning and designing an investigation.	Scientists make use of their creativity in the planning and designing an investigation.	“For example, if a scientist wants to carry out an experiment of transpiration to prove that it does take place in plants. Before setting that experiment out, he or she has to use imagination and creativity in doing that experiment.” (Muzi).
Tentative	Scientific theories can be modified, not changed, while laws are not subject to any kind of change whether evolutionary or revolutionary	“Discovery of more information when the experiment is repeated some time later, may be ten years later, can lead to the improvement of a theory. I don’t think it is possible for a theory to be discarded altogether” (Themba).
Scientific laws and theories	Theories are observations or experimental results while laws are conclusions or generalizations made based on the observations or experimental evidence.	“Theories are the facts that have proven through using an experiment and a scientific law is the conclusion that is reached after the experiment.” (Hlobi)

NOS aspect	**Inadequate conceptions**	**Representative Quotes**
	A scientific theory is a scientific claim that is well supported by empirical evidence, and well accepted by the scientific community, therefore and not subject to change while laws are not proven. Theories therefore have a universal application while laws apply only under certain condition.	"A thorough research has been done in some theories but not laws. In some cases laws will not apply but theories apply when used. In most cases scientist consult other different scientist to come up with a certain theory (Sizakele)
Theory-Laden	Scientists are objective. They reach `objective' conclusions exclusively on the basis of objective observations. Scientists studying the same phenomenon follow certain instructions when carrying out investigations which ensure that they reach the same conclusions.	"If both groups follow the same instructions correctly they will both reach the same conclusions." (Fortunate) "If two scientists follow the same method and interpret the data correctly, they will come up with same conclusions" (Hlobi).
Social and Cultural Influence	Science is supposed to be objective and universal, and not influenced by the culture, of the society in which it is practiced	"Science is universal; it does not reflect social and political values, philosophical assumptions and intellectual norms of the culture in which it is practiced." Photosynthesis, for example, occurs the same way in Africa or in Asia" (Fortunate).

Participants' concept maps constructed prior to instruction provide further evidence supporting the claim that the focus group participants started with a comparably poor understanding of NOS. The participants' prior concept maps concept maps had very few connections between the concept maps as shown by the two concept maps below. Some of these concepts are incorporated as Appendix N.

The participants' prior concept maps revealed the following conceptions about science:

- Science and religion are separate ways of knowing.
- Science refers to the activities carried out by scientists as well as the body of knowledge that is generated as a result.

- Observations and inferences are viewed as processes of science.
- Science involves creativity and imagination.

Their maps also indicated the following misconceptions or gaps in their understanding of NOS:

- The absence of a link between science and subjectivity as well as social and cultural values suggest that the pre-service teachers believe scientific knowledge is completely objective.
- There is no indication of an awareness of how the processes of science (observations and inferences) are related to each other and to the products of science, as well as how the difference aspects of scientific knowledge (facts, laws and theories) link to each other.
- Though the pre-service teachers pointed out that science involves creativity, there is no indication of whether the students understand the role of these processes in developing scientific knowledge.

At the end of the programme, Muzi, Futhi and Hlobi were able to make more advances in their understanding of NOS than Themba, Sizakele, Fortunate and Londiwe. Muzi, Futhi, and Hlobi held more constructivist views of NOS. They viewed science more as an attempt to make sense of natural phenomena rather than discovering truth. They therefore acknowledged the role of creativity, imagination, and subjectivity in the development of scientific knowledge. On the other hand, Themba, Sizakele, and Fortunate evidently held on to their prior views of NOS. For example, at the end of the intervention, Muzi defined science as being about making sense of natural phenomena. He argued that the process involves both the discovery and creation of knowledge. In line with this definition of science, he viewed scientific theories as ideas created to explain regularities in nature rather than actual representations of reality**.** He also correctly pointed out that scientific ideas must however be supported by empirical evidence**.** Sizakele, on the contrary, was adamant that scientific knowledge is developed from empirical evidence alone without the involvement of human inference, creativity and imagination as indicated below in her own words:

> *"Like I said, they need creativity when they are carrying out the experiment, when they come up with theories, they only collect the data, and record it as it is, because if they can use creativity and imagination, even when they are interpreting the data, then what was the use of doing that experiment* (Sizakele, exit interview).

By the end of instruction, Futhi, Hlobi, Muzi, and Themba made more valid connections compared to the rest of the focus group participants. Distinct from Futhi and Muzi, the elaborateness of Themba's concept map was irreconcilable with his ill developed understanding of NOS, as revealed by his VNOS responses. Two of the other participants, Sizakele and Londiwe, who also did not realize much gain in their NOS understanding did not submit their post-instruction concept maps, and one of them, during post interviews, pointed out that she had difficulty constructing the concept map. Muzi and Futhi who had achieved more gains in their NOS understanding as judged by their VNOS responses were able to construct all of following new propositions after instruction:

- All scientific knowledge is partly subjective.
- Science is influenced by social and cultural values.
- Development of theories involves a great deal of creativity.
- Inferences are based on observations.
- Theories are based on inferences.
- Scientific laws are more grounded on scientific facts.
- Scientific theories and laws are tentative.
- Theories are more tentative than scientific laws.
- Scientific laws describe observations.
- Scientific theories explain scientific laws.
- Scientific laws do not develop from scientific theories.

Only one participant, Sizakele, who achieved lesser gains in her NOS understanding, submitted a concept map that seemed to be of her own creation. This assertion is based on the fact that her map was comparative to her NOS views at the end of the intervention. As already pointed out, two of the other participants did not hand in their concept maps, whilst one participant's map did not seem original as it did not match his ill developed understanding of NOS, as revealed by his VNOS responses. Sizakele's concept map showed fewer new links compared to the rest of the participants' concept maps. Analysis of the concept map indicates that the student still believed that scientific claims are based solely on observations of the natural world without the influence of personal elements. Below is a list of the propositions represented by Sizakele's map:

- Scientific theories explain observations.

- No connections between theories and inferences, but laws are indicated as based on inferences.
- Products of science (laws, theories, and facts) describe observations.
- Scientific theories are more tentative than laws.
- Similar to the her prior concept map, no links between science and subjectivity and between science and social and cultural values, indicating that the participant still does not believe these have an influence on science.

Table 4.13 compares the number of correct propositions that the selected group participants were able to make prior and after the NOS instruction.

Table 4.13 A comparison of number of propositions about NOS made by the selected group of participants prior and after NOS instruction

Name of selected group participant	Pre-Instruction NOS concept maps	Post participation NOS concept maps
Futhi*	8	18
Muzi*	7	18
Hlobi*	10	14
Themba		16
Fortunate	7	9
Sizakele		Not submitted
Londiwe		Not submitted

***Participants who achieved relatively higher gain in NOS understanding.**

The participants who achieved higher gains in NOS conception, especially Futhi and Muzi were able to construct a relatively higher number of propositions about NOS compared to the Sizakele, who achieved lesser gains in her NOS understanding. In line with, Abd-El-Khalick and Lederman (2009), these results indicate a relationship between developments in an ability to reflect on and understand one's own learning and cognition (Schraw & Dennison, 1994) and gains in NOS understanding. This observed relationship implies that learning NOS is more of a cognitive rather than an affective learning outcome (Abd-El-Khalick & Akerson, 2009).

Following is a discussion of personal characteristics that were found to play a role in enhancing or hindering the focus group participants' development of more informed views. These factors were established by comparing the members of the selected group who had more gains of NOS with those who achieved lesser gains.

4.4.1 Valuing NOS as an important teaching and learning goal

One factor that was found to have an impact on the pre-service teachers' development of NOS views was the internalization of the importance of teaching and learning NOS. This factor seemed to be closely linked to participants' ability to spontaneously reflect on the NOS issues. Even though, at the end of instruction, all pre-service teachers stated that they believed NOS was important, only those who developed more informed views seemed to have quickly understood the importance of teaching and learning NOS. This realization motivated the participants to deeply engage themselves with the NOS issues resulting in better gains in NOS understanding. For example, Hlobi seemed to have quickly realized the importance of learning NOS as noted in her personal reflection of the third NOS lesson:

> *"I have been thinking that NOS really confuses one when it is brought to the lesson taught on that particular day. To my own surprise, I realized that it is a good thing to learn NOS. I have also realized that NOS is very important because it teaches you more things about science. Knowing science (content) is not enough you have to know beyond that, thus I can conclude that science is completely different from other subjects because it opens one's mind (*Hlobi, personal journal).

Also, linked to her realization of the importance of NOS, she viewed all the aspects of NOS discussed in class as valuable for developing a scientific literate citizen. She feels that elementary science should focus on making students distinguish inferences from observation. She believes that such an understanding is necessary since students will most of the time be involved in carrying out investigations and therefore the meaning and differences between the two process skills must be clearly understood.

Similarly Muzi and Futhi also perceived NOS as fruitful for their own teaching and learning as indicated below.

> *"Actually, I have realized that in order for someone to understand how science works, he or she must learn about the NOS first"* (Muzi, final reflective journal).

Moreover, in his reflection of the third lesson of the programme, he pointed out that the learning and understanding of NOS was the best way of leaning science.

"*Learning and understanding NOS, I think is the best way of learning science because previously I would learn a lot about scientific theory, but I did not know what a scientific theory is. But now, I understand that a scientific theory can change if evidence is found to dispute it"* (Muzi, personal journal).

When he was asked about the aspect of science that he believes should be taught, he pointed out that all aspects are important but he valued NOS teaching more as he believes it enhances the learning of science content as indicated below:

"I don't think that there is any other aspect that is more important than the other. I think they should be equally taught. Given a choice, I can teach NOS followed by the processes of science more than the products of science. I believe that if somebody has understood NOS and the processes, it will be much easier to understand the products of Science" (Muzi, exit interview).

He also realized that teaching NOS to students may serve to develop positive attitudes towards the learning of science in general. Futhi also noted that explicit discussion of NOS issues while learning science content was necessary as it enhances the learning of science content.

*"Before we did not have time that we had now, because like when we are talking, for example, about these theories, because we used to learn about these theories and we knew that this is a theory by so and so, but we never go deep and discuss about them. It was just something we learnt and remember for the sake of passing tests. What I can say is that the programme is a wonderful programme, it really helped me a lot even when I learn any science related subject" (*Futhi, exit interview).

Even though she felt that the elementary students she was going to teach were not going to be able to learn most of the NOS aspects, she, in line with Hlobi, noted that a discussion of the differences between observations and inferences was a necessary base for understanding science.

"At primary, may be you can teach the processes of science; the difference between observations and inferences, because this is what contributed to my difficulties. I also had difficulty in differentiating observations and inferences. I think may be at primary

> *level if we can make a clear distinction between these terms, then if they got the terms correct, learning about the NOS will be much easier, when they reach may be high school"*(Futhi, exit interview).

On the other hand, the four students who made lesser gains in their understanding of NOS seemed to have either not valued NOS as an important aspect of learning science, or taken too long to do so. This failure could be attributed to their lesser disposition to reflect on ideas as well as their more performance oriented disposition. The pre-service in this programme were not going to be examined directly on NOS issues at the end of the year examination, and they were aware of this fact. So, to them, discussing NOS issues seemed to have been a waste of time that could be spent more on the science content that they were to be examined on. Kattoula (2008) found that students' motivation to learn certain concepts is linked to course assessment and grading. Unlike the pre-service teachers' who made more advances in their development of NOS, Themba's failure to understand NOS as an inherent part of learning science is indicated in his response, when he was asked whether or not he had enjoyed learning NOS.

> *"Honestly, I would say I enjoyed, at the same time I did not enjoy it. I did not enjoy it because there is no time specifically located to NOS. I did enjoy it because it clarified some certain aspects. As far as I am concerned, it must have its allocated time" (*Themba,exit interview).

Themba's lack of reflection on his development of NOS views is another indication of his failure to value NOS as an important goal worth spending time on whilst learning science content. This feeling about NOS as not very important, also emerged when asked whether he was able to daily reflect on his development in NOS understanding, he stated that he could not do so because of lack of time. He however, points out that he was able to use the journal to reflect on the other aspect of his learning.

> *"The reflective journal is however useful because I can use it to jot down something that I did not understand. Then I can organize some time and go to the lecturer to get help. I did not do this because of the time factor, I wished to go back and find the correct thing. I have been able to use it in the other subjects, I used it to jot down problems and when I got home, I would read on my own and I was able to solve them" (*Themba, exit interview).

Sizakele and Fortunate also pointed out that it really took them time to enjoy learning about NOS which is an indication that they struggled appreciating the value of NOS in their learning of science.

> ***Interviewer:*** *Would you say you have enjoyed learning about NOS?*
>
> ***Sizakele:*** *After a time, after a time because at first I was less interested. But now I even enjoy writing the journal. In short, I am trying to say I am starting to enjoy the NOS, but at first, I was less interested.*
>
> ***Fortunate****: Yes, at last, I enjoyed. At first, I could not understand what really NOSis about. It took me time, I won't lie. And also, I think is the time; we do not have enough time, so when we look at NOS, what really is it? So, but, at last, I got to understand it. I like it now.*

4.4.2 Engagement with the NOS concepts

The second factor that mediated the selected group understanding of NOS was more cognitive in nature. The pre-service teachers' engagement with the NOS concepts was found to interact closely with their development of NOS understanding. Futhi and Muzi, and Hlobi who displayed a deeper engagement with the NOS concepts made relatively more gains in their understanding of NOS than the rest of the members of the selected group. For example, Futhi and Muzi realized that they needed to understand the meaning of the key terms in NOS, and how they interrelate in order to understand NOS.

> ***Interviewer:*** *How have your views regarding NOS changed?*
>
> ***Futhi:*** *They have changed a lot, because at first, I think what made me not to understand clearly was that may be I had a misunderstanding of some of the terms. So, I think understanding these terms, such as a theory has helped me in understanding NOS.*
>
> ***Interviewer****: Do you think concept maps and reflective journals were useful.*
>
> ***Muzi:*** *Yes, developing the concept map really had an impact on developing my understanding. It really enlightened my mind on how certain concepts relate to each other.*

Indeed Muzi and Futhi were able to develop relatively more elaborate concept maps that showed more valid propositions about NOS as illustrated by their concept maps. Their maps are included as Appendix M. Even though Hlobi's concept map has lesser connections compared to that of Futhi and Muzi, her reflective journal indicated that she was deeply engaged in learning about NOS. She recorded almost daily what she had learnt about NOS as well as issues that she believed she needed clarification on. Some extracts from her reflective journal form part of Appendix L.

She also pointed out during the exit interview that the reflective journal played a significant role in enhancing her understanding of NOS.

> "*The reflective journal, the concept map really played a big role, because I was able to see where I did not understand and make a follow up or consult through using what I had written on the reflective journal*" (Hlobi, exit interview).

Muzi's deeper engagement with NOS is also evidenced by his ability to use the NOS terms correctly during interviews and in his questionnaire responses as demonstrated by the extract below:

> *"Science is not objective as many people think or understand about science, because inferences or interpretations of data are influenced by other ways of knowing such as religion, philosophy, social and cultural values, prior knowledge and many" (*Muzi, final reflective journal).

As a further indication of their deeper consideration of NOS issues in the context of their learning experiences, these participants were able to clarify and provide more justifications for their NOS views during interviews.

> ***Interviewer:*** *What has contributed most to your change in the way you view science?*
> ***Muzie****: Actually, it is learning about NOS. I could make an example of some activities. We had some couple of activities; that one when we shot into the box (Rutherford's content embedded activity), we all made the same observations and came up with different interpretations. And also where there we read a passage where each and every one came up with a different aspect of what he or she thought the passage was about. It*

> *then clicked to me that, ey, but we are looking at the same passage but we interpret it differently.*

He therefore concluded that:

> *"Science is not objective as many people think or understand about science, because inferences or interpretations of data are influenced by other ways of knowing such as religion, philosophy, social and cultural values, prior knowledge and many" (*Muzi, final reflective journal).

Another instance where Muzi indicated that he had deeply reflected on his classroom experiences is illustrated by his argument that scientific ideas build on prior ideas.

> ***Interviewer:*** *Do you believe theories can be falsified?*
>
> ***Muzi:*** *Actually, I can say they can be modified, and once you have modified, the one you had initially you no longer going to use it because you have modified it, so in short I can say they can be falsified.*
>
> ***Interviewer:*** *Can they be replaced by a new theory?*
>
> ***Muzi:*** *Yes, but there is a connection; the new theory will always be connected to the old theory.*
>
> ***Interviewer:*** *Can you justify that or explain why you think there will always be a connection?*
>
> ***Muzi:*** *Like if I can go to the atomic theory, we can see that it was first started by Thompson. Thompson viewed an atom as the protons and electrons as concentrated together, then after then Rutherford then came and developed his own hypothesis from Thompson's theory, so you can see that there is a connection, when he developed his theory from Thompson, he said the electrons are not just concentrated but are just floating around the nucleus, and then after Rutherford, came Bohr who states that the electrons are not just floating but are arranged in shells. You can see that there is a connection; these people are building on what we already have.*

Similarly, Futhi was able in most cases, to provide a context from which she developed her understanding of NOS. She pointed out that she was surprised to realize that scientific constructs such as the atomic model and the gene are a product of scientists' creativity rather than direct observation. Unlike, the students who achieved relatively minor gains in NOS understanding, she was able to develop a balanced view of the nature of theories. She noted that not every idea is valid, but every created idea in science must be substantiated by empirical evidence.

> *"By learning about the theories of matter, I came to conclude that science needs empirical evidence to support theories, and that not every theory is accepted in the scientific realm*" (Futhi, personal reflective journal).

To explain her belief in the influence of philosophical assumptions on science, Futhi was able to provide a relevant example from what they had learnt from class:

> *"Yes, I was thinking about the controversy in the extinction of dinosaurs. They were having the same data, but these two groups of scientists came up with different conclusion"* (Futhi, exit interview).

A very shallow engagement with NOS was expressed by the participants who achieved lesser gains in NOS understanding. Some of these students, Londiwe, and Sizakele failed to submit their final concept maps and daily reflective journals which indicated that they had made very little effort to engage themselves with the NOS. Themba who seemed to have drawn a concept map that was as elaborate as those of the two students who achieved higher gains in NOS, had actually reproduced one of these pre-service teacher's concept maps and final reflective journals. This assertion is based on the fact that, unlike the other focus group participants, his concept map did not tally with his views of NOS as revealed by his VNOS responses. The purpose of the concept map and reflective journal was to engage the students deeply with the NOS material as they searched for meaning of the NOS terms and reflected on their understanding of NOS. The failure to participate in these exercises was evidence of a shallow approach to learning about NOS. Fortunate, the only one of these pre-service teachers who submitted an original concept map depicted fewer connections between the concepts compared to other pre-service teachers who achieve higher gains in NOS conceptions. Fortunate's post concept map is shown as part of Appendix M. Their shallow engagement with NOS is further evidenced by their inability to expand on their NOS views and their inability to use the key NOS terms consistently during interviews, as illustrated by the extract below taken from interview transcripts of Themba and Fortunate.

