

https://dspace.org/

A comparison of grade 11 learners' and pre-service teachers' understandings of nature of science

Musekiwa, Kizito

2017

http://hdl.handle.net/10539/22728

Musekiwa, Kizito (2017) A comparison of grade 11 learners' and pre-service teachers' understandings of nature of science, University of the Witwatersrand, Johannesburg, <http://hdl.handle.net/10539/22728>

Downloaded from a DSpace repository. https://dspace.org/

A Comparison of Grade 11 learners' and Pre-service Teachers' understandings of Nature of Science

Chapter One

Introduction to the study

1. Introduction

Most educational reforms worldwide advocate for the development of teachers and learners' understanding of the construct nature of science (NOS), as an important goal of science education (see for example, NRC, 1996; Achieve Inc., 2013; AAAS, 1993; Lederman, 1992, 2007). The NOS is a complex and multi-faceted concept which has been controversial within the science education community for more than half a century. The construct NOS, has been perceived differently by scientists, philosophers of science, teachers and researchers resulting in the absence of an agreed universal definition of the concept (Lederman, 1992; Abd-El-Khalick and Lederman, 2000; Schwartz, Lederman and Lederman, 2008). The most widely used and accepted definition is the Lederman (1992, p. 331) which refers NOS as 'the epistemology of science, science as a way of knowing or values and beliefs inherent to the development of scientific knowledge". Meichtry (1993, 1998) is of the view that the term "nature of science" has been used interchangeably in literature to refer to an understanding of both the nature of scientific inquiry, (NOSI), and the nature of scientific knowledge (NOSK). She argues that even though the term NOS has been used to represent NOSK only, literature has shown that NOS also includes the nature of the scientific enterprise and the nature of scientists as well (Meichtry, 1993).

A survey of the literature reveals that some authors (for example, Lederman, 1992; Abd-El-Khalick, 2003; Schwartz, Lederman and Crawford, 2004) have used the term NOS while referring to NOSK only while others (Abd-El-Khalick, 2004, Schwartz and Lederman, 2002, Khishfe, 2014) have conflated NOS and NOSK to mean NOS. Recently, Lederman, Lederman, Bartos, Bartels, Meyer and Schwartz (2014) have argued for a new conception of NOS which refers it to the characteristics of scientific knowledge, deriving from how the knowledge is developed. This new definition considers NOS to be a blend of both NOSK and NOSI. According to Vhurumuku and Mokeleche (2009), NOS is a term used to describe an individual's understanding of the products of science, NOSK, the

processes of science NOSI and the scientific enterprise. The products of science are the ideas, theories principles and laws making the body of knowledge called science. The processes of science refer to how the scientific knowledge is developed and validated.

Even though there is no consensus on a concise definition of NOS, an understanding of NOS has been an important goal of science education at all levels of learning from primary school right up to tertiary (AAAS, 1993, NRC, 1996). An understanding of NOS enhances learners' understanding of science successfully, learning of science content and participation in socio-scientific decision making (Driver, Leach, Miller and Scott, 1996; McCommas, Clough and Almzroa, 1998). Mathews (1998a), Laugksch (2000) and Miller (2006) refer to this as scientific literacy. Lederman (2007) agrees that an understanding of NOS is a significant aspect of scientific literacy. According to Lederman, Antik and Bartos (2014, p. 286) "scientific literacy includes the knowledge of science but also extends to application of this knowledge to make decisions about personal and societal situations that have science and non-science components". It is expected that science education at all levels of education should help in-service teachers, pre-service teachers and learners attain a higher level of understanding of NOS and consequently be more scientifically literate.

Given the aforementioned importance of an understanding of the NOS for scientific literacy for all, this study sought to compare South African Grade 11 high school learners' views of some aspects of the NOS with those of Bachelor of Education undergraduate, Pre-service teachers'. The basis of this comparison is that research has consistently shown that many South African teachers show inadequate understandings of both science content and the NOS (Dudu, 2014, Kriek and Grayson (2009) and Dekker's and Mnisi, 2003). It was therefore interesting to compare the understandings of learners at a former Model C Government school in Gauteng with prospective teachers, pre-service teachers at a public University in the same province. Questionnaires and interviews were used to collect data for the comparison.