Interviewer: *At what stage do they make use of creativity and imagination?*

Themba: *I think at the conclusion stage.*

Interviewer: *Can you use an example to clarify your view?*

Themba: *No, I do not have any example.*

In another instance when Themba was asked about the functions of roles and theories, he seemed to have appreciated the importance of theories in science as illustrated below:

Interviewer: *Between theories and laws, which construct is more important and why? Or you think they are equally important?*

Themba: *I think theories are important because they help scientists to further their investigations.*

However, when Themba was asked about the aspect of science that he believes must be emphasized in teaching, he provided a contradictory response indicating that he had not thought deeply about the role of theories in the context of the activities, but was simply reproducing knowledge from credible sources.

*"We have to focus on the science that involves manipulating, where the learners will manipulate variables for the purpose of developing the processes rather than the content of science. Processes are more important than the content of science. I am not the supporter of theories because theories that we are learning, all these things will be considered wrong, unlike the processes. Processes will remain the backbone of science" (*Themba, exit interview).

Similarly, Fortunate also demonstrated a lesser inclination to deeply engage with the NOS issues, as inferred from the below illustration:

Interviewer: *So, are you saying that science is not completely objective.*

Fortunate: *Yes, even though I won't give reasons why I am saying so.*

Sizakele seemed to struggle with the meaning of the terms law and theory:

Interviewer: *Is there a difference between a scientific theory and a scientific law?*

> ***Sizakele:*** *Yes, there is a difference between the two. When we talk about a scientific law we are talking about something that (a pause) is observed in the environment, but when we talk about a theory, it describes, when a law explains, so it explains something observed, no, a law, a theory explains. Am I not confusing myself?*

On the whole, consistent with Abd-E-Khalick and Akerson (2004), the participants who expressed a deeper engagement with the NOS concepts were able to achieve relatively higher gains in their NOS understanding. Southerland, Johnston, and Sowell (2006) assert that an ability to deeply process material is facilitated by students' reflection ability and need for cognition. This corroborates Irez and Cakir's (2006) assertion that prospective teachers' reflective thinking about their learning experiences could help to improve their NOS conceptions.

4.4.3 Pre-service teachers' epistemic beliefs

The pre-service epistemic beliefs also interacted with students' ability to develop more informed views of NOS. Harteis, Gruber and Hertramph (2010) define epistemic beliefs as "individual convictions about knowledge and knowing" (p.201). The participants' personal convictions about knowledge and knowing seemed to interfere with their ability to find some NOS views plausible. All the pre-service teachers who held on their prior inadequate views in spite of the contradictory evidence, held a view that knowledge is "absolute, certain and non- problematic, right or wrong as it originated from observations of reality or from an external authority" (Rebich & Gautier, 2005, p356). This assertion is based on statements made by this group of teachers. The strong reliance on authority for knowledge rather than from reflective judgment was more apparent in one pre-service teacher who pointed out that her school teacher had a strong influence on her changes in the way she viewed NOS.

> ***Interviewer:*** *Is there any other experience that you feel influenced your views, outside the classroom situation?*
> ***Fortunate:*** *I used to work hand in hand with one of the teachers at Mncozini. I remember one time; I asked him about the African science. Is science different, so he helped me a lot.*

Fortunate seemed to have adopted this view simply because it came from a perceived authority figure rather than from reflecting on her classroom experiences. Although, as a result of guided reflection, she was able to reach an understanding that science is contextual rather than universal, her strong belief of knowledge as being provided by authority rather than reason prevented her from finding the idea plausible, hence could not achieve conceptual change as demonstrated by the excerpt below:

> ***Interviewer****: Some people claim that science is affected by the context in which it is being practiced, while other say it is universal.*
> ***Fortunate:*** *I will go for the view that science is universal. What makes people to view it in a very different way is our culture, but science is one. I would like to give an example of germination. when you plant something, everywhere the plant needs water , even when you plant in Africa or else in America, in order for it to grow it would need water, so that is why I say it is universal. The way may be we interpret it or the way we view it.*
> ***Interviewer:*** *Do you think science is only about making observations or is also about making interpretations of what we observe.*
> ***Fortunate:*** *I would say it involves both the interpretation and the observation. You observe and then you interpret what you observe.*
> ***Interviewer:*** *Do you think scientists coming from different contexts would interpret their observations exactly the same way?*
> ***Fortunate:*** *No.*
> ***Interviewer:*** *Would you say therefore say science is universal or is influenced by the society in which is being practiced?*
> ***Fortunate:*** *Okay, it is influenced by the society where it is being practiced; I can say that because of the different interpretations that they would have at the end*
> ***Interviewer:*** *We are now at the end of our interview. Is there anything you would like to ask or say?*
> ***Fortunate:*** *I think madam, what if you can help me**.** Is science universal? What is your view?*

The pre-service teachers' view of knowledge as coming from first hand observations of reality rather than from evaluation of available evidence also interfered with their ability to evaluate the plausibility of the target NOS aspects (Irez & Cakir, 2006). For example, when Londiwe was asked about problems that she experienced when learning NOS, she pointed out her difficulty in accepting anything that she had not observed. According to her understanding, for something to be known it has to be directly observed (Conley, Pintrich, Vekiri & Harrison, 2004; Irez & Cakir, 2006). Therefore, anything that cannot be directly observed is simply a product of one's creation and imagination.

> *"Sometimes it is hard to change from what you have known to be true to something else, and sometimes you have to change without experimenting what you have been told, just have to know it just like that. The activities were convincing, but not very much because sometimes the theory has to develop from the first view to the second view; it is not very clear how the very first theory came about. I sometimes think they just sit down and think about it" (*Londiwe, exit interview).

It is worth noting that for Londiwe and the other participants who held a similar realist view of knowledge, experiments were viewed as providing direct evidence about phenomena rather than clues that scientist use to make sense of natural phenomena. These pre-service teachers therefore found difficult to accept that theories can change as a result of reinterpretation of the same evidence, as illustrated by the following responses:

> ***Interviewer:*** *Do theories change?*
> ***Londiwe:*** *They change, but do not change. Not necessarily that they change but they develop from one theory to another. It is not possible for a theory to change. I think that if the evidence is not satisfactory, people question the theory. If someone thinks differently in terms of carrying out the experiment, he can come up with new results or evidence that would result in a better theory*
> ***Interviewer****: Why do theories change?*
> ***Themba:*** *They change just because new information has been gathered.*
> ***Interviewer****: Do you think that this is the only reason that causes theories to change?*
> ***Themba:*** *Mhh. They might be another reason, but the one I believe in is that due to new information.*
> ***Interviewer:*** *So, if there is no newly discovered information, theories cannot change?*
> ***Interviewee:*** *I think so.*

These pre-service teachers believe that experimental results do not need to be interpreted but speak for themselves (Akerson & Donnelly, 2008). Londiwe and Themba were therefore probably at a level of cognition where they understood knowledge claims as uncertain, but base this uncertainty on missing information or on the method of acquiring the information (Irez & Cakir, 2006). From the above observation, it can be concluded that even though these students might have understood the role of context, creativity and imagination as well as empirical evidence when they carried out activities, their beliefs about knowledge and knowing made it difficult for them to embrace them as plausible representations of how science is really done. They therefore maintained their prior inadequate views about NOS. This is in line with Clough (2006) who argues that de-contextualized and moderately de-contextualized activities may easily create in students, two contradictory conceptions about how science works one that is in line with the activity done in class, and a different one that represent their belief about how science really works. Sizakele's absolute (dualist) view of knowledge surfaced as she strongly argued that there is one correct answer to every question that scientist put forth.

> ***Interviewer:*** *Do you believe there is one true answer to every question?*
> ***Sizakele:*** *Yes, may be different people can interpret it a different way, but there is one true answer, because, even if you can look at their summary of what is in the observations, you can find that it is similar, but it is the way they have put it.*

In line with the above assertion, when Sizakele was asked about whether scientists use their creativity and imagination when developing theories, she stated that:

> *"When they come up with theories, they only collect the data, and record it as it is. If they can use creativity and imagination, even when they are analysing the data, then what was the use of doing that experiment?"* (Sizakele, exit interview).

Sizakele's strong belief that there is one answer to every question also appears when she was asked if it were possible for two scientists to come up with same explanations of the same data. Again, possibly based on the activities done in class, she became aware that making sense of data is subjective, but her strong view of knowledge as non-problematic right or wrong make it difficult to find this view of science believable.

> ***Interviewer:*** *Is it likely for two different scientists who are working with same data to come up with different interpretations of the same data.*

> ***Sizakele**: It will not be different, but they can come with different explanations, but when you can try to look closely at their explanations of that same data is more like the same, but it is the way they are putting it that will bring a different angle from the other one. But, from the same data they come up with the same thing, may be the way they are going to interpret it that will differ, but even there it is the same, it is the same.*

Similar to the some participants in Abd-El-Khalick's (2001) study, the pre-service teachers' absolutist view of knowledge was a reason for their lack of comfort with the tentative NOS. Themba, for example, indicated a discomfort with uncertainty, as he pointed out that he is against teaching or learning theories because of their subjectivity to change, instead he prefers focusing on the processes of science.

> *"I am not the supporter of theories because theories that we are learning, all these things will be considered wrong, unlike the processes. Processes will remain the backbone of science" (*Themba, exit interview).

His strong belief in certainty of knowledge is further revealed by his assertion that science was meant to be universal, but it is only different because of social and cultural factors. This indicates that the participants do not view knowledge as a social construction of reality, rather as a depiction of reality, and thus, views the scientists' social and cultural beliefs as an impediment to the otherwise believed to be an objective endeavour of discovering truth about natural phenomena.

In line with Irez and Cakir's (2006) argument the participants who developed more informed views of NOS did not reveal any problem with the uncertain nature of scientific knowledge. They accepted that knowledge claims are not certain and seemed not to believe that there was only one answer to any given question, hence they were able to accept the constructivist view of science as representing real science.

> *"I think science is now, is sort of an interesting subject, and because it is not like you are being spoon-fed. Everything done in science should undergo certain processes, like have empirical evidence and if you bring a new idea or evidence, a theory can change, unlike the other subjects, it is just has to be the way it was even before"* (Hlobi, exit interview).

These results supports the assertion that students with an absolutist view of knowledge are less likely to be open-minded and to consider evidence that conflict with their prior beliefs and achieve conceptual change (Rebich & Gautier, 2005). These students who achieved higher gains in their NOS understanding were therefore probably at higher epistemic cognitive level where they understood knowledge as contextual and relative, and had also developed a metacognitive awareness of their thinking and were comfortable with ambiguity and tentative answers. Indeed evidence points out that the students who achieved greater changes in their understanding of NOS were quite aware of their thinking, and were therefore able to reflect on personal NOS views. For example, Futhi indicated that she was self-conscious of her own learning. She pointed out that she understood theories and laws as different kinds of scientific knowledge and that one does not develop into the other. She also pointed out that she had also developed the view that scientific knowledge is not the actual representation of reality, but ideas created by scientists to interpret nature and that science is influenced by social beliefs and one's background.

> *"My conceptions of NOS have changed in the sense that I now understand that theories do not develop into laws rather explain laws while laws describe regularities as observed in nature. I also had a misconception that science is truth found from empirical data whereas science involves human creativity and imagination and is also tentative*" (Futhi, final reflective journal).

She was also aware of her struggles in learning NOS, such as making a distinction between process skills and NOS.

> *"My difficulties in learning NOS is that it took me time to understand the meaning of other concepts, for example, making a distinction between process skills and NOS"* (Futhi, final reflective journal).

This struggle was indeed revealed in her final reflective journal and interview responses as she referred to the processes of science such a questioning, investigating, observing as aspects of NOS.

> "*Aspects of NOS a scientifically literate citizen should know are some of the processes of science such as observations, questioning, investigating, classifying, measuring, using*

> *number, communicating data etc. This is because these processes are most applied in everyday life noticeably and haphazardly"* (Futhi, written assignment).

On the other hand, evidence from this study indicates that students who did not achieve much gain in their NOS understanding were not very much reflective of their own conceptions about NOS and were therefore unaware of their development or lack of development of NOS views. For example, when Sizakele was asked to point out how her views have changed, her response indicated her lack of reflection on her development in NOS understanding, as she had only this to say:

> *"The thing of theory and law, to me there were just one thing. I thought a law was just another word for a theory. But now I understand the distinction between the two"* (Sizakele, exit interview).

In many cases, the students were also not aware of the struggles they had with understanding NOS. Themba and Sizakele were unaware that their thinking about NOS was in disagreement with the constructivist NOS aspects discussed in the programme. For example, Sizakele also believed her views of NOS had drastically changed as indicated below:

> ***Interviewer****: How have your views changed in the way you understand science?*
> ***Sizakele:*** *There has been a great change because some of the views I had about science were wrong.*

She however still strongly viewed science as an objective endeavour that is solely based on empirical data without the involvement of creativity and imagination.

This highlights Clough's (2006) assertion that some students may not be aware that their developed conceptions are an incomplete fit with a new encounter. He argues that this realization is necessary to make a student feel a strong need to search for more information that will help them resolve the conflict and consequently develop fully informed views.

Similarly, Fortunate also indicated an inability to reflect on her own personal understanding of NOS, as most of the statements in her journal were an expression of what was said in class rather than of her changes or lack of changes in her personal understanding of NOS. She also believed her views have changed, evidently unaware of how different her views were compared to the target NOS views. Unlike the other students, who achieved gains in their NOS understanding, Londiwe explicitly stated that she found it difficult to think about her personal understanding of any concept learnt, and also did not believe it was useful. This is based on her response when asked about whether she found the reflective journal useful in her learning about NOS. She had this to say:

> *"I tried to use them, but, esh…me, I am not used to reflecting about what I have been doing. So it makes it difficult for me to retrieve what I have been doing. I am not used to it, and I don't think it is useful. I don't sit down to think about what I have learnt and I don't think it is useful" (*Londiwe, exit interview).

In this study, students' beliefs about knowledge and knowing as well as their capability to reflect on their own thinking about NOS seemed to be a factor mediating their ability to achieve conceptual change in their views of the nature of the scientific endeavour.

4.4.4 Views about teaching and learning science

The pre-service teachers' beliefs about learning and teaching science are another factor that had an influence on their development of more informed NOS views.All the pre-service teachers who embraced a more constructivist perspective of teaching and learning of science, where the teacher is believed to be a facilitator of learning, rather than a transmitter of knowledge, seemed not to have a problem with accepting the constructivist view of science as evidenced by their development of more informed views of the target NOS aspects. For example, Futhi pointed out in her assignment that learners in science lessons must be given a chance to:

> *"Explore, make observations, and test their ideas and not just memorize facts"* (Futhi, written assignment).

During interviews she also pointed out that she believed that involving learners in carrying out activities and discussions is more useful than just giving them information. She also held a constructivist view of learning as she pointed out that learners must figure out things themselves, and the teacher should only help where necessary.

Muzi, who also developed more constructivist views of NOS, also believed in learner centred pedagogical approaches that promote students' interaction with the phenomena under study to enable them to create their own understanding. He believes learners' prior ideas should be considered in instruction and creativity and open mindedness should be encouraged by allowing them to create and test their ideas. In line with this his beliefs about teaching, he believes that learners should ask questions, say out their ideas and reflect on them. Such a view of learning and teaching is more consistent with a view of science as a human attempt to understand natural phenomena, rather than a discovery of reality. This view of science enabled Muzi and the other pre-service teachers who made more gains in their understanding of NOS, to find the inferential and creativity NOS plausible and fruitful which consequently facilitated their conceptual change.

On the other hand, Sizakele and Fortunate viewed science as best taught by transferring knowledge to the learners. For example, Sizakele displayed her traditional view of teaching when she pointed out in one of her assignments that the teacher should:

> *"Let the pupils ask and keep asking so the teacher can explain how the world works"* (Sizakele, written assignment data).

In line with her transmission view of teaching, she believed that learning is about acquiring or 'reproducing' knowledge from credible sources as revealed by her statement:

> *"I read a lot of science books and they teach me new things that I did not know before"* (Sizakele, written assignment data).

Fortunate also believed in the use of experiments to prove facts to students, and she viewed learning as being about practicing what has been learnt in class. Both pre-service teachers seemed not to view learning as involving the learner in constructing their own meaning as they reflect on their experiences and ideas. Such a view of teaching and learning is closely linked to their understanding of scientific knowledge as being certain and that there is only one answer to the questions that scientists put forth. This view made it difficult for the student to accept the creative and subjective nature of scientific knowledge as shown by her interview responses to the VNOS- questions

> ***Interviewer:*** *Do you believe there is one true answer to every question?*

> ***Sizakele:*** *Yes, may be different people can interpret it a different way, but there is one true answer, because, even if you can look at their summary of what is in the observations, you can find that it is similar, but it is the way they have put it.*
>
> ***Sizakele:*** *Yes, that is what I say the way you are going to interpret it, you are going to interpret it exactly what you observed, but when you are putting it down you will need creativity to make it clearer*
>
> ***Interviewer:*** *If I get you very well, you mean that creativity is not involved in the interpretation of data, but interpretation must be based solely on the collected data?*
>
> ***Sizakele:*** *Yes, there you do not need creativity, but you are writing exactly what you observed, like when use a graph to interpret your data, then that is where the creativity comes in.*

Themba and Londiwe viewed teaching science as being about developing learners' ability to carry out the processes of science. This view of teaching was more in line with an understanding of science as being about using the processes of science to discover knowledge about natural phenomena. These students therefore had problems developing sophisticated understanding of the role of both empirical evidence and creativity in the development of scientific knowledge. Themba viewed models, for example, as a direct representation of reality obtained through experimentation, while Londiwe believed that since such entities cannot be directly observed, they must be just a product of scientist' imagination and creativity. Scientists tried to investigate the structure and failed and thus created the structure solely from their mind. Themba's strong belief that credible knowledge in science is obtained through only carrying out experiments is indicated in his argument that evolution is not a scientific theory, but just an accepted hypothesis. The strong process view of scientific knowledge is also indicated by the pre-service teachers' definition of science:

> *"Science is both the body of knowledge and the discovery of facts that are linked together into a coherent understanding of the natural world*" (Themba, written assignment).
>
> *"Science is a systematic attempt to discover and expose nature's patterns" (*Themba, post-questionnaire).

The process approach to teaching science that is emphasized in the science methods course seems to promote a discovery view of science rather than a constructivist view, hence participants held difficult appreciating the inferential and creative nature of scientific knowledge, as revealed by the lower number of pre-service gaining informed views of these aspects of NOS.

4.4.5 Pre-service teachers' religious beliefs

In line with Southerland, Johnston and Sowell (2006), religious beliefs were not helpful in clarifying differential gains in this group of pre-service teachers' understanding of NOS. Unlike in Abd-El-Khalick and Akerson's (2004) study, most of the selected group participants including those who held inadequate views did not view science and religion as being in conflict. Also, none of the students demonstrated negative attitudes towards scientific claims that could be linked to their religious views. However, as also noted by Southerland, Johnston and Sowell (2006), the influence of religious beliefs could have been mediated through the participants' personal beliefs about knowledge and knowing. All the focus group participants in this study who did not achieve much gains in their NOS understanding believed that knowledge is "absolute, certain and non- problematic, right or wrong" (Rebich & Gautier, 2005, p.356) while those who developed more informed conceptions did not hold such beliefs.

Among the seven focus group participants, only two believed that there is a conflict between religion and science. The pre-service teachers' belief in a conflict between science and religion seemed to originate from their failure to accept science and religion as distinct ways of knowing that are based on different values and assumptions. Sizakele revealed a struggle accepting the absence of a conflict between the two ways of knowing when asked whether one can be simultaneously a scientist and a Christian:

> *"May be you like science, but you are a Christian; you are going to pursue your studies in science. Along your studies, you can see there is a problem between the two, but because Christianity is not your profession, but your religion, you end up adjusting. Even if you see that there is a conflict, but because science is your profession, you end up adapting that they are different. You try to separate them, may be because of your profession, and may be because you are going to teach'*

Themba had this to say regarding his view about science and religion:

> *"I strongly view science as being in conflict with religion. The conflict is in the way they arrive at their conclusions. The authority of science is in the evidence and reasoning, while religion evades evidence and logic in order to justify his or her conclusion. It is therefore a myth to believe that there is no conflict between science and religion"* (Themba, written assignment data).

Themba believed that since religion is not based on evidence, but on faith, it is inevitably in conflict with science. The participant apparently used the standards of science to pass judgment on the authority of religion. This tendency to use science to judge other worldviews could be caused by an exaggerated view of science as the only way of understanding the world. This view is consistent with the positivist view of science that these two pre-service teachers hold (Haidar, 1999). Haidar point out that such a positivist view of science was the reason behind many Arab intellectuals' failure to appreciate religion, art and poetry as acceptable means of understanding the world.

Unlike Themba and Sizakele, all the other pre-service teachers in the focus group were able to appreciate that science and religion are both valid, but different ways of knowing. Muzi stated for example in his assignment that:

> *There are matters that cannot be usefully examined in a scientific way; for example beliefs by their nature cannot be proven or disapproved such as existence of supernatural powers and beings" (*Muzi, written assignment data).

Themba is likely to promote an exaggerated view of science among his students, which may create a negative attitude towards science among students who value other ways of knowing. In line with Southerland, Johnston and Sowell (2006), the study findings further accentuates the importance of including a discussion of the bounded NOS in science instruction in order to promote an accurate view of science and consequently prevent negative attitudes towards learning and teaching science. Science should not be presented as being in conflict with students' religious viewpoints, rather as another way of knowing (Abd-El-Khalick & Akerson, 2004; Shipman, Brickhouse, Dagger & Letts, 2002). This is in line with Akerson and Donnelly's (2008) assertion that in science classrooms, students should be given an opportunity to build scientific concepts alongside their cultural beliefs. It is worth noting that the differences between religion and science were also discussed in this intervention, which could be a reason why most of the focus group participants seemed convinced that there was no conflict between the two.

4.5 Summary

Results of the study are summarized below. Sections in which these results are found are indicated in parenthesis.

In conclusion, the results of the study indicate that:

- The participants' conceptions of NOS were generally, inadequate before participating in the explicit reflective NOS intervention (Section 4.1.1). Most of them believed that science is an endeavour that is solely based on observable facts without the involvement of human inference, creativity and subjectivity (Section 4.1.2). As a result of this view of the scientific endeavour, most participants believed that scientific theories and models represented truths, rather than scientists' understanding of natural phenomena (Section 4.1.2.2).
- The explicit reflective approach had a positive influence on the pre-service teachers' views because as a result of the intervention, a considerable number of participants had developed at least partially informed conceptions of the different investigated aspects of NOS (Section 4.2).
- With regards to participants' perceptions of the impact of the course elements on their NOS views, a relatively higher number of selected group participants reported that the explicit reflective attention to NOS aspects as well as metacognitive strategies were responsible for changes in their NOS views (Section 4.3).
- Participants' development of NOS views were mediated by certain cognitive and motivational factors (Section 4.4) and these were: participants' ability to engage deeply with NOS concepts (Section 4.4.2); their epistemic beliefs (Section 4.4.3); participants' appreciation of the value of NOS (Section 4.4.1) and the participants' views about teaching and learning science (Section 4.4.4).

In addition, it was observed that:

- Participants did not achieve similar gains in NOS understanding across the target NOS aspects. The improvements in NOS understanding were more pronounced with regard to the functions of and relationship between laws and theories, tentative NOS, subjectivity, social and cultural embeddedness of science and the inferential NOS (Section 4.2.2).
- There was a very small improvement (+16.7%) in the number of pre-service teachers holding informed views of the role of creativity in the stages prior to data interpretation.
- Chi-square tests indicate that changes in participants' views of NOS from prior to post instruction were statistically significant, except with regards to their understanding of the role of creativity and imagination prior to the data interpretation of an investigation (Section 4.2.2.4).

The next chapter presents the discussion of the key study findings.

CHAPTER 5

DISCUSSION OF KEY FINDINGS

5.0 Introduction

The study investigated the effects of an explicit reflective approach on Swaziland pre-service elementary teachers' understanding of NOS. The main research question was: How does an explicit reflective approach to NOS instruction influence Swaziland pre-service elementary teachers' conceptions of NOS?

The research sub-questions were:

1. What are Swaziland pre-service elementary teachers' views about NOS prior to participating in an explicit reflective NOS intervention?
2. How do the pre-service teachers' views of NOS change from pre- to post instruction as a result of the explicit reflective approach?
3. What specific elements of the intervention do the pre-service elementary teachers themselves report contribute to these changes?
4. What factors enhance or impede the development of participants' NOS views in the context of the explicit reflective NOS instruction?

Results have been analysed and presented in chapter 4. This chapter provides the discussion of key findings according to the above research questions.

5.1.1 Pre-service teachers' pre-instruction NOS views: A Positivist worldview

The pre-test results agree with previous studies (Abd-El-Khalick, 2001; Akerson, Abd-El-Khalick & Lederman, 2000; Boo & Hoh, 2006; Buaraphan, 2011; Dekkers & Mnisi, 2003; Dogan & Abd-El-Khalick, 2008; Iqbal, Saiqa & Rizwan, 2009) that have also revealed that teachers do not possess adequate views of NOS. In line with Abd-El-Khalick's (2001) study, most of the Swaziland pre-service teachers' views prior to the NOS intervention were more consistent with a positivist worldview. The participants believed that science is a completely objective enterprise concerned with discovering facts about natural phenomena. Scientific knowledge is regarded as certain and not subject to change. However, contrary to a positivist stance, most of the participants did not believe in a universal step-wise scientific method of carrying out investigations. Most participants (70.8%) believed scientists make use of their creativity and imagination in the process of carrying out their investigations. Consistent with the findings made by Abd-El-Khalick (2001, 2005) and Akerson, Abd-El-Khalick and Lederman (2000), this creativity was however believed to be confined only to the stages of planning and design of an investigation, and not employed in the interpretation stage. Participants, who stated that creativity is involved after the stage of collecting data, believed that these skills were only involved in the presentation of data to other people. The pre-service teachers therefore viewed data interpretation as a description of data or a relationship between variables (Ryder & Leach, 2000). Consequently, theories and models were regarded as actual representations of reality rather than scientists' explanations for observable phenomena.

The pre-service teachers' understanding of NOS is more likely influenced by the type of science instruction that they have been exposed to during the years of their schooling. Generally, the Swaziland science curriculum is focused more on developing students' understanding of the products of science, than on how such knowledge is developed. Even though the goals of the curriculum includes the learners' ability to develop investigative and problem solving skills (Ministry of Education, 2007), research on classroom practice indicate that most lessons are more focused on developing an understanding of scientific concepts. Rarely are students engaged in inquiry activities, and in most if not all cases, investigations are those aimed at proving already known facts to students (Mthethwa, 2007). Palmquist and Finely (1999) point out that this approach to teaching science gives students the impression that scientific knowledge represents proven facts that are not subject to change. In line with this assertion, most of the pre-service teachers argued that their belief in the non-tentative NOS is based on the fact that the science they have learnt at school has not changed. This supports Clough and Olson's (2004) assertion that the failure to discuss how scientific knowledge is developed, drawing students' attention to the role of human inference, creativity, and imagination and accepted theories as well as how such knowledge has changed over time, greatly distorts students' understanding of the scientific endeavour. To confirm that the discussion of how scientific knowledge is developed is generally not considered an inherent part of the science instruction that these pre-service teachers were exposed to, none of them was aware of how scientists came up with model of an atom. Moreover, one pre-service teacher, when asked about the evidence that scientists use to determine the structure of an atom, pointed out that they were simply given the structure to memorize without any discussion on how it was developed.

The verification laboratory activities that are closely associated with the content focused curriculum seem to be responsible for the pre-service teachers' misconceptions of the role of investigations or experiments. Most participants, prior to the intervention stated that experiments are activities used to verify already known facts or as a method of teaching science content, rather than an inquiry approach. In line with this belief about investigations, most of the participants believed that there can only be one answer to any question posed. This finding supports Clough and Olson's (2004) assertion that cookbook laboratory experiences are part of the reason for students' mistaken beliefs about NOS.

Furthermore, the teachers' failure to discuss the meanings of important terms used in science such as theories and laws is another factor responsible for erroneous views of NOS as revealed by some of the participants' responses. When the meaning of such terms is not made an inherent part of teaching science, students are left with no other option than to construct their own meaning based on their classroom and out of classroom experiences. A majority of participants were not aware of the meanings attached to theories and laws, and as a result expressed many different inadequate views of the functions of and relationships between laws and theories. Similar to Emirates teachers' views of science (Haidar, 1999), the Swaziland pre-service teachers' conceptions of theories and laws were mainly influenced by their religious views. The pre-service teachers mainly believed that laws are made by God, and are therefore certain, while theories are human discoveries, and since man is incapable of knowing the real truth, theories are believed to be imperfect, and therefore subject to change.

Considering the fact that the participants in this study were in the final year of their education programme, but still harboured a lot of misconceptions about NOS, it can be concluded that the science education at the college does not have a positive influence on the pre-service teachers' understanding of the nature of the scientific endeavour. Even the unit "What is science" which is taught to the pre-service teachers, specifically for the purpose of developing their understanding of how science works, is seemingly not effective in correcting the pre-service teachers' misconceptions about NOS. This unit is based on an assumption that the pre-service teachers can develop an understanding of NOS, simply by carrying out the processes of science. Instead, the unit seemed to have reinforced the pre-service teachers' inadequate views of NOS, making their conceptions even more resistant to change. This is based on the observation that some of the selected group participants seemed very convinced that scientists make use of the processes of science to discover truth about natural phenomena, and evidently could not be influenced to embrace the constructivist conceptions of the character of science. In line with Kukuk's (2008) study, the participants did not understand that investigations only provided clues that scientists use to create ideas to make sense of natural phenomena. These teachers are therefore very likely to promote a similar view of investigations to students, hence distorting students understanding of the nature of the scientific enterprise and the knowledge it produces.

The findings therefore call attention to the importance of making pre-service teachers aware that science is not just about making observations of nature, but it is mainly concerned about creating explanations for such observations. They should also be made aware that the processes of collecting and interpreting data are not completely objective, but "guided by scientists' prior knowledge, beliefs, training, experiences, and expectations as well as accepted theories in the scientific community"(Lederman & Abd-El-Khalick, 1998, p. 23). The belief that scientific knowledge is derived through carrying out objective observations and inferences may be the cause of the pre-service teachers' view that scientific constructs correspond to reality. Almost all of them initially believed that theories and models represent truths about natural phenomena. As a result of this view of scientific knowledge, pre-service teachers believe that scientific knowledge is certain and not subject to change.

The results of this study therefore provide further support for Clough and Olson's (2004) assertion that students' views of NOS are influenced by their science classroom experiences. This makes it crucial therefore to explicitly discuss with the pre-service teachers how the activities they are engaged in class resemble or differ from real science in order to enhance their development of a more accurate understanding of the character of science. It is also important to explicitly discuss the meaning of terms as used in science in order to prevent development of erroneous views. As pointed out by many science educators, teachers' accurate understanding of NOS is the basis for the development of a scientifically literate society because when teachers are well informed about NOS, they can support students' development of scientific literacy during their teaching of science (Morgil, Temel, Güngör-Seyhan & Ural-Alşan, 2009).

5.1.2 The influence of the explicit reflective approach on the pre-service teachers understanding of NOS

The results of the study provide further evidence in support of the usefulness of the explicit and reflective approach in upgrading participants' understanding of NOS. The content embedded NOS curriculum, which made use of activities and history of science episodes as context to explicitly discuss the target aspects of NOS, was evidently effective in helping students develop a more informed understanding of NOS. At the end of the study more students appreciated the role of human inference, creativity and subjectivity in the development of scientific knowledge. Most of the selected group participants reported that it was mainly the explicit discussions about NOS in the context of activities and history of science episodes that were responsible for their development in understanding of NOS. One of the selected group participants actually pointed out that their lack of accurate understanding of important terms used in science such as inferences, theories, and laws and scientific facts, were responsible for their misconceptions of NOS. Indeed most of the participants, prior to the intervention, did not differentiate between observations and inferences, and hence were ignorant of the inferential and creative nature of theories and models. Most students thought that scientific theories and models were facts about natural phenomena discovered through direct observations or experimentation. Discussion of the meaning ascribed to these terms as well as guided discussions of NOS issues in the context of the learning activities therefore apparently played a significant role in the development of these pre-service teachers' understanding of what science is and how it works.

Focusing on enhancing the pre-service teachers' understanding of how the scientific concepts that they were learning were developed also seemingly contributed to students' development of NOS views. Many of the pre-service teachers who articulated more informed NOS views were able to provide suitable examples from the history of the development of the concepts that they learnt about in order to support their NOS views. For example, one student pointed out that learning about the development of the laws of genetics, as well as the chromosome theory, helped him to abandon the view that theories develop into laws. He was able to develop an understanding of the descriptive and explanatory role of scientific laws and theories respectively. Another student who explicated a more informed view of the role of the experimental NOS used the same context, to justify his understanding of the role of experiments in science. The student pointed out that experiments are essential for gaining evidence required to provide the empirical base for ideas put forth by scientists. This conception of the role of experiments implies that the participant was aware that though science involves creating ideas to account for natural phenomena, not all ideas are acceptable, but only those that concur with empirical evidence (Lederman & Lederman, 2004; Lederman, 2006).

However, it is noteworthy that the NOS instruction seemed ineffective in enhancing the most participant' understanding of the predictive role of theories. This is probably a result of the historical narratives which were mainly focused on the explanatory role of theories. This assertion is supported by one student who overtly pointed out that since theories explain laws, scientific theories always come before scientific laws. This participant was perhaps unaware that an existing theory can be used to deduce new generalizations or relationships among phenomena (McComas, 1998). This reveals the need for including historical accounts and activities that will also reveal the predictive role of theories in guiding further research (Abd-El-Khalick, 2006).

As already mentioned, the pre-service teachers' improvement in NOS understanding was inconsistent across the different NOS targets. The pre-service teachers achieved relatively more gains in their understanding of the tentative NOS, functions of laws and theories, as well as the distinction between observations and inferences. However, the fact that a considerable number of participants still held inadequate views of the different target aspects of NOS, supports the assertion that students' conceptions about NOS, just like conceptions about the natural world are resistant to change (Clough, 2006), and therefore a considerably longer period of time may be necessary to bring about more fruitful conceptual change than just a three months intervention. The misconceptions about NOS that participants held prior to the intervention could be one factor that explains why some participants found it difficult to adopt the target aspects of NOS. Misconceptions are a component of the students' conceptual ecology and therefore play a crucial role in influencing the extent to which a new idea is understandable, believable, and useful, and thus impacting on conceptual change (Yuruk, Ozedemir & Beeth, 2003).

In line with Chan (2005), the study also revealed that an instruction that focuses on raising the status of one conception may concomitantly lower the status of an opposing conception. Chan, in his study, revealed that raising the status of the creative NOS had an effect of lowering that of the empirical NOS. This was not observed in this study, but an almost similar scenario was noted in terms of participants' beliefs about the stages where creativity and imagination is involved when carrying out investigations. In this study, most pre-service teachers prior to the NOS intervention believed that creativity and imagination in science were only employed at the stages of designing an investigation and in data collection, and not in the data interpretation stage. As a result of the NOS instruction, some of these participants at the end of the study adopted the view that such mental activities were only involved at the data interpretation stage, instead of the target view that they occur at all stages of the investigation. Also, a Chi-square test revealed that there were no statistically significant changes in the pre-service teachers' views of the involvement of creativity and imagination at the stages before the interpretation stage. It is worth noting that this instruction was focused more on developing the participants' understanding that creativity and imagination was also involved at the stage of making inferences. This highlights the value of paying equal attention to all NOS aspects in instruction, including those that participants seemed to be initially aware of, in order to avoid lowering the status of one correct conception in an attempt to raise the status of a related conception.

Below is a discussion of learner characteristics that have been found to influence the focus group participants' development of more informed views.

5.1.3 Pre-service teachers' reports of the influence of course components

The selected group reports of the influence of course components on their NOS views supports previous studies that have revealed that an explicit approach to NOS instruction and metacognitive strategies can be useful in enhancing NOS conceptions. Four out of the seven selected group participants pointed out that the explicit reflective attention to NOS issues played a significant role in augmenting their NOS views. One of the selected group participants who developed sophisticated conceptions of NOS pointed out that the clear explanations of the meaning of important terms such as observations, inferences, scientific laws and theories was responsible for her growth in her understanding of NOS. She actually pointed out it was this lack of clarification that was responsible for her erroneous views about the nature of the scientific endeavour. The participant assertion underscores Clough and Olson's (2004) contention that students should be made aware of the meaning of such terms as "laws" and "theory" in order to help them develop an informed view of the epistemology of science. Another participant pointed out that the discussion of NOS in the context of decontextualized activities and history of science episodes played a significant role in developing his understanding of the different aspects of NOS.

Metacognitive strategies were also reported by four of the participants as having played an important role in developing their NOS conceptions. The participants' assertion of the role of metacognitive activities in enhancing their views is supported by the fact that participants who achieved higher gains in their NOS understanding developed more elaborate concept maps than those whose NOS views were only poorly developed. Consistent with these findings, Abd-El-Khalick and Akerson (2004) state that metacognitive strategies can be effective in bringing about conceptual change as they encourage learners to think deeply about the NOS ideas which may consequently enhance their NOS conceptions. Abd-El-Khalick and Lederman (2009) also provide further evidence for a connection between improved metacognitive awareness and gains in NOS understanding. Abd-E-Khalick and Lederman (2009) postulate that this relationship substantiates the claim that learning NOS is a more of a cognitive than an affective learning outcome; hence further backing up the call for an explicit rather than an implicit approach to NOS instruction.