1.1 Background and context

Educational transformation is one of the major priorities of the post-apartheid South African governments. In a bid to redress the inequalities and inequities in education adopted during the apartheid era, South Africa, like other developing countries views education as key to transforming society for the better (Enslin and Pendlebury, 1998). One of the major goals of educational transformation in South Africa since 1994, has been to make education efficient, effective, democratic and of high quality (Sedibe, 1998; Jansen, 1998).

To achieve transformation, curriculum reforms were undertaken to improve the quality, efficiency and effectiveness of the educational system from 1994. For example, from 1998 a new curriculum, Curriculum 2005, C2005 was introduced. The curriculum was seen as progressive and based on constructivists' epistemology. It embraced out-come based education as a model for the education system (van der Horst and McDonald, 1997). The C2005 was used from 1998 but had several implementations and running problems in schools. It was revised and renamed the National Curriculum Statement, (NCS). C2005 stressed the importance of an understanding of the NOS as one of the specific aims of teaching and learning science. At General Education and Training (GET), level which covers Grades 7-9. Some of the learning outcomes of natural science, according to C2005 in conjunction with out-come based education (OBE), included understandings of tenets of the NOS. For example, the C2005 aimed to:

- To demonstrate knowledge and understanding of the relationship between science and culture
- To demonstrate an understanding of the changing and contested nature of knowledge in the natural sciences
- To demonstrate knowledge and understanding of ethical issues, bias and inequities related to the natural sciences

(DoE, OBE, 2001, p. 22)

The NCS was further revised with the introduction of Curriculum Assessment Policy Statement, CAPS (DoE, 2011) document for every subject in the curriculum. For science education, there were separate CAPS (DoE, 2011) documents for natural sciences, life sciences, physical sciences and agricultural sciences. The CAPS (DoE, 2011, p. 13) document for GET phase also emphasizes the importance of an understanding of the

nature of science and the relationship between science and other subjects as an outcome of science education. At Further Education and Training, (FET), level, that is Grade 10-12, the revised science curriculum document CAPS (DoE, 2011), encourages promotion of students' understanding of nature of science in learning physical science. One of the specific aims stated in the CAPS (DoE, 2011) document is to promote:

> ...knowledge and skills in scientific inquiry and problem solving; the construction and application of scientific and technological knowledge; an understanding of the nature of science and its relationships to technology, society and the environment.
> (DoE, p. 6).

The specific aim stated above stipulates that at the end of the FET phase, the Grade 12 Physical Science curriculum, learners are expected to have a good understanding of NOS and hence attain a reasonable degree of scientific literacy. This means that if the teaching and learning of Physical Science is guided by the CAPS (DoE, 2011) curriculum, learners at the Grade 11 level are also expected to have a good understanding of aspects of the nature of science, NOS.

The Bachelor of Education undergraduates, Pre-service teachers who participated in this study were high school graduates of the CAPS (DoE, 2011) curriculum. Their learning of science was guided by this very same curriculum. The Pre-service teachers were in their third year at University and were about to get into the fourth year. They had gone through three years of science teacher education programs. Clough, Almzroa and McCommas (2000) argues that most undergraduate science and science education curriculum at many universities do not include NOS instruction and just like school science focus mainly on science content that is scientific facts, theories, concepts and laws. As alluded to, it was interesting to find out if there were any differences in NOS understandings between high school Grade 11 learners and Bachelor of Education, undergraduates, Pre-service teachers.

Accordingly, the purpose of this study was to compare the Grade 11 learners' and Pre-service teachers' understanding of NOS. Understanding of NOS is a major component of scientific literacy (AAAS, 1993) and an important outcome of science education. In a way, the study assessed the impact of the recent science education curriculum reform efforts in South Africa, CAPS (DoE, 2011) and the associated emphasis on NOS compared to the university science education curriculum and its emphasis on NOS. It was interesting to

make the comparison to find out if there were any progressions in understanding of the construct as learners move from high school to university.

The study was undertaken with the hope that its findings could benefit both school science and teacher education in South Africa. There was hope that the findings would inform both curriculum implementation at the secondary school level in South Africa as well as inform curriculum development and implementation in South African tertiary institutions. It is well accepted that a scientific literate citizenry is a form of human capital that influences the general economic well-being of a nation (Laugksch, 2000). At national level, a high scientific literate rate benefits the economy, scientific research, science policy making, democracy and society (Holbrook and Rannikmae, 2009). South Africa is a developing country which desperately needs a high scientific literacy rate amongst its citizens.