5.1.4 Factors influencing the pre-service teachers' development of NOS views

As already pointed out, the results of the study indicate that the pre-service teachers had not all developed informed views of the target aspects of NOS by the end of the intervention. Some pre-service teachers retained their prior views, for example, 29.2% still did not accept the role of creativity and imagination in the development of scientific explanations and representations of natural phenomena. They held on to the view that scientific knowledge is developed from empirical evidence alone. Four factors were found to mediate the focus group participants' development of more informed views. These included cognitive and motivational factors.

Participants' level of engagement with the NOS concepts as well as their personal beliefs about knowledge and knowing were found to influence the development of the participants' understanding of NOS. The pre-service teachers who displayed a deeper engagement with the NOS material as well as an ability to reflect about their knowledge and thoughts in relation to what was learnt, were able to achieve more gains in their understanding of NOS. These findings agree with Akerson and Abd-El-Khalick (2004) and Southerland, Johnston and Sowell (2006) who also revealed that these factors played a substantial role in the development of pre-service and in-service development of NOS views respectively. The results of the study also agree with Rebich and Gautier's (2005) as well as Clough's (2006) contention that conceptual change is a difficult gradual process that demands a deep processing of knowledge. The tenacity of NOS misconceptions implies that NOS programmes must include strategies that can stimulate pre-service teachers' metaconceptual and metacognitive abilities in order to facilitate conceptual change. Strategies that can be used include concept maps, structured reflections, modelling, and co-teaching NOS ideas to peers (Abd-El-Khalick & Akerson, 2009; Akerson, Morrison & McDuffie, 2006).

According to Abd-El-Khalick and Akerson (2004) metacognitive activities provide opportunities for learners to think deeply about the NOS ideas and therefore promote meaningful rather than rote learning. Novak (in Cardellini, 2004) asserts that such metacognitive strategies are the best ways of enhancing conceptual change as they encourage students to integrate new knowledge with existing knowledge. Consistent with Novak's assertion, several pre-service teachers in this study pointed out that the concept map played a significant role in developing their understanding of NOS. Some of the pre-service teachers also pointed out that the concept maps also motivated them to deeply engage themselves with the NOS material as they searched for meanings of the various terms.

Pre-service teachers' development of more informed views has also been shown by this study to be influenced by their beliefs about knowledge and knowing. Teachers who held an absolutist view of knowledge had a problem accepting the tentative creative and subjective NOS. They failed to understand the relationship between a scientific claim and the evidence supporting it. For example, one student who strongly held a 'seeing is knowing' view, could not understand the role of evidence in support of the model of an atom, and consequently viewed models as solely a product of scientists' imagination and creativity. The results also support the contention that students' epistemic beliefs have a great impact on learning controversial topics such as NOS (Rebich & Gautier, 2005). Rebich and Gautier (2005) point out that student with more sophisticated views about knowledge are better able to consider perspectives that are different from their own, and are hence likely to achieve conceptual change.

Based on the aforementioned results, I contend that there is a need to amalgamate the explicit reflective NOS instruction with other strategies of teaching science that may help enhance participants' personal beliefs about the nature of knowledge and knowing, in order to boost their development of more informed NOS views. There is evidence that more inquiry oriented teaching strategies of teaching science can help promote epistemic beliefs among science students (Conley, Pintrich, Vekiri & Delena, 2004). Conley and his colleagues made use of science instruction that engaged elementary students in making observations, comparing findings from different studies, and creating claims to explain their observations. They assert that such an approach helps students understand that answers to questions do not come from authorities, but are a result of investigations, rationalization, and imagination, and are therefore subject to change. They further state that this inquiry approach helps to lower the status of the conception that knowledge is certain, while raising the status of the tentative nature of knowledge as well as an understanding of the role of empirical evidence in justifying claims.

Rebich and Gautier (2005) suggest that incorporating debatable topics in science instruction may develop students' epistemic belief. Their assertion is supported by McDonald's (2010) study that revealed that the integration of explicit argumentation instruction with an explicit reflective NOS instruction can lead to developments in participants NOS views. In line with Rebich and Gautier (2005), McDonald (2010) argues that developing students' argumentative skills enhances their ability to consider evidence and to contrast this evidence with alternative viewpoints which ultimately enhances their adoption of more advanced epistemic views. The claim that certain learning environments provide better contexts for developing participants' beliefs about knowledge and knowing is in line with the argument that students' beliefs about how science operates are shaped by their school science experiences.

The findings in this study indicate that the more content driven curriculum with its verification laboratory activities has a detrimental effect on the pre-service teachers' epistemic beliefs. Most pre-service teachers believed scientific knowledge corresponds to reality discovered through carrying out experiments rather than scientists' construction of reality. Such beliefs may be a reason why 37.5% of pre-service teachers found it difficult to find the creative, subjective and tentative aspects of NOS as plausible descriptions of NOS. This therefore underscores the need for an explicit reflective attention to NOS issues during the teaching of science in order to enhance learners' views. It is imperative to discuss with the students how the activities they are engaged in school science resemble or differ from real science in order to enhance their development of a more accurate view of the character of science.

The study results further revealed that the focus group participants' beliefs about teaching and learning science are related to their development of more informed views. The pre-service teachers who possess more positivist views of teaching and learning science seemingly had difficulty embracing the more constructivist views of NOS. Participants who viewed teaching as a process of transmitting knowledge to learners and learning as being about reproducing the content and its structure in their mind viewed science more as a body of certain knowledge. Similarly, participants who viewed teaching more as being about developing learners' competence in using the processes of science viewed science more as a process of discovery of knowledge rather than a meaning making endeavour. On the other hand, participants who harboured more constructivist conceptions about teaching and learning of science; viewing learning as a process whereby learners construct their own meaning as they reflect on their experiences, and instruction consequently as a process of supporting this reflection rather than communicating knowledge were more able to adopt the more constructivist view of NOS.

This study concur with previous studies (Mellado, Bermejo, Blanco & Ruiz, 2007; Southerland, Johnston & Sowell, 2005; Tsai, 2002) that also established a link between pre-service teachers' views about NOS and their views about teaching and learning of science. This finding therefore highlights the importance of addressing such beliefs in teacher education programmes as these may have a bearing on classroom practices (Brickhouse, 1989). The revised Swaziland science curriculum is based on the constructivist approach to science teaching and learning. Teaching methods are expected to become more learner centred and skills based. Therefore a number of methods and techniques that emphasize problem solving and active participation such as group work, laboratory investigations based on real life problems, classroom debates on controversial issues, field trips, project work, and drama are recommended (Ministry of Education, 2007). Teachers' informed views of NOS may have a positive influence on the teachers' perception of the new curriculum.

The results of this study also reveal a relationship between the pre-service teachers' perceptions of teaching and learning about NOS and their development of more informed NOS views. This factor was found to be mediated by participants' ability to spontaneously reflect on issues as well as their strong need for cognition. Participants who were are able to quickly internalize the importance of NOS as a result of their prompt deliberation on issues, deeply engaged themselves with the NOS material and consequently achieved higher gains of NOS. These students realized the importance of NOS in their understanding of science concepts. Unlike, the other participants who did not achieve much gain in their understanding of NOS, they did not regard NOS as an extra learning or teaching goal, but as an "inherent aspect of science" a description used by (Schwartz & Lederman, 2002, p.228).

The findings in this study agree with those of previous studies (Abd-El-Khalick & Akerson, 2004; Akerson & Donnelly, 2008; McDonald, 2010; Schwartz, Akom, Skjold, Hong, Kagumba & Huang, 2007; Schwartz & Lederman, 2002) that also revealed that an appreciation of the value of teaching and learning NOS plays a significant role in motivating teachers to critically examine and change their NOS view.

Similar to the findings of Southerland, Johnston and Sowell (2005), there is no empirical evidence in support of the influence of religious views on the focus group participants' differential gains in NOS views. In agreement with Sherry, Southerland and Enderle's (2012) proposition, the NOS intervention included a discussion of the bounded NOS where students were helped to view religion and science as two separate ways of knowing with different values and assumptions (Abd-El-Khalick & Akerson, 2004). As a result, most of the focus group participants held the view that science and religion are different ways of knowing.

Only two of the seven focus group participants believed science and religion are in conflict, and this perspective seemed to be caused by the participants' failure to accept that science and religion are two separate ways of knowing with different values and assumptions. It is worth noting that these two pre-service teachers held the traditional positivist view that knowledge is discovered using the processes of science. In line with Haidar's (1999) assertion, the results of the study points out that more positivist views of NOS are more likely to portray science as being in conflict with religion. Haidar contends that this positivist viewpoint was in fact a reason for many Arab intellectuals' failure to appreciate religion, art and poetry as other means of understanding the world. The findings therefore imply that an understanding of science as one of many ways of making sense of the world rather than the only way of gaining knowledge may help prevent "religious disturbance or symbolic violence" (p. 818). For example, with such a view, participants are more likely to accept scientific explanations of natural phenomena such as evolution that seem to conflict with their religious explanations.

5.2 Summary

In line with several previous studies, the findings of the current study fortify Clough's (2006) assertion that any instruction that lacks an explicit attention to NOS issues is inefficient in correcting teachers' misconceptions about NOS that have been developed over their years of schooling. The study showed that prior to the explicit reflective NOS programme, most participants held naïve views of the nature of the scientific endeavour. However, at the end of the NOS programme**,** most teachers were able to adopt more informed conceptions of NOS. This is in agreement with findings of many previous studies that investigated the influence of this approach on pre-service teachers' NOS understanding. In support of the assumption that changes in pre-service teachers' views were as a result of the explicit and reflective NOS programme, the selected group participants pointed out that the explicit reflective approach played a significant role in enhancing their NOS views.

Most of the selected group participants also pointed out that the metacognitive strategies used in the study were helpful in the learning of the NOS concepts. This finding is in agreement with the claim made that metacognition is necessary to enhance conceptual change. To further strengthen this claim, this study revealed that the focus group participants who were more reflective of their learning and cognition were able to achieve higher gains in their NOS understanding than those who were less reflective. The observed relationship between metacognition and gains in NOS understanding is best explained by the assumption that the development of NOS conceptions is more of a cognitive than an affective learning outcome (Abd-El-Khalick& Akerson, 2009).

Participants' improvement in NOS understanding was not achieved equally across the different target NOS concepts. There was a very minor increase in the number of participants holding informed views of the role of creativity and imagination at the stages before data interpretation. This insignificant development of NOS was attributed to the fact that the NOS programme was more focused on the role of creativity in data interpretation. As a result, some participants believed that creativity did not play much role in the stages before the interpretation of data. This result therefore implies the need to pay equal attention to all NOS aspects in order to avoid lowering the status of one correct conception in an attempt to raise the status of a related conception.

Four personal factors were found to mediate the development of the selected group participants' NOS conceptions. These were the participants' ability to deeply engage with NOS, their epistemic beliefs, the valuing of NOS as an important learning goal, as well as their beliefs about teaching and learning. This finding suggest that integrating an explicit NOS programme with strategies aimed at improving participants with respect to each of the revealed student characteristics may enhance the efficacy of the explicit approach in developing teachers' NOS conceptions.

In the next chapter, the conclusions, contributions and limitations of the study will be discussed. The chapter will end with a proposal of issues that may be investigated in the future as well as recommendations that emerge from the findings of the current study.

CHAPTER 6

CONCLUSIONS, LIMITATIONS, CONTRIBUTIONS MADE BY THE STUDY, RECOMMENDATIONS AND POSSIBLE FUTURE RESEARCH

6.1 Conclusions

The study findings revealed that the Swaziland pre-service teachers hold inadequate views of almost all the NOS aspects. Almost all the participants held an empiricist view of NOS. They believed that scientific knowledge is solely based on collected data without the involvement of human inference, creativity and imagination. As a result, participants believed that science is a completely objective endeavour, and thus scientific knowledge is certain.

The study findings also indicate that the pre-service teachers achieved differential gains in their understanding of NOS, as a result of an explicit reflective NOS instruction. An in-depth study of seven of the participants revealed that pre-service teachers' learning dispositions, epistemic beliefs, their perception of the value of NOS, as well as their views about teaching and learning mediated the pre-service teachers' development of more informed views. These factors imply that an explicit reflective approach integrated with strategies aimed at developing participants' metacognitive strategies as well as their epistemic beliefs may facilitate the pre-service teachers' development of more informed views.

6.2 Limitations and delimitations of the study

6.2.1 Limitations

The first limitation of the study is a result of the design that was used to assess the impact of the intervention on the pre-service teachers' views of NOS. The evaluation did not include a comparison group, but only measured changes in participants' views of NOS. This makes it difficult to exclusively attribute changes in participants' conceptions on the intervention. Other programmes that the participants were exposed to during the course of the intervention could have had an impact on the participants' NOS views, thus making the effects of the intervention seem larger or smaller than they really were. For example, as a point of fact, the explicit reflective attention to NOS was only integrated in the teaching of the chemistry and biology, and not in the physics and science methods courses. The approaches as well as the content discussed in these other programmes no doubt, had some influence on the participants' understanding of NOS. Clough and Olson (2004) argue that NOS is always part of the science story, meaning that any science instruction communicates certain ideas about NOS to students. As an attempt to find out reasons for changes in participants' NOS conceptions, teachers' reports on what they believed was responsible for their changes in NOS views were determined. Most pre-service teachers' attributed their changes in NOS views to the explicit reflective NOS instruction. However, the reliance on self-reports, rather than using a comparative group, does not reveal what might have actually happened if the NOS programme had not been implemented.

A second limitation of the study is the fact that there were no classroom observations made. There is therefore no direct evidence regarding the extent to which the explicit reflective approach to NOS instruction was implemented. The study relied on the instructors' self-reports of learning experiences that pre-service teachers were engaged in. They could have been biases resulting in a report that was different from what actually took place in the classroom. Participants' perceptions of their changes in NOS views articulated in their reflective journals and interviews however, served to back up instructor's assertions pertaining to learning experiences.

The third limitation is the duration of the study. The three months may not have been long enough to produce the intended changes in participants' NOS views. Jansen (2007) points out that the validity of study findings is enhanced when it takes place over an extended period. Also, the fact that the intervention took place during the final year of the participants' study could have had an impact on their performance as their main concern at that level was their grades. In fact, three of the participants did raise this concern during the exit interviews. It is worth mentioning that in this situation, the time of the evaluation was decided by the time and duration of the intervention as prescribed by its designers.

The fourth limitation was that the study used some data collecting techniques that were not familiar to the participants. The participants were using concept maps and reflective journals for the first time, as a result some of them faced challenges in using them, and this could have been one factor that influenced their level of participation.

Finally, participants' difficulties in expressing themselves in writing limited their ability to provide detailed responses that would have resulted in richer data. Many of them failed to clearly expand on their views in the VNOS questionnaires and reflective journals. Interviews provide a good forum to follow up participants' responses and to ascertain meanings that they ascribe to different key terms, but due to time limitations it was impossible to interview more participants in order to gain a much better understanding of their NOS views.

6.2.2 Delimitations

The study was carried out in an individual science classroom of Swaziland pre-service teachers that was conveniently and purposively selected because of having introduced an explicit reflective NOS instruction in the teaching of the science course. Also, the factors that have been found to mediate the pre-service teachers' views of NOS are based on a purposively selected focus group that possessed almost identical inadequate NOS views prior to instruction and also shown maximum difference in their gain in NOS conceptions. This non-random selection of the sample does not allow the generalization of the study findings to the whole population of pre-service teachers in the country. The group of pre-service teachers that were participants in this study was doing courses in chemistry, physics, biology and mathematics; it is therefore not possible to infer what effects the approach may have among pre-service teachers who are less inclined to science learning. It is worth noting that although the elementary teacher education programme allows teachers to specialize in different fields during their final year, elementary teachers are expected to teach all subjects, including the areas they have not specialized in. Teachers with no specialization are also going to teach science in schools, making their views of NOS an issue worth exploring.

6.3 Contributions made by the study

Firstly, prior to the current study, there was no existing literature on Swaziland pre-service teachers' understanding of NOS. The study has brought to light the extent to which Swaziland pre-service teachers lack an accurate understanding of NOS. The study has revealed that participants' erroneous views of NOS are closely linked to the more product oriented approach to science instruction that they are exposed to throughout their schooling. Moreover, the study findings indicated that the process skill instruction that the pre-service teachers are engaged in is not effective in augmenting their NOS views. The process skill instruction was apparently based on an assumption that students can learn the epistemology of science simply through carrying out the processes of science. The in-depth study of the focus group also pointed out that such an implicit approach to NOS instruction could be another reason for pre-service teachers' incorrect conception of NOS. In the absence of an explicit discussion of the nature of the processes of science, the pre-service teachers tend to believe that scientists use these processes to discover truth about natural phenomena. As a result, most of them (83.5%) were not aware of the role of creativity and imagination in the development of scientific constructs.

Secondly, before this study it was not known how the explicit reflective approach to NOS instruction can affect Swaziland elementary pre-service teachers' NOS views. Although there are many studies that have been carried out in different countries on the influence of the explicit reflective approach on pre-service teachers views, no such study had been carried out in Swaziland. The current study has provided evidence of the effectiveness of the explicit reflective approach implemented in the context of activities and history of science episodes in developing Swaziland pre-service teachers' NOS views. It has also revealed that the explicit reflective approach can be useful in improving elementary teachers who are pursuing a diploma in primary teaching. Previous studies have focused on pre-service teachers who were either pursuing a bachelor's degree or a Masters in primary education.

The current study also concurs with Abd-El-Khalick and Akerson (2004) and Southerland, Johnston and Sowell (2006) regarding personal factors that mediate teachers' development of more informed understanding of the epistemology of science. Moreover, in agreement with Southerland, Johnston and Sowell (2006), the results of this study indicates that a NOS programme that includes a discussion of the bounded NOS can help participants develop an understanding that science and religion are separate ways of knowing with different values and assumptions.

Lastly, the results of the current study provide evidence in support of the CCM that postulates that learning is a dynamic mind restructuring process whereby the status of one conception is raised above other conceptions (Duit & Treagust, 2003). This understanding of learning implies that instructional activities should focus on raising the status of a correct conception above its related erroneous conception. The current study findings indicate that activities aimed at raising a target conception may not only lower the status of rival misconceptions, but also that of related prior correct conceptions. The NOS instruction that was largely focused on developing participants' understanding of the role of creativity at the interpretation stage of an investigation was found to reduce the prominence of the role of this mental activity in the stages before data interpretation. Some pre-service teachers who after NOS instruction, adopted the view that creativity is involved when data is interpreted, started to believe that such creativity is not used in the design and data collecting stages of the investigation. This study finding therefore emphasizes Ozdemir & Clark (2007) contention that all conceptions that are part of the students' conceptual ecology should be addressed in order to prevent the formation of further misconceptions.

6.4 Recommendations

On the basis of the findings made by the study, the researcher recommends that:

- The Ministry of Education ought to consider making learners' understanding of NOS one of the goals for science education in order to highlight the importance of addressing NOS issues in the classroom.
- Further research is carried out in order to ascertain practicing teachers' level of preparedness to address NOS in the classroom.
- The pre-service science teacher education and school science programmes integrate the explicit reflective NOS instruction with authentic inquiry activities and/or argumentation instruction in order to help participants achieve sophisticated beliefs about knowledge and knowing as well as their beliefs about learning and teaching science.
- Pre-service teachers' science programmes incorporate metacognitive strategies in their NOS curricula in order to enhance teachers' ability to learn meaningfully and to also enable them to reflect and regulate their own learning.
- Pre-service teacher NOS programmes encourage pre-service teachers to reflect on the benefits of learning and teaching the constructivist views of NOS in order to enhance their adoption of more informed views.

6.5 Possible Future Research

The study was performed among pre-service teachers who were specializing in science education. Since all elementary teachers in Swaziland, are trained to be classroom teachers, it would be valuable to find out the non-science specialists' views of NOS, as well as how their views are influenced by an explicit reflective NOS instruction.

Consistent with some of the rationalizations for advocating students' development of NOS, most of the focus group participants pointed out that learning NOS has improved their understanding of science content as well as their attitudes towards learning and teaching science. Scrutinizing the students' performance in tests (generally more science content driven) did not reveal any differences between pre-service teachers with different conceptions of NOS. However, it is not certain that these tests were focused on assessing comprehension or simply the ability to recall information. It would therefore be valuable to carry out a study aimed at finding out if advancement in NOS understanding does have an impact on the Swaziland pre-service understanding of science subject matter as well as their attitudes towards science.

Also, one student pointed out that he prefers learning NOS as a separate subject from learning science subject matter, and in line with this assertion, the instructor pointed out some students seemed to have a problem trying to make sense of NOS while also trying to understand the subject matter. Other participants, however, seemed to prefer that NOS actually be made part and parcel of learning and teaching science content. In order to facilitate decisions regarding the best approach to adopt in augmenting pre-service teachers' views, a study needs to be carried out with a larger sample of pre-service teachers in order to establish their perceptions regarding this subject. Further research also needs to be done for the purpose of finding out the kind of NOS programmes that can be more useful for improving learners' and teachers' understanding of NOS.

The study findings also revealed that pre-service teachers' ability to achieve conceptual change is linked to their epistemic beliefs. This therefore suggests that integrating the explicit reflective NOS instruction with strategies aimed at improving pre-service teachers' epistemic beliefs may help facilitate their NOS views. Engaging students in more authentic inquiries and in debates about controversial issues has been shown to develop students' epistemic beliefs (Conley, Pintrich, Vekir & Delena, 2004; McDonald, 2010). It would be therefore worthwhile in the future to find out if the inclusion of such strategies in NOS instruction does result in higher gains in the Swaziland elementary pre-service teachers' understanding of NOS. Such information is necessary in order to make more informed decisions regarding the best ways of improving the pre-service teachers' views.

Developing pre-service teachers' understanding of NOS is not enough to enable them to address NOS issues in the classroom. Reports of different studies indicate that a number of other factors are necessary. According to Schwartz & Lederman's (2002) study, teachers' knowledge of the traditional science content , intentions to teach NOS as well as appropriate pedagogy are some of the other factors that are necessary. Future research should therefore focus on the design and evaluation of interventions that will not only focus on developing pre-service teachers' NOS understanding, but also their ability to address NOS in their teaching. In order for teachers to plan to teach NOS, it is necessary that they appreciate the value of addressing the construct in their teaching. This therefore makes it also necessary to investigate how pre-service teachers' develop an appreciation of the value of NOS.

Lastly, the study has also revealed a relationship between the pre-service teachers' understanding of NOS and their beliefs about teaching and learning science. Pre-service teachers who held more constructivists views about teaching and learning were also found to able to harbour more constructivist views about NOS. The current Swaziland science curriculum is based on the constructivist approach to teaching and learning and therefore prescribes teacher methods that emphasizes problem solving and active involvement of the learner, such as laboratory investigations based on real life problems, debates on controversial science topics and project work. A study by Mthethwa (2007) revealed that such methods are rarely employed in the classroom. It would therefore be valuable to find out if practicing teachers' understanding of NOS has an influence on teachers' perceptions about using such strategies in the classroom.

6.6 Summary

The study has revealed that an explicit reflective approach has a potential of developing Swaziland pre-service elementary teachers' NOS views. Participants who started out with very naïve views of NOS; believing that science was solely a body of facts about natural phenomena discovered through carrying out experiments were able to appreciate both the role of human inference and creativity in making sense of observations.

Participants' reports of the role played by the explicit reflective discussions of NOS programme in developing their NOS understanding helped to substantiate the assumption that changes observed in participants' conceptions were actually a result of the explicit reflective NOS programme. Participants' reports were necessary as the study did not involve a comparison group.

An in-depth study of a smaller selected group revealed that participants' degree of engagement with NOS concepts, their epistemic beliefs, their perceptions about the importance of learning and teaching NOS, as well as their beliefs about teaching and learning science seem to have a bearing on their development of more informed views.

These findings suggests that explicit reflective approaches that incorporate teaching strategies aimed at developing pre-service teachers with respect to these personal characteristics, may enhance the usefulness of the explicit reflective approach in boosting NOS views.

Furthermore, the use of metacognitive strategies may be valuable in motivating teachers to reflect upon their development in NOS understanding and hence, promote conceptual change.

Further research is needed to determine the best strategy for enhancing students' NOS conceptions. It is also important to find out other gains of explicitly addressing NOS in the classroom, beyond developing participants' conception of NOS. Such knowledge is necessary in order to persuade teachers to address NOS issues in the classroom. There is no empirical evidence, so far, backing up the various justifications postulated for developing students' NOS conceptions.

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APPENDICES

Appendix A: De-contextualised Activities

Activity 1: Young? Or Old?

Aim: To help the pre-service teachers understand that observation made when viewing a phenomenon are not completely objective, but are influenced by our experiences, beliefs, knowledge and expectations (Chalmer, 1999).

1. A figure that shows a young and an old lady at the same time is placed on the overhead. Students are then asked to look carefully and state what they observe. More often than not, students only see the face of the old lady.
2. Then the instructor requests one student who has already identified the image of the young lady to help the rest of the class become aware of the young lady's likeness by showing them for example, "how the nose of the old lady forms the cheek and chin of the young lady" (Lederman & Abd-El-Khalick, p. 25). Many students may still be unable to see both images.
3. To help students see both images, they are shown the figures of the old and the young woman separately. Students are subsequently given an opportunity to look again at the original figure with an intention of seeing both faces.
4. This is followed by a discussion on how it is possible to look at the same figure and yet observe different images.

NB. The figure is found in Lederman & Abd-El-Khalick, pp.56-58).

Reflection on NOS

The students are then asked whether it is possible for scientists to look at the same set of data and make different observations. Students are also guided towards appreciating that just like some of them were unable to recognize the face of the young lady in the picture, some scientists may fail to perceive certain piece of data as applicable to their study question. This is then followed by a discussion of factors that are likely to impact on how scientists' understand a phenomenon.

Activity 2: The Rabbit/ Duck

This activity is tackled in the same manner as the above Old? or Young? activity. The students are made to look carefully at the drawing that simultaneously depicts a rabbit and a duck with an effort of observing both images.

Activity 3: The Aging President

Aim:

1. To draw pre-service teachers' attention to the role of scientists' mind-sets on the way they interpret a phenomenon.

2. To help pre-service teachers appreciate that "scientists do not eagerly give up their perspective even in light of conflicting evidence" (Lederman & Abd-El-Khalick, 1998, p.28).

1. A figure representing the president is placed on the overhead projector. The students are then told that this is a picture of a president at the beginning of his term. They are then told that they will be shown other drawings of the president made at later stages of his two terms of office.
2. Students are asked to observe the drawings carefully and state the changes that occurred as the president grew older.
3. Several drawings of the president as he ages are shown and students keep reporting the changes they observe in the president's face.
4. Usually, it is not until a certain stage (Figure 18.7 in Abd-El-Khalick & Lederman, 1998, p.66) that students begin to observe something apart from the face of the president. If they have never seen the drawing, they may still not quite 'see' the body of a female.
5. Further figures of the president are placed on the overhead and students are asked to describe what they see. (Students may still be unable to recognize the female body)
6. Students are then shown the drawings next to each other (Figure 18.9 in Abd-El-Khalick & Lederman, 1998, p.68.) and asked to state the figure where they begin to notice the female body.

7. This is followed by a discussion on why they were unable to see the female body. They are also asked if they would have been able to see the female body had they been told prior to looking at the drawing that is was of a female body.

NB. The figures of the aging president are found in Lederman & Abd-El-Khalick, pp.60-68).

Reflection on NOS

Through questioning students are led to an understanding of how the activity resembles the scientific endeavour. The guided discussion should help students realize that the kind of knowledge and expectations that scientists bring into an investigation affect what they perceive in available data. And, most of the time, scientists do not readily abandon their perspective (e.g. that the drawing was a face) even if contradictory evidence is disclosed. “Usually, it takes quite remarkable evidence, over a relatively long period to make them embrace a different viewpoint” (Lederman & Abd-El-Khalick, 1998, p.28).

Activity 4: That's Part of Life

Aim: To help pre-service teachers appreciate the value of context (prior knowledge, experiences, and expectations) in understanding a phenomenon.

The text below is placed on an overhead projector. Students are asked to carefully read the text and state what they think it is about.

“The procedure is actually quite simple. First arrange things into different groups. Of course, one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities, that is the next step, otherwise you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than too many. In the short run this may not seem important but complications can easily arise. A mistake can be expensive as well. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity of this task in the immediate future, but then one never can tell. After the procedure is completed .one arranges the materials into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more and the whole cycle

will then have to be repeated. However, that is part of life." (Lederman & Abd-El-Khalick, 1998, p.54*)*

1. Students are stimulated to provide possibilities of what the passage is about. If after sometime the students fail to come up with the meaning of passage is, they are told –that; is possible that it might be just a bunch of words without a meaning. They are then asked whether or not they agree with that assertion. (The idea is to cause students to be dissatisfied with the idea that meaning is derived solely from data)
2. Students are finally informed that this passage is about *'doing the laundry'*. They are then requested to read the text again and state whether the words finally have a meaning to them. Students wonder the way the passage suddenly falls into place.
3. Students are then asked whether a person who has never used or seen a washing machine would be able to make sense of the text even if she or he were told that the passage was about *doing the laundry*.

Reflecting on NOS

Students are then asked to tell how the activity resembles the way science work. This then leads towards a guided discussion of the importance of context in making sense of data. The individual words and sentences, even though they individually make sense, they do not make a sense as a whole in the absence of the context. Students then reflect on the importance of context in making sense of collected data. The activity is concluded by emphasizing that ".trying to make sense of collected data may be unproductive if scientists do not bring in their prior knowledge, experiences, and expectations in order to put the data into context" (Lederman & Abd-El-Khalick & Lederman, 1998, p.24).

The Mass Extinction of dinosaurs

Aim: To help pre-service teachers appreciate the influence of scientists' mind-set on the way in which they make sense of a phenomenon.

Students are given the historical episode to read:

"*It is believed that about 60 million years ago, toward the end of the Cretaceous period (geological symbol: K) and the beginning of the Tertiary period (geological symbol: T), the dinosaurs, which during the Cretaceous period reigned the lands, became extinct (Whether there truly was a `mass extinction' or not, is another interesting question.)*

For many years, scientists have speculated about the probable cause for that extinction. New and breaking evidence was uncovered in the early 80's and since then more evidence has been accumulated by literally hundreds of scientists. The major evidence-was-an anomalous and unearthly concentration of the element iridium in the geological record at the boundary between the Cretaceous and the Tertiary periods (referred to as the K-T boundary). Anomalous shocked quartz, stishovite (a mineral derived from quartz under extremely high pressures) and other pieces of evidence were also investigated. Based on the accumulated evidence, scientists have formulated many hypotheses to explain the extinction, two of which gained wide acceptance. The two hypotheses were advanced by two groups of scientists. The first group, known as the impactors, suggested that a huge meteorite (10 kilometres in diameter) hit the earth at the end of the Cretaceous and led to a series of events that caused the extinction. Another group, referred to as the volcanists, claimed that massive and violent volcanic eruptions were responsible for the extinction. Each group insisted that their hypothesis explained the evidence better: The controversy went on for several years and is not quite over yet. This is an interesting case of starting from the same evidence and reaching differing conclusions when scientists approach an issue from different perspectives (or paradigms). In this case, these two perspectives can generally be referred to as 'Catastrophism' (the belief that drastic, large scale, and abrupt events have shaped the face of the earth in rather short periods of time) espoused by the impactors, and `Uniformitarianism' or `Gradualism' (the belief that natural elements of the same type and vigor have gradually shaped, and continue to shape, the earth's surface formations over extended periods of time) espoused by the volcanists. (Lederman& Abd-El-Khalick, 1998, p. 26)

Students are then asked to:

1. State the two dominant hypotheses that have been put forth to account for the extinction of dinosaurs.
2. Explain why different hypotheses were put forth to explain the same phenomenon.
3. Make a connection between the historical episode and NOS.

All activities taken from: Lederman, N.G., & Abd-El-Khalick, F. (1998). *Avoiding de-natured science activities that promote understandings of the nature of science*. In W.F. McComas (Ed), The nature of science in science education: Rationales and strategies, 83-126. Dordrecht, the Netherlands: Kluwer Academic Publishers.

Appendix B: The Views of the Nature of Science Questionnaire (VNOS- C)

1. What, in your view, is science? What makes science (or scientific discipline such as physics, biology, etc.) different from other disciplinary inquiry (e.g., religion, philosophy)?
2. What is an experiment?
3. Does the development of scientific knowledge require experiments?
    - If yes, explain why. Give an example to defend your position.
    - If no, explain why. Give an example to defend your position.
4. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
    - If you believe that scientific theories do not change, explain why. Defend your answer with examples.
    - If you believe that scientific theories do change: (a) Explain why theories change; (b) Explain why we bother to learn scientific theories.

      Defend your answer with examples.

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.
6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting the nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine how an atom looks like?
7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what species is?
8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypotheses, formulated by another group of scientists, suggested massive and

violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

9. Some claim that science is infused with social and cultural values. The science reflects the social and political values, philosophical assumptions and intellectual norms of the culture in which it is practiced. Others believe that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.
    - If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.
    - If you believe that science is universal, explain why. Defend your answer with examples.
10. Scientists perform experiments / investigations when trying to find an answer to the questions they put forth. Do scientists use their creativity and imagination during their investigation?
    - If yes, then at which stages of the investigation do you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
    - If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

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Appendix C: Adapted VNOS-C Questionnaire

SECTION A: General Information
(Please complete the following information)

Name of Pre-service Teacher				
Gender				
Age (please tick √)	Below 20 years	20-25 years	25-30 years	Above 30 years

<u>SECTION B:</u> VIEWS OF THE NATURE OF SCIENCE

Please Note the following

- **There are no right or wrong responses any item**. The intention is to elicit your views on some issues related to Nature of Science (NOS).
- Please read each item carefully and then write as much as you can in response to any one item.
- Make sure to address all subsections of an item and provide supportive or illustrative examples when asked to.

1. What, in your view, is science? Also explain what makes science different from other forms of enquiry (e.g. religion or philosophy).
2. What is an experiment?
3. Does the development of scientific knowledge require experiments?
    - o If yes, explain why. Give an example to defend your position.
    - o If no, explain why. Give an example to defend your position.
4. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
    - o If you believe that scientific theories do not change, explain why. Defend your answer with examples.
    - o If you believe that scientific theories do change:
      (a) Explain why theories change;

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

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.
6. Science textbooks often represent the atom as having a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting the nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine how an atom looks like?
7. Scientists perform experiments / investigations when trying to find an answer to the questions they put forth. Other than in the stage of planning and design, do scientists use their creativity and imagination in the process of performing these experiments / investigations?

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

8. AIDS causes much suffering among the people of Swaziland. The government is trying to help people cope with the disease. However, according to the media, some scientists say that the HIV virus causes AIDS, while other scientists say that the HIV virus is not the cause of AIDS. **How are different conclusions possible if both groups have access to and use the same set of data to derive these conclusions?**
9. Some people claim that science reflects the social and political values, philosophical assumptions and intellectual norms of the culture in which it is practiced. Others believe that science is universal. That is, science is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.
    - If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.
    - If you believe that science is universal, explain why. Defend your answer with examples.

Adapted from:

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

Appendix D: Follow up Semi Structured Interviews

The VNOS-C questionnaire was used to explore interviewees' understanding of NOS. Follow up questions were used to allow participants to clarify and justify their responses. Students will also be requested to define other terms such as discover, prove, invention, theory, involved in the questionnaire, as they crop up during the course of the interview.

1. What, in your view, is science? Also explain what makes science different from other forms of enquiry (e.g. religion or philosophy).
2. What is an experiment?
3. Does the development of scientific knowledge require experiments?
    - If yes, explain why. Give an example to defend your position.
    - If no, explain why. Give an example to defend your position.

   After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
   - If you believe that scientific theories do not change, explain why. Defend your answer with examples.
   - If you believe that scientific theories do change:

     (a) Explain why theories change;

     (b) Explain why we bother to learn scientific theories.

     Defend your answer with examples.
4. After scientists have developed a scientific theory (e.g. atomic theory, evolution theory), does the theory ever change.
   - if you believe that scientific theories do not change, explain why. Defend your answer with examples.
   - If you believe that scientific theories do change: (a) Explain why theories change;

     (b) Explain why we bother to learn scientific theories. Defend your answer with examples.
5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.
6. Science textbooks often represent the atom as having a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting the nucleus. How certain are scientists about the

structure of the atom? What specific evidence do you think scientists used to determine how an atom looks like?

7. Scientists perform experiments / investigations when trying to find an answer to the questions they put forth. Other than in the stage of planning and design, do scientists use their creativity and imagination in the process of performing these experiments / investigations?