1.2 The Research problem

Science education in South Africa is in a state of disarray as evidenced by the low national pass rates in science subjects, physical science in particular, and students' poor performance at mathematics and science assessment platforms at international levels such as Trends in International Maths and Science Study, TIMSS (Dempster and Reddy, 2007, and Kriek and Grayson 2009). The performance of both teachers and learners in the teaching and learning of science has been mediocre despite several interventions such as availing of physical resources, upgrading science teacher qualifications and revision of the science curriculum, for example, CAPS (DoE, 2011). Nothing much has changed in terms of the quality of teaching and learning science (Mji and Makgatho, 2006; Makgato, 2007 and Dudu,2014). Research suggests that science teachers need to include explicit approaches to NOS teaching for effective results. Explicit science teaching approaches include teaching about and with NOS as well assessing learners' understandings (Abd-El-Khalick, 2013).

In South Africa, while curriculum documents emphasize the importance of an understanding of NOS in the teaching and learning of science CAPS (DoE, 2011), most science in-service and pre-service teachers disregard and under value NOS in their teaching. This could be one of the factors that have led to poor performance in the science

subjects. An understanding of NOS by both pre-service and in-service teachers and learners would improve their perceptions of science and create conducive settings for effective teaching and learning. Consequently, the intention of this study was to establish if pre-service teachers and learners have adequate understandings of NOS and to create awareness about this issue.

1.3 Research objectives and questions

This study investigated the difference in NOS understandings between South African high school learners (Grade 11) and third year science education university Pre-service teachers, studying for a Bachelor of Education degree majoring in Physical Science. The study sought to find out the extent of the differences of understandings (if any) between the high school learners and pre-service teachers. The study was guided by the following research questions:

1. What are the Grade 11 learners' understandings of nature of science?
2. What are the Pre-service teachers' understandings of nature of science?
3. To what extent are the High school learners and Bachelor of Education pre-service teachers' understanding of nature of science different?

The conceptual framework overview

The conceptual framework guiding the study is the construct, NOS. Lederman et al. (2014) refer NOS to the characteristics of scientific knowledge, NOSK, that are necessarily derived from how that knowledge is constructed. For a good understanding of NOS individuals must have informed, adequate, or sophisticated views of the NOSI and NOSK aspects (Lederman et al., 2002 Akerson and Donnelly, 2008 Kang and Wallace, 2005). Some authors (Abd-El-Khalick and Lederman, 2000, Akerson and Donnelly, 2008, Abd-El-Khalick, 2012) have used the terms acceptable, proper, developed or contemporary to refer to a good understanding of NOS. On the other hand, a poor understanding of NOS has been referred to as inadequate, naïve, undesirable, inconsistent or undeveloped.

Research has shown that generally most in-service teachers, pre-service teachers and learners hold naïve, uninformed views of the NOSI and NOSK aspects. For example, there is a common misconception on one of the NOSI aspects, scientific method amongst both pre-service and learners. They both believe that there is a recipe like stepwise procedures which all scientists follow when they do science (Lederman et al., 2002). This belief in the scientific method has been consistently shown in both pre-service teachers and learners through research instruments such as questionnaires and interviews. Another NOSK aspect is the differences between laws and theories. It has also been misinterpreted by both pre-service teachers and learners. Most of them harbour the view that laws and theories mean the same thing while others think that one will eventually develop into another (McCommas, 1996). The conceptual framework for the study is detailed in Chapter 2.

1.5 Literature review overview

Previous research on different groups' understanding of NOS have dwelled more on assessing the NOSK aspects at the expense of NOSI aspects. There is a dearth on research on NOSI aspects mainly because of the previous perceptions of NOS (Lederman et al., 2014). The new conception of NOS as explained earlier, blends NOSI and NOSK aspects to make NOS aspects. There is extensive research on pre-service and in-service teachers' understanding of the NOS (Abd-El-Khalick, Bell and Lederman,1998, Bell, Lederman and Abd-El-Khalick,2000, Lederman, 1992, Pomeroy ,1993, Morrison, Raab and Ingram,2009), few studies on high school learners (Lederman and O'Malley,1990, Moss 2001, Meichtry,1993) and very few studies comparing teachers (pre-service or in-service) and learners (Lederman,1992, Dogan and Abd-El-Khalick,2008).