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

8. AIDS causes much suffering among the people of Swaziland. The government is trying to help people cope with the disease. However, according to the media, some scientists say that the HIV virus causes AIDS, while other scientists say that the HIV virus is not the cause of AIDS. **How are different conclusions possible if both groups have access to and use the same set of data to derive these conclusions?**

9. Some people claim that science reflects the social and political values, philosophical assumptions and intellectual norms of the culture in which it is practiced. Others believe that science is universal. That is, science is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

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

Adapted from:

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

Appendix E: Exit Interviews

1. Have you previously had an opportunity to learn or critically think about NOS (what science is)? If yes, please state the instance / s where you learnt about the subject?
2. What was your first reaction to learning about NOS? What is your attitude now? What do you feel has contributed towards your attitude change?
3. How do you feel your views have most changed regarding NOS? How did you understand this aspect before? How do you understand it now?
4. What do you feel had the most influence on developing your understanding?
5. Describe any other experience that you have had that you feel influenced your understanding of NOS.
6. What have been your difficulties in learning about NOS?
7. Have your attitudes towards learning and teaching science changed? Please give reasons.
8. In your view, what science should you teach to students?
9. In your view**,** what are the best ways of teaching science? Could you describe what an ideal science teaching environment would look like?
10. In your view, science is best learned by which ways? What do you think about the responsibilities of students when learning science? What is the most important determinant for the success of learning science? Why?
11. Do you believe the pupils you will teach can learn NOS? Explain.
12. If your answer to 11 is yes, please explain which aspects of NOS they can learn.
13. Do you view religion as being conflict to science? Explain your answer.
14. Interviewees will then be questioned about their post-instructional NOS views as evidenced by their post-intervention VNOS-C questionnaires.

Adapted from: Schwartz, R., Akom, G., Skjold, B., Hong, Kagumba, R., & Huang, F. (2007). A change in perspective science education graduate students' reflections on learning NOS.NARST, New Orleans, LA. Available at: http://homepage.wmich.edu/~rchwart

Appendix F: Reflective Journal questions

1. How have your conceptions of NOS changed?
2. What has specifically contributed to your changes in NOS views?
3. What have been your difficulties in learning the NOS issues addressed in the lesson?
4. What aspects of NOS do you believe a scientifically literate citizen should be aware of?
5. What aspects of NOS should be emphasized in your classroom? Explain.
6. How can NOS be most effectively taught in your classroom? Justify your ideas.

Adapted from: Southerland, D. & Dennick, R. (2002).Exploring culture, language, and perception of the nature of science. *International Journal of Science Education*, 24, 25-36.

Appendix G: Targeted NOS aspects and illustrative examples

NOS ASPECT	CATEGORY	DESCRIPTION	REPRESENATIVE QUOTES
EMPIRICAL NOS	INFORMED	All scientific claims are supported by evidence, and this is what makes science different from other ways of knowing.	Unlike other disciplines like religion, scientific claims have to be supported by empirical evidence. Taking for instance, 'Mendel's laws of segregation', to support these laws, experimenting was involved, he grew pea plants and used the information gathered from experiments as evidence to support what he had postulated**.**
	PARTIALLY INFOMED	All Scientific claims are supported by evidence- this is not, however seen as what distinguishes science from other ways of knowing.	Science is different from other forms of inquiry because science requires creativity and imagination.
	INADEQUATE	Science is different because it is proven or truth.	Science most of the time are proven facts while other enquiries consists of non-proven facts.
OBSERVATIONS AND INFERENCES	INFORMED	Scientific constructs (inferences) are scientists' interpretations of empirical evidence rather than observations or copies of reality.	The atomic theory was not exactly derived from visible atoms, protons, neutrons, or electrons. To come up with the theory, the scientists conducted experiments where then from the data collected, analysis and inferences were made to come up with the atomic theory.
	PARTIALLY INFORMED	Scientists constructs (inferences) are human interpretations of empirical evidence rather than observations. Scientists are however certain about the structure of an atom as it is supported by empirical evidence.	
	INADEQUATE VIEW	Scientific constructs (inferences) are facts discovered through experimentation o direct observation.	Bohr used cathode rays and showed the fact that the atom has a nucleus and electrons were orbiting around it. A microscope was used to come up with the structure of an atom." .
SCIENTIFIC LAWS AND TEORIES	INFORMED	Scientific laws describe regularities as observed in nature while theories explain such observations.	Laws describe regularities in nature, for example, the law of conservation of mass which states that the mass of reactants will be equal to the mass that you will end up with. The law on its own has no explanation, therefore there has to be a theory that will explain the

NOS ASPECT	CATEGORY	DESCRIPTION	REPRESENATIVE QUOTES
			law. Like Dalton's atomic theory which states that atoms are neither destroyed nor created; this explains the law of conservation of mass.
	PARTIALLY INFORMED VIEW	Awareness that theories are more based on creativity and imagination than laws, but failure to distinguish the different roles played by this constructs.	Theories are based more on creativity and imagination than laws.
	INADEQUATE VIEW	A hierarchical view of theories and laws/ a lack of understanding of the different roles played by the two construct.	Scientists start with theories, and from theories, they develop laws.
TENTATIVE NOS	INFORMED	All scientific knowledge changes in light of new evidence and / or as a result of a different way of looking at existing evidence.	In science, facts, theories and laws are subject to change. This is because of new discoveries and new ways of explaining evidence.
	PARTIALLY INFORMED	Scientific theories are not certain) because their development involves human inference, imagination and creativity, without giving instances that can cause a theory to change.	Scientific theories are tentative because it involves human inference, imagination and creativity and also because the interpretation of data is subjective.
	INADEQUATE	Not all Scientific knowledge subject to change / scientific knowledge can only be modified.	Theories are based on creativity and imagination and are therefore subject to change, while laws are based on what is seen and are not subject to change. I believe that a scientific theory never change because before a theory can be made, scientists do a lot of experiments to prove whether it is true or not."
SCIENTIFIC METHOD	INFORMED	Scientists do not follow a single method, but make use of creativity and imagination in designing and planning their investigation.	There are no specific methods of getting knowledge. An investigator may use any suitable means of investigating or researching.
	PARTIALLY INFORMED	Creativity is involved only in the design stage but not in data collection.	In data collection there is no creativity and imagination needed there but you observe and record what you see.
	INADEQUATE	Scientists have to follow a single scientific method when carrying out investigations.	"the steps used in carrying out experiments (investigations) are not just assumed but were carried out and tested by qualified scientists and proven to be the better method of discovering whatever is in question in that particular time.
CREATIVITY IN INTERPRETING DATA	INFORMED VIEW	Interpreting data involves creativity and imagination. Scientific constructs' (theories and models) are viewed as human constructed ideas used to explain observations.	Mendel inferred that there are factors that are transferred from parent to offspring, and postulated that these factors are the ones that carry the genetic information and in that statement there is a lot of creativity and imagination,"

NOS ASPECT	CATEGORY	DESCRIPTION	REPRESENATIVE QUOTES
			"Science is a systematic way of knowing that involves creating ideas; it is not solely based on observations.
	PARTIALLY INFORMED VIEW	Scientists use creativity and imagination in data interpretations. Some scientific constructs are however solely based on human creativity and imagination.	"Sometimes scientists use creativity and imagination because there is no evidence of that fact."
	INADEQAUTE VIEW	Scientific claims are developed solely based on empirical evidence without the involvement of creativity and imagination.	Scientists do not use imaginations and creativity, because to come up with theories and laws, experiments or investigations were carried out "Using the same set of data and each group basing its findings on that same data they can draw conclusions in one accord A theory is something that is out there in nature and scientists just discover it.
SUBJECTIVITY IN SCIENCE	INFORMED	Cultural, social, and political factors, and / or prior knowledge, prior expectations and different ways of thinking impact on data interpretation which therefore makes it possible for two scientists to come with different inferences based on the same data.	"When you look at something, you usually see that thing in relation to what you know. It is therefore possible to have different conclusions if they have different prior knowledge and experiences. Different conclusions are possible because interpreting data or making inferences is influenced by a number of factors which will lead to different conclusions. These factors may include other ways of knowing such as religion, philosophy, social and cultural factors.
	PARTIALLY INFORMED	Different scientists can interpret evidence differently. No reason given. / Correct reasons given, but such a view is contradicted by the pre-service teacher's response to another item, therefore indicating an incomplete understanding of the impact of subjectivity in science.	Scientists make use of different ways of carrying out investigations but they all collect the same data and after data collection they arrive at the same conclusions.
	INADEQUATE	Interpretation of data is completely objective.	"If two scientists follow the same method and interpret the data correctly, they will come up with same conclusions".
SOCIAL AND CULTURAL INFLUENCE	INFORMED	The scientists' social, political, and philosophical assumptions influence how they interpret or make sense of data. These contexts influence the scientists' mind-set which in turn influences how he or she approaches any given data.	The evolution theory originally talked about 'the man hunter' before women was accepted in the scientific realm. After being accepted, it talked also about the 'woman gatherer' which shows an influence of cultural and social beliefs." … "For example, two hypotheses were put forth to explain the mass extinction of dinosaurs indicating the influence of

NOS ASPECT	CATEGORY	DESCRIPTION	REPRESENATIVE QUOTES
			different philosophical assumptions on science."
	PARTIALLY INFORMED	The participant points out that social and cultural values impact on science, but at a different point, the respondent points out that there is only one answer to any given question, which implies a not so fully developed view of context on the development of scientific knowledge.	Scientists from different cultures and society have different prior knowledge which influences the way they interpret data.
	INADEQAUTE	Science is the same everywhere. It is not influenced by social, cultural, political, or philosophical values. Science is viewed as more based on discovery of facts about natural phenomena that are the same everywhere.	"Science is universal, that is, there is only one science; for example, for a bean to germinate it requires water, air, and sunlight, not only in Africa, but worldwide "For example. We know that when you apply more heat in boiling water, it will evaporate either in Africa or Asia.

Appendix H: Letter requesting permission from the Regional Education Office

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

FACULTY OF EDUCATION
Department of Science, Mathematics and Technology Education

May, 17, 2011

The Regional Education Officer

Manzini

Swaziland

Dear Sir / Madam

Re: Permission to conduct research in the XXX College of Education

Pre-service Teachers' Understanding of Nature of Science

I am a MEd student at the University of Pretoria in the Science and Mathematics Department of the Faculty of Education. As part of the programme, I am required to carry out a research project.

I am requesting permission to conduct research in the XXX College of Education. The aim of the study is to investigate the impact of the programme aimed at augmenting the pre-service elementary teachers' understanding of the nature of science (NOS).

The research will be conducted during the second half of 2011, the beginning of the students' third academic year. During the normal programme, participants will be engaged in a three months intervention aimed at augmenting their NOS understanding. This study will evaluate the impact of the intervention on the development of their NOS conceptions. Each student will be asked to complete an open ended questionnaire both prior and after the intervention. During the course of the intervention, students will keep reflective journals and concept maps to track changes in their NOS views. Information from some of the participants' reflective journals, students' artefacts, as well as interviews will be used determine participants' perception of the elements of the course and other factors that impact on their development of more informed NOS views.

The questionnaire will obtain basic biographical information about the student teacher as a participant, as well as information regarding her or his understanding of NOS. This activity will take about 30-60 minutes. Participation in this phase will not compel them to participate in the follow up interviews; however should they decide to participate in the interviews their participation will be appreciated. The interviews will take 45-60 minutes.

The instructor of the module will also keep a reflective journal that will be examined for evidence of factors that impact on students' gains in NOS understanding.

Participation is strictly voluntary and anonymity, confidentiality and other ethical obligations will be maintained throughout the whole research process. Neither you as the Nazarene's school manager, nor anyone at the college, will be offered inducements to participate in this study. The findings (not data) of the study will be communicated to your office, the Nazarene Schools' manager and to the college.

Thanking you in advance for your cooperation in this regard.

Yours Faithfully

Khanyisile B. Nhlengethwa	KBNhl.	17 May 2011
Researcher	Signature	Date
Dr. A.L. Abrie	[signature]	17 May 2011
Supervisor	Signature	Date

By signing this permission letter, you indicate that you grant permission for the study to be conducted in the institution.

The researcher undertakes that:

- Participation by pre-service teachers from your institution in this research is voluntary, meaning that you could withdraw from this research at any time.
- You will at all times be fully informed about the research process and purposes.
- In line with the regulations of the University of Pretoria regarding the code of conduct for proper research practices for safety in participation, no one from your school will be placed at risk or harmed in any way, e.g. no responses will be used to assess you, or your institution.
- Your privacy and that of participants with regard to confidentiality and anonymity will be protected at all times.
- Research information will be used only for the purposes of this enquiry.
- Your trust will not be betrayed in the research process or its published outcomes, and you will not be deceived in any way.

I herby give my permission that pre-service teachers from my institution may take part in this research if they so wish.

OR

I Prefer that no pre-service teacher from my institution take part in this research project.

XXXX	XXXX	19/05/2011
The Regional Education Office		
(Name)	**Signature**	**Date**

19 MAY 2011
MANZINI
SWAZILAND

Appendix I:Letter to the teacher training institution

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

FACULTY OF EDUCATION
Department of Science, Mathematics and Technology Education

May, 17, 2011

The Principal

Dear Madam

Re: Permission to conduct research in the XX College of Education

Pre-service Teachers' Understanding of Nature of Science

I am a MEd student at the University of Pretoria in the Science and Mathematics Department of the Faculty of Education. As part of the programme, I am required to carry out a research project.

I am requesting permission from you to allow pre-service teachers from the college to participate in this research project. The aim of the study is to investigate the impact of the programme aimed at augmenting the pre-service elementary teachers' understanding of the nature of science (NOS).

The research will be conducted during the second half of 2011, the beginning of the students' third academic year. During the normal programme, participants will be engaged in a three month intervention aimed at augmenting their NOS understanding. This study will evaluate the impact of the intervention on the development of their NOS conceptions. Each participant will be asked to complete an open ended questionnaire both prior and after the intervention. During the course of the intervention, students will keep reflective journals and concept maps to track changes in their NOS views. Information from some of the participants' reflective journals, students' artefacts, as well as interviews will be used determine participants' perception of the elements of the course and other factors that impact on their development of more informed NOS views.

By signing this permission letter, you indicate that you grant permission for the study to be conducted in the institution.

The researcher will undertake that:

- Participation by prospective teachers from your institution in this research will be voluntary, meaning that they can withdraw from this research at any time.
- You will at all times be fully informed about the research process and purposes.
- In line with the regulations of the University of Pretoria regarding the code of conduct for proper research practices for safety in participation, no one from your school will be placed at risk or harmed in any way, e.g. no responses will be used to assess you, or your institution.
- Your privacy with regard to confidentiality and anonymity will be protected at all times.
- Research information will be used only for the purposes of this enquiry.
- Your trust will not be betrayed in the research process or its published outcomes, and you will not be deceived in any way.

I hereby give my permission that pre-service teachers from my institution may take part in this research if they so wish.

OR

I Prefer that no pre-service teacher from my institution take part in this research project.

Name of Institution

18/05/2011

18 -05- 2011

Appendix J: Letter to instructor

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

FACULTY OF EDUCATION
Department of Science, Mathematics and Technology Education

May, 17, 2011

Dear Madam

Protocol Letter of Invitation:

Research project Swaziland pre-service elementary teachers' Understanding of Nature of Science (NOS)

I am a MEd student at the University of Pretoria in the Science and Mathematics Department of the Faculty of Education. As part of the programme, I am required to carry out a research.

I am inviting you to be a participant in the study aimed at assessing the impact of the programme aimed at augmenting the pre-service elementary teachers' understanding of NOS. As the instructor of the programme, you will be required to keep a journal. The reflective journal will be examined for evidence of factors that impact on students' gains in NOS understanding.

If you are willing to participate in this study, please sign the form on the next page as a declaration of your consent, i.e. that you participate in this project willingly. Under no circumstances will your name be made known publicly and pseudonyms will always be used.

Thanking you in advance for your cooperation in this regard.

Yours Faithfully,

Khanyisile B. Nhlengethwa ______________ ______________

Researcher **Signature** **Date**

Dr. A.L. Abrie ______________ ______________

Supervisor **Signature** **Date**

By signing this permission letter, you indicate that you understand that

- € Your participation in this research is voluntary, meaning that you could withdraw from the research at any time.
- € You will at all times be fully informed about the research process and purposes.
- € In line with the regulations of the University of Pretoria regarding the code of conduct for proper research practices for safety in participation, no-one from your school will be placed at risk or harmed in any way, e.g. no responses will be used to assess you, or your college.
- € Your privacy with regard to confidentiality and anonymity will be protected at all times.
- € Research information will be used only for the purposes of this enquiry.
- € Your trust will not be betrayed in the research process or its published outcomes, and you will not be deceived in any way.

I hereby agree to take part in this research project.

OR

€ **I prefer not to take part in this research project.**

_________________________ ______________

Instructor **Date**

Khanyisile B. Nhlengethwa ____________________ __________________

Researcher **Signature** **Date**

Dr. A.L. Abrie ______________

Supervisor **Signature** **Date**

Appendix K: Letter to the pre-service teacher

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

FACULTY OF EDUCATION
Department of Science, Mathematics and Technology Education

May, 17, 2011

Dear Sir/Madam

Protocol Letter of Invitation:

Research project on Developing Elementary Teachers' Understanding of the Nature of Science

I am a Science lecturer stationed at XXXX College of Education, currently enrolled for a MEd degree in Science and Mathematics with the University of Pretoria. As part of the programme, I am required to carry out a research project.

I am inviting you to participate in this research project. The aim of the study is to investigate the impact of a programme aimed at augmenting pre-service elementary teachers' understanding of the nature of science (NOS).

During the normal programme, you will be engaged in a three months intervention aimed at augmenting your NOS understanding. This study will evaluate the impact of the intervention on the development of your NOS conceptions. You will be asked to complete an open ended questionnaire both prior and after the intervention. During the course of the intervention, you will be required to keep a reflective journal and to draw concept maps to track changes in your NOS views. Information from your reflective journal, concept maps, tests and assignments, as well as interviews will be used determine your perception of the elements of the course and other factors that impact on their development of your NOS views.

The questionnaire will obtain basic biographical information about you as a participant, as well as information regarding your understanding of NOS. This activity will take about 30-60 minutes. Participation in this phase will not compel you to participate in the follow up interviews; however should you decide to participate in the interviews your participation will be welcome. Interview sessions will take about 45-60 minutes.

The study is carried out under the supervision of Dr. L.A. Abrie, lecturer at the University of Pretoria's Department of Science, Mathematics and Technology Education.

If you are willing to participate in this study, please sign the form on the next page as a declaration of your consent, i.e. that you participate in this project willingly and return it with your questionnaire. Your Principal will not be made aware of your participation or non participation in this research and any information given will not be shared with her.

Thanking you in advance for your cooperation in this regard.

Yours Faithfully,

Khanyisile B. Nhlengethwa	____________	____________
Researcher	**Signature**	**Date**
Dr. A.L. Abrie	[signature]	17 May 2011
Supervisor	**Signature**	**Date**

Appendix L: Reflective personal journals of some of the selected group participants

Hlobi's personal diary

01 September 2011

The nature of Science

According to my understanding I thought Science theories were suggested not that they come from a hypothesis I now know that theories start as idea and go different processes in order to be called science theories. This is a difficult concept which requires one to study it carefully because it has terms which are the same so it also gives me hard time

02 September 2011

The nature of science is not an easy concept and always gives challenge when coming to understanding it there are terms which always give me hard time in understanding them due to the fact that they look the same, these are scientific theory, scientific fact, scientific laws I really need help because I totally do not understand the nature of science. I need to consult my teacher and read books which are about the nature of Science

05 September 2011

It was a better lesson because I was able to get to know what does the nature of science is because all along I have been having problem with the word itself the nature of Science. As we discuss few points about nature of Science I was enlighte with some few points though I still have a big problem with this concept

16 September 2011

The nature of Science

As lesson progresses the nature of Science is starting to be clear. All I along I was confusing theory and law but today everything I was clear. All long I have been thinking that nature of Science really confuses one when it is brought to the lesson taught on that particular day. To my own surpise I realise that it is the good thing to learn nature of Science I have also realise that nature of Science is very important because it teach you with more things which are about Science. Learning about Science is not enough you have to know beyond knowing Science thus I can conclude that science is completely different from other subject because it open one's mind.

27 September 2011

The nature of Science

Observation and inferences

The lesson was very interesting so in short I am enjoying NOS. I have realise that Nature of Science is an interesting lesson which one can enjoy if he/she given him or herself to analyse and study it well, I thought that observations and inferences are the same so today I realise that they are totally different I also like the way the lecturer teach the observation and inferences, She put us in suspense of what was inside the box. This arouses intesest and make us to want to find out what was the object inside the box. I had also realise that there is no correct theory until proven by empirical evidence and accepted by scientific community thus theories can change. but the question is since we say theories are subject to change so it is wise to read old books which are about Science? I think it is a topic to debate. Yes but I think you need to consult many books not just using one book. I tink I need to consult the teacher for more clarification. All in all Science is interesting

29 September 2011

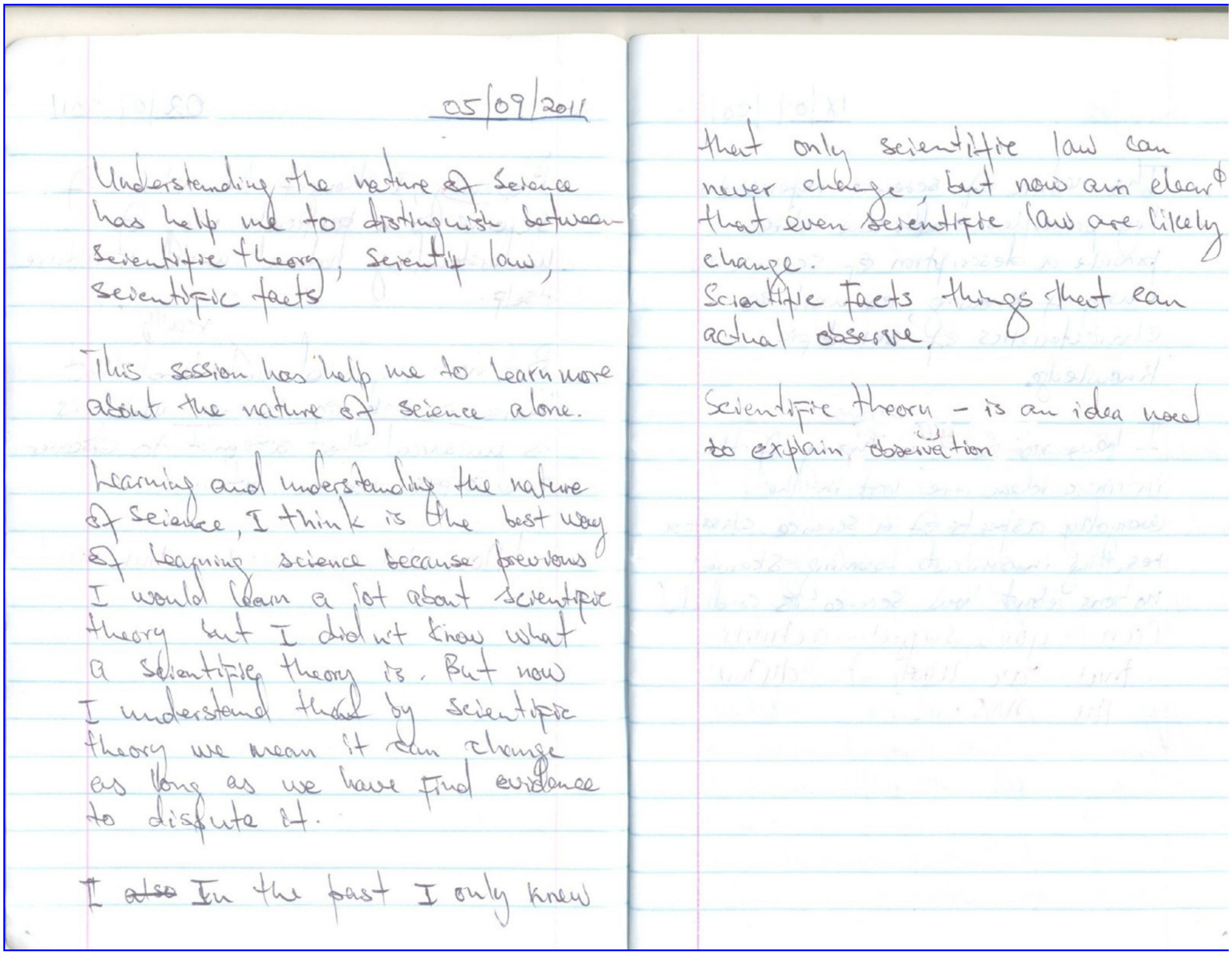
The atomic theory

I am enjoying the nature of science. As we were learning about the atomic theory I realise that many people were involved in making the the atomic theory and everything was based on empirical evidence,

04 September 2011

I remember the very first day when I was told I will be learning about nature of Science many questions flooded my minds and I was confused and I concluded that Science is going to be difficult. It was even worse when she gave us the words for making a concept map. To my own surprise I have realise that Science is easy because I am also able to correct the concept map I make the first day.

Part of Muzi's personal reflective diary



05/09/2011

Understanding the nature of Science has help me to distinguish between Scientific theory, Scientif law, Scientific facts

This session has help me to learn more about the nature of science alone.

Learning and understanding the nature of Science, I think is the best way of learning science because previous I would learn a lot about scientific theory but I did n't know what a scientific theory is. But now I understand that by scientific theory we mean it can change as long as we have find evidence to dispute it.

I ~~also~~ In the past I only knew that only scientific law can never change, but now am clear that even scientific law are likely change.

Scientific Facts things that can actual observe.

Scientific theory - is an idea used to explain observation

Futhi's personal journal

08-09-2011

By learning about theories and laws, it made me understand that Science needs one to be a critical thinker, which means that it involves creativity and imagination

13-09-2011

By learning about the theories about matter, I come to conclude that Science needs empirical evidence ~~to~~ support theories. And not every theory is accepted in the Scientific ream. I also learned that theories act as a base for new facts. they guide further research or investigation leading to the to the development of knowledge

Futhi's final reflective journal

1. My conceptions of the Nature of Science have changed in the sense that, I now understand that theories do not develop into laws rather theories explains laws while laws describe regularities in nature. I also had a misconception that Science is truth found from emperical data whereas Science involves human creativity and imagination and it is also tentative. I did not also think that Science is affected by culture, Social beliefs and background, but the tentativeness of Scientific knowledge has made me understand their influence better.

2. What has specifically contributed to my changes in Nos views is scientific literacy. This means that teachings and clear explanations of some Scientific processes and products of science (facts, laws and theories) had made me understand what Science is really about. For example, I was really surprised to learn that the atomic model was through human creativity and imagination; nobody has ever seen an atom. Also in the study of heredity, nobody has ever seen a gene.

3. My difficulties in learning the Nos issues addressed in the course is that it took me time to adjust my prio understanding of other concepts to the new information I learn. For example making a distinction between process skill and Nos. I also used to use words wrongly because I had not got clear meanings of them

For example, the words, hypothesis and theory; inferences and observation etc.

4. Aspects of the nature of Science a scientifically literate citizen should know are some of the processes of Science such as observation, questioning, investigating, classifying, measuring, using numbers, Communicating etc. This is because these processes are mostly applied in everyday life noticeably and haphazardly.

5. Aspects of the nature of Science to be emphasized in class are the functions of the different products of Science such as scientific laws and theories. This is because an understanding of the nature of Science is also likely to boost interest in Science and Science classes and also improve the learning of Science content.

6. The nature of Science can be most effectively taught in the classroom through use of proper language and Constructivism. By use of proper language, it means that when teaching Science teachers should avoid wrong use of words such as facts, theories, laws, prove etc. By constructivism, it means that learners need to be given a chance to construct their own understanding and knowledge, through experiencing things and reflecting on those experiences and the teacher should act as a facilitator among the learners to emphasize on concepts that need to be emphasized.

Muzi's final reflective journal

1. My conception of the nature of science has really changed. At first, it was not easy to understand what is the nature of science and how is it important to learn about it. But as lesson were going on, it enlighten and broaden my conception or understanding about the nature of science. Actually I have realized that in order for someone to understand how science works, must learn about the nature of science first.

2. Learning and reading on my own during science lessons has contributed to the changes ~~in nature of~~ my view in the nature of science

3. Learning about the nature of science to me, was ~~not~~ difficult at first, because I couldn't understand the important of learning about it. It was also difficult to differentiate between scientific laws and theories. But later on I began to have more interest ~~as~~ learning about the nature of science and increased my knowledge on understanding some scientific concepts better.

4. The knowledge it produces because it really shape an individual to enjoy the learning of Science.

5. Science is not objective, as many people or citizens think or understand about science,

because inferences or interpretation of data are influenced by other ways of knowing such as religion, philosophy, social and cultural practises, prior knowledge and many more.

6. Nature of Science can be most effectively taught in classroom during any science lesson by allowing the learners to express their views during lessons. What ever concept that is being learned in class, the teacher should include a nature of science to make the understanding or learning process enjoyable.

Fortunates' final reflective journal

My conceptions of the Nature of Science has completely changed. Each and everyday my mind is filled with new ideas. I always assimulate and that makes me to have a clear understanding of any lesson taught in class that is, sometimes put theory into practise, also helps one to think abstractly because NOS involves creativity and imagination.

At first I thought theories develop to laws and laws do not change. I thought, for one to develop a law there must be some theories inorder to formulate one law. But after the NOS lesson I was totally convinced because it was stated that a theory can be defined as an inferred explanations for observable phenomena. They are based on emperical evidence and theories must be linked to existing knowledge and be open to falsification or modification.

It was said that both theories and laws are tentative that is subject to change. It was said that theories are more tentative than laws because they are more based on creativity and imagination than laws. Laws are based on what we see.

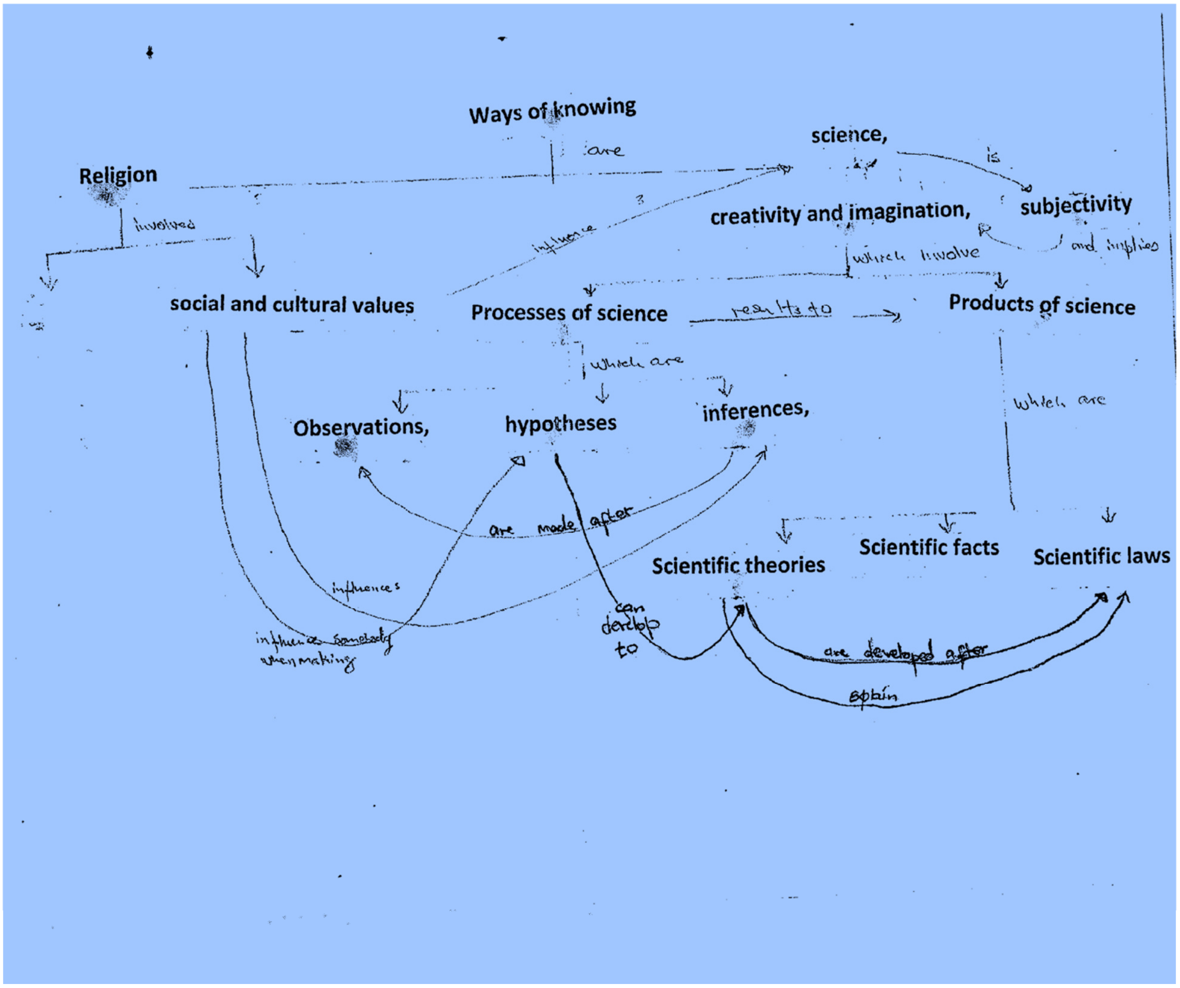
It was said that theories do develop into a law. For example; Mendels law of heredity. Today I got to understand that scientists are doing experiments to come up with laws and theories infact science is a way of ~~knowledge~~ knowing but by doing or undergoing some experiments Along the way ~~the~~ (for example, in genes) the generation of certain parents changes, this was discovered after Mendel's underwent experiments of pollination. Infact what makes science science is the effort that scientists put in coming with theories and laws to describe the environment.

2. The way the Nature Of Science was taught made one to change the way she or he viewed Nature Of Science before. A clear explanation or clarification was given to each and every topic based on Nature of science. Clear clarification is very crucial for one to understand a certain concept.

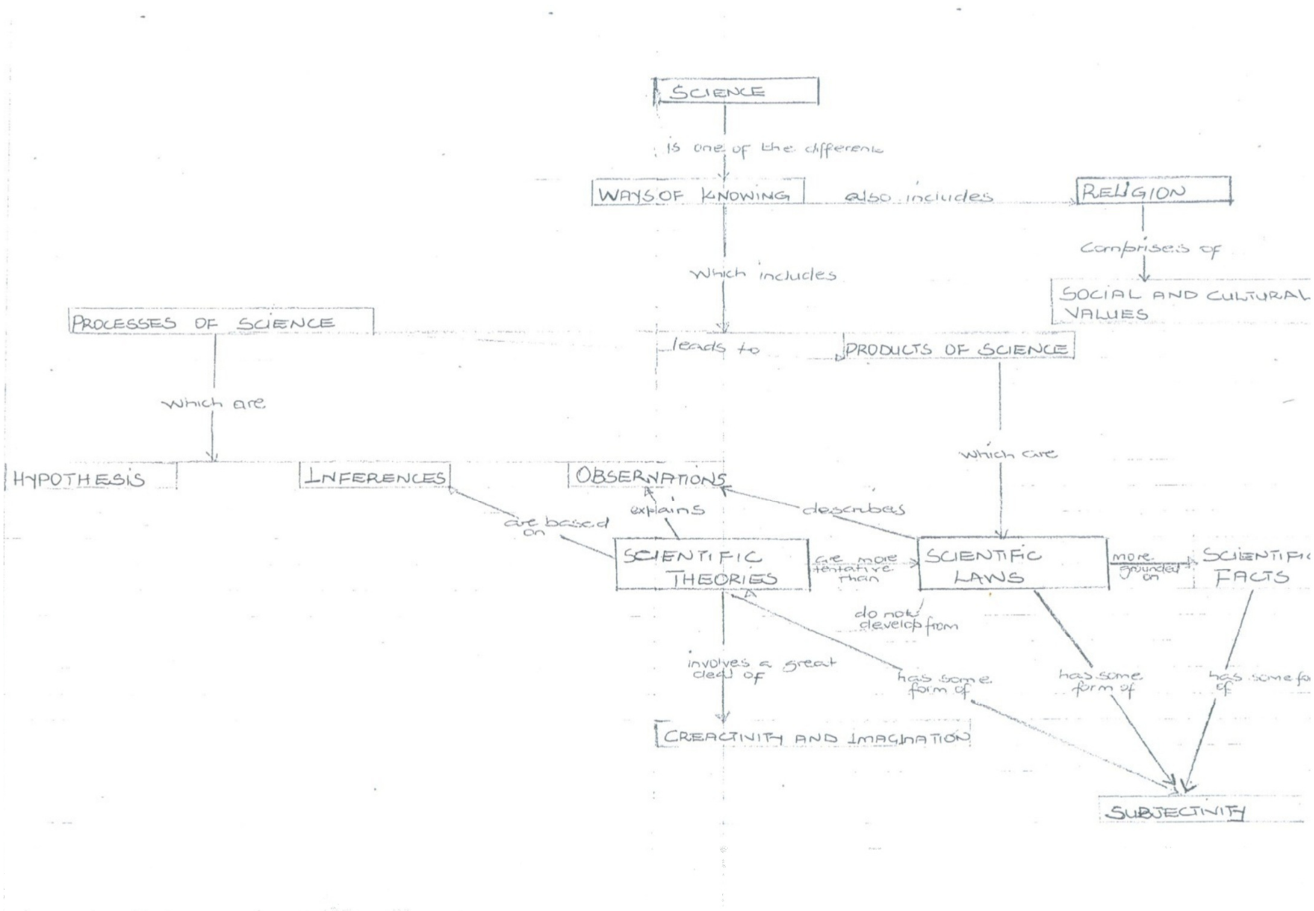
3. Sometimes I was left behind, that is, not understanding what was taught in that particular time. I noticed that NOS cannot be predicted. Inorder to come out with a theory or law you need emperical evidence. Science is tentative, you cannot discover something and then sit down there and think that other scientists agree or are happy with your discovery they will continue to research more and more which eventually make science tentative compared to other disciplines. When looking at Mendeleev's law he came to its through the ~~disciplines~~. ~~When~~ Work of Johaan. That is science is subject to change so I view science as nothing else but about

Appendix M: Concept maps of four focus group students depicting their understanding of NOS after NOS instruction

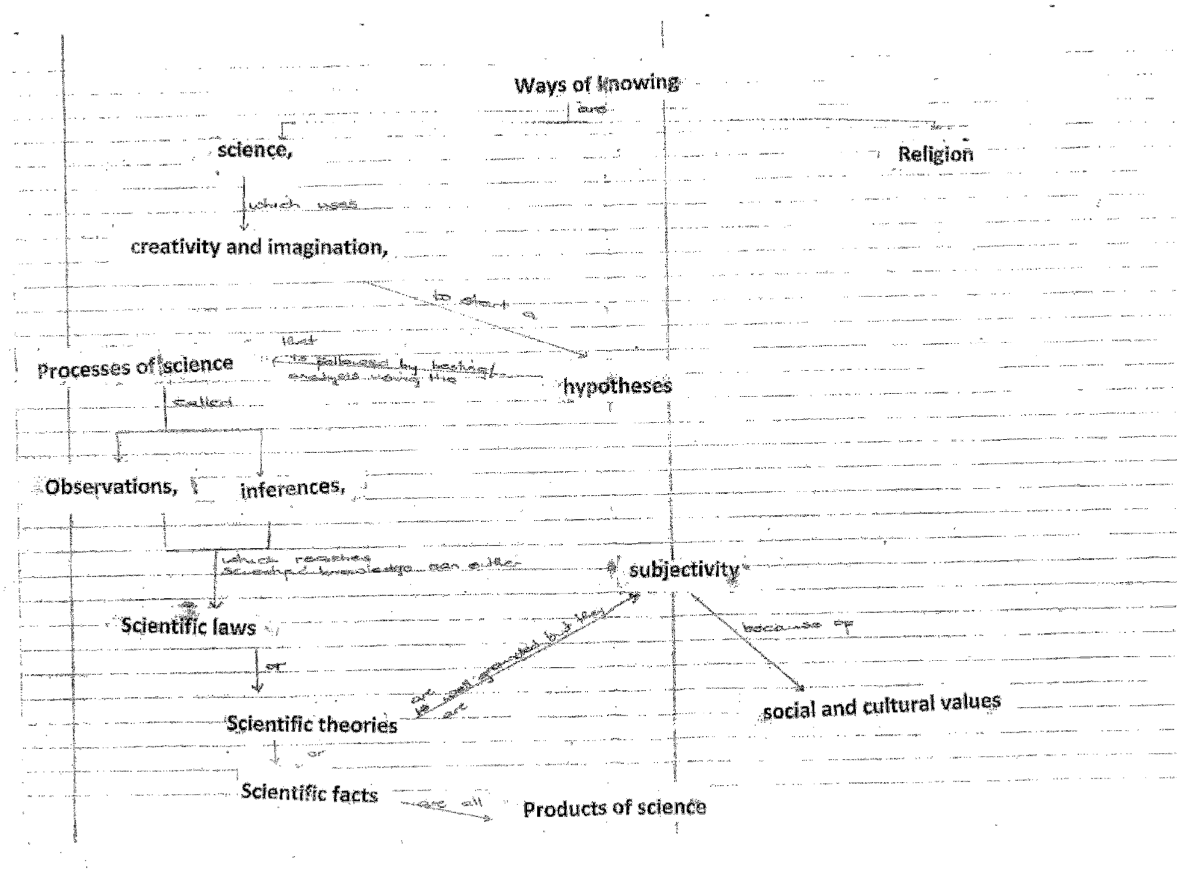
Muzi's concept map



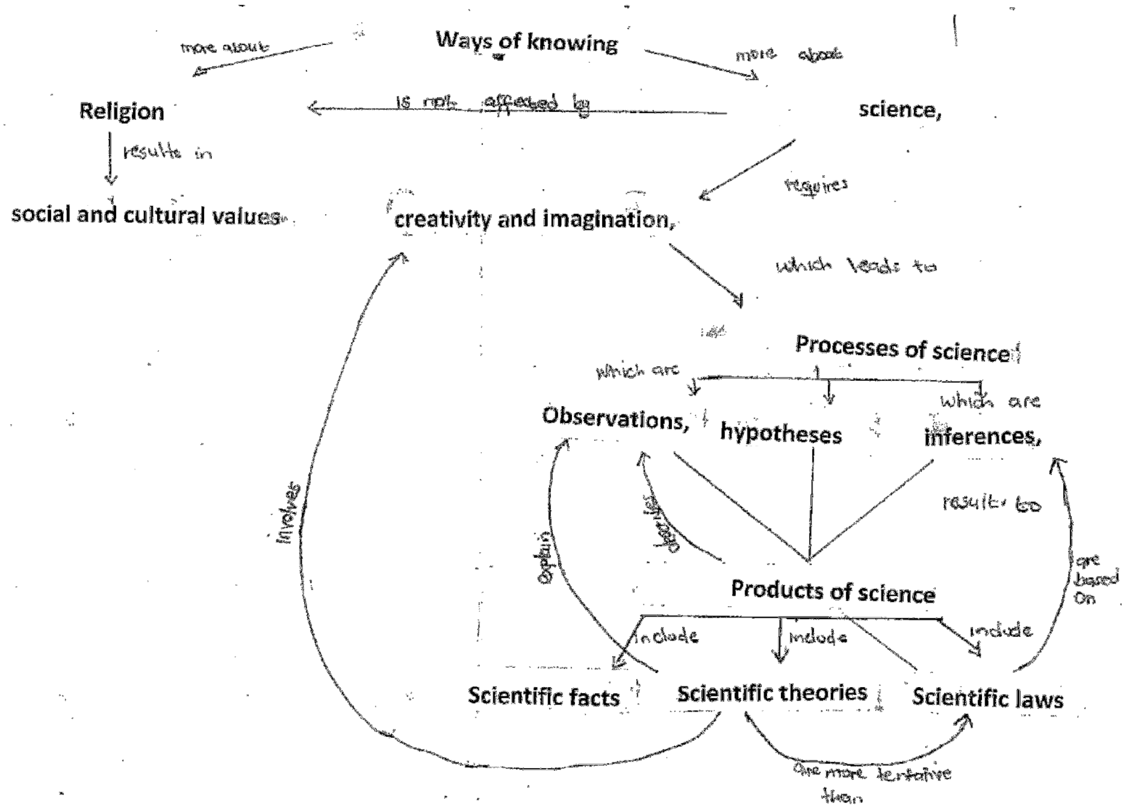
Futhi's concept map



Hlobi's concept map

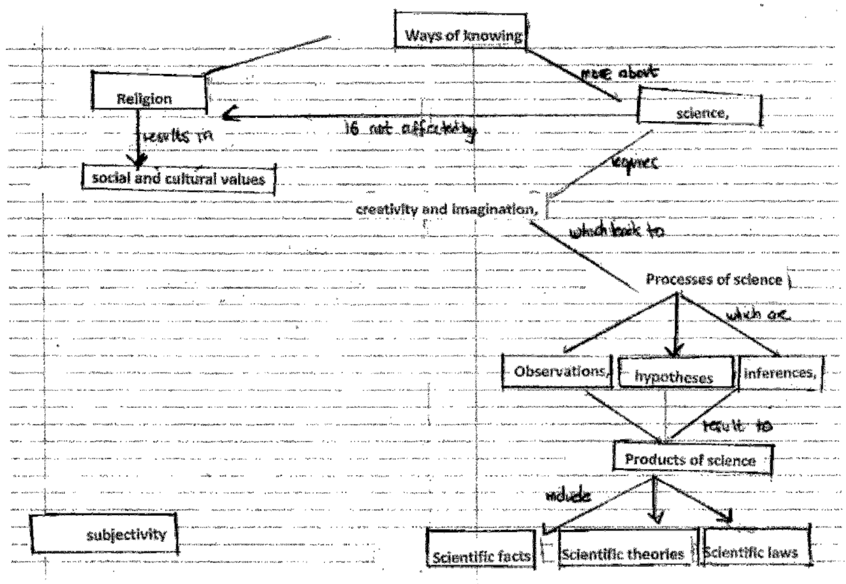


Fortunate's concept map

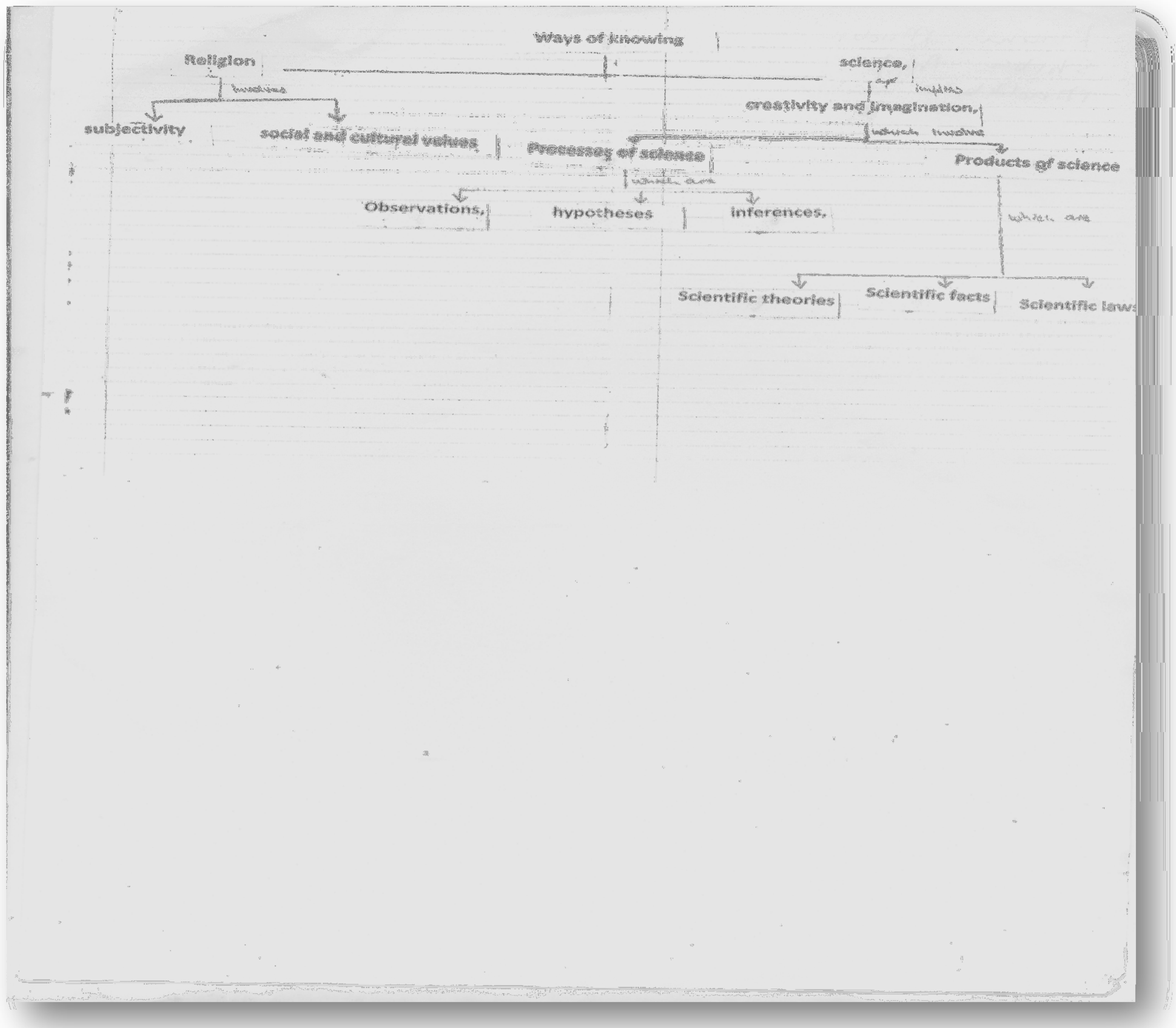


Appendix N: Concept maps of three focus group students depicting their understanding of NOS prior to NOS instruction

Fortunate

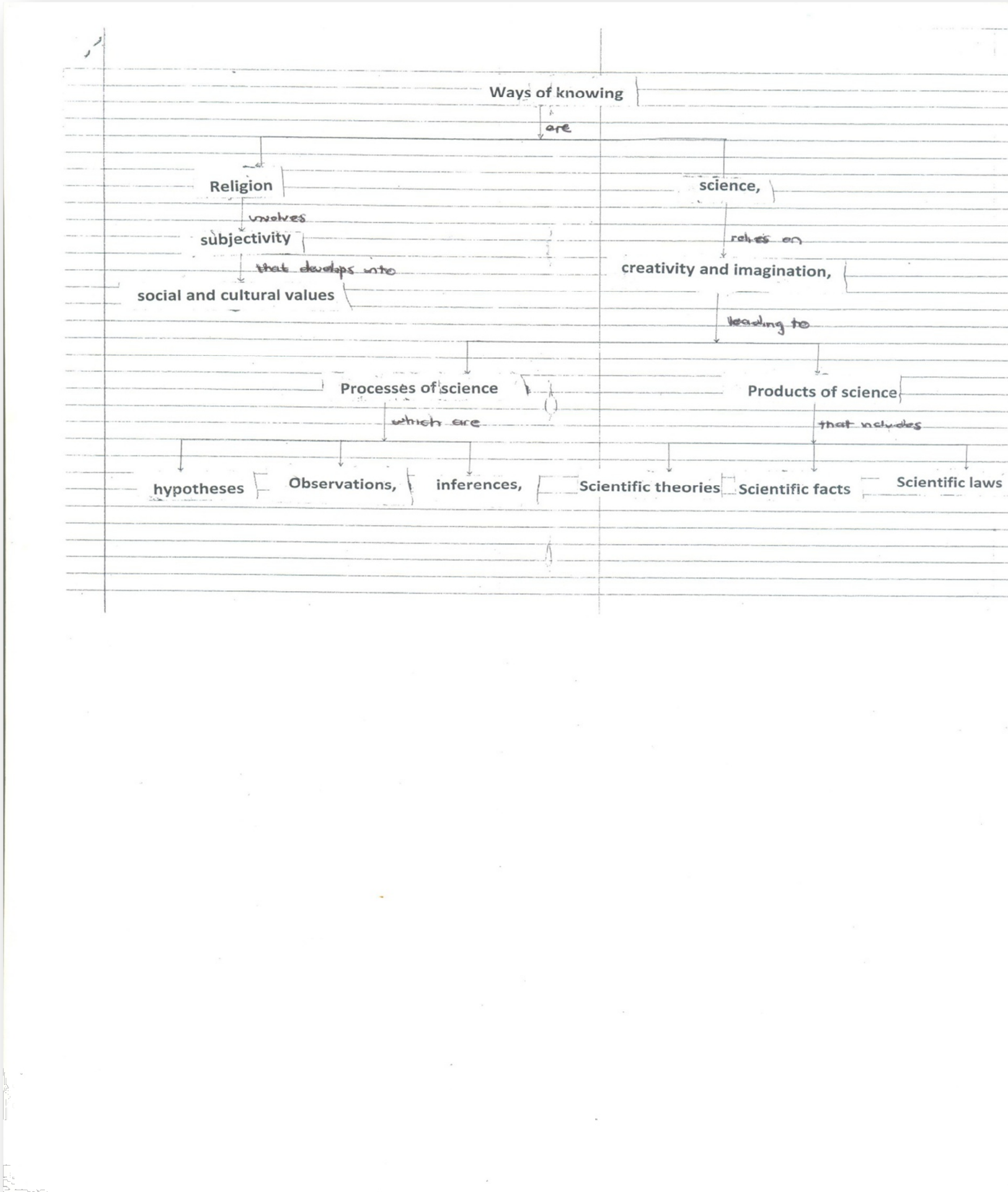


Muzi



Ways of knowing
Religion
science,
creativity and imagination,
subjectivity
social and cultural values
Processes of science
Products of science
Observations,
hypotheses
inferences,
Scientific theories
Scientific facts
Scientific laws

Hlobi


Ways of knowing
are
Religion
science,
involves
subjectivity
relies on
that develops into
creativity and imagination,
social and cultural values
leading to
Processes of science
Products of science
which are
that includes
hypotheses
Observations,
inferences,
Scientific theories
Scientific facts
Scientific laws

Appendix O: NOS Assignment

Themba

a)

i) If someone may ask me "what is science," I will answer him or her by telling the following; the word "science" probably brings to mind many different picturers such as fat textbooks, white lab coats and microscope. All of those images reflect some aspect of science, but None of them provides a full picture because science has so many facets. These images all show an aspect of science, but view of science is more than any particular instance.

First and foremost, science is both a body of knowledge and a process. In schools science may sometimes seen like a collection of isolated and static facts listed in a textbook, but thats only a small part of the story.

Science is also a process of discovering that allows us to link isolated facts into coherent and comprehensive understanding of the natural world. Science is a way of discovering what is in universe and how those things work today, how they worked in the past and how they are likely to work in the future. Scientists are motivated by the thrill of seeing of Figuring out something that no one has before.

science is a global human endeavor people all over the world participate in the process of science

Sizakele

investigates the natural world, while religion deals with the spiritual and supernatural, hence the two can be complementary. Many religious organizations have issued statements declaring that there need not to be any conflict between religion and science.

(b).Science is best taught by question and answer, let the pupils ask and keep asking so that you as the teacher can explain how the world works. Also science fair projects but mainly for the higher grades and lastly involvement of practical during science classes makes science best taught.

What makes the most successful science teaching:

A successful teacher (a prepared teacher). This means finding all the necessary teaching/learning materials and having up to date knowledge of the subject matter.

-accurate content is vital

-lesson plan, reflect not only relevant accurate content but also be adapted to the variety of learning needs.

Lastly an ideal science teaching environment would have a well ventilated room enough light well and prepared teacher in terms of teaching learning materials and lesson plan.

(c) In my own view science is best learned by doing. I think the best way to learn science is to read a lot of science books. I read a lot of books and they teach me new things that I did not know before. In fact we can learn from books. Research is another way to learn science. You can write about new things you learned from your research. When you stick to an idea you can really get a lot down on paper about your topic

Also learning is about retrieving especially science, so it is important to make retrieval practice an integral part of the learning process. For example, concept mapping which requires learners to construct a diagram-typical using nodes that shows relationship among ideas, characteristics or materials. These concepts are then written down as a way of encoding them in the person's memory (learner).