It is noteworthy that many of these studies have been done in the North American context and very few have been done elsewhere in the world. Studies that have examined learners' and pre-service teachers' understanding of NOS have considered mostly NOSK aspects such as the tentativeness of scientific knowledge, role of creativity and imagination in science, differences between laws and theories and observations and inferences, and the social and cultural embeddedness of science (Abd-El-Khalick, Bell, Blair, Crawford and Lederman, 2003).Research instruments such as questionnaires, for example, Views of Nature of Science, VNOS by Lederman and O'Malley (1990) and

interviews have been invariably used to assess the understanding of NOS. Very few studies (Akerson and Donnelly, 2008,) have compared pre-service teachers and high school learners' understanding of NOS aspects. Most studies have reported that both learners and teachers, both pre-service and in-service, harboured views that were inconsistent with the current conceptions of NOS. More on the study's literature review will be looked in detail in **Chapter 2.**

1.6 Research methodology overview

This study was about comparing Grade 11 high school learners' and Bachelor of Education undergraduate students, Pre-service teachers' understandings of some NOS aspects based on their social experiences at school and university respectively. Both quantitative and qualitative research approaches guided by the positivists and interpretivists' paradigms respectively were considered ideal for this study. Ten Grade 11 learners and ten Pre-service teachers volunteered to participate in the study. Ethical clearances were obtained from the university, the school and the department of education for permission to carry out the study at their premises with their students as participants. The Views About What Occurs in Science Questionnaire, VAWOSQ, was administered to the two groups at separate occasions to assess their understanding of 10 Nature of Scientific Inquiry, NOSI and 10 Nature of Scientific Knowledge, NOSK aspects. The VAWOSQ was developed by Aldridge, Taylor and Chen (1997) and it underwent rigorous validity, reliability and integrity tests. After the questionnaire responses, follow up interviews were conducted using selected items from Views of Nature of Science, VNOS (Lederman et al., 2002) and Views about Scientific Inquiry, VASI (Lederman et al., 2014) interview schedules to give the participants a further chance to ascertain and elaborate on their questionnaire responses. The Mann-Whitney U test was statistically used to compare if there were any differences in the understanding of Nature of Science, NOS between the two groups. The questionnaire data were triangulated with the interview data to check for concepts, patterns or themes. Chapter 3 gives more details on the research's design methods and data analyses

1.7 Chapter Summary

In this **Chapter 1**, the context and background to the study including the rationale of conducting the study and research questions have been presented. The objectives of the study and research questions have been stated. The conceptual framework, literature review and research methodology have been briefly discussed

In **Chapter 2** the conceptual framework guiding the study is discussed. A literature review on studies of both pre-service and in-service teachers' and learners' understandings of NOS follows. This literature includes previous studies on NOS done in South Africa.

Chapter 3 first outlines the philosophical assumption, the research paradigm guiding the study. The research methodology follows where the research design, methods and research instruments are discussed. The study context was the description of the study sample and the sites where the study was conducted are presented. This chapter includes data analysis techniques used.

Chapter 4 looks at data presentation, discussion and analyses.

In **Chapter 5,** conclusions are made based on the analysis and interpretation done in Chapter 4. Recommendations, limitations and reflections of the study are discussed in this chapter.

Chapter Two

Conceptual framework and literature review

2. Introduction

The purpose of this study was threefold; to investigate the Grade 11 learners' understanding of the nature of science, NOS, to investigate the Bachelor of education undergraduates, Pre-service teachers' understanding of the nature of science and to compare the differences, if any, in understanding of the NOS between the two groups mentioned above. This chapter firstly looks at the conceptual framework guiding the study which is the construct, nature of science, NOS. The construct, NOS will be defined and discussed together with two of the three aspects that make up the construct, the nature of scientific knowledge, the nature of scientific inquiry and the nature of the scientific enterprise. The aspects of the NOS understanding to be compared will then be identified and briefly discussed. Pre-service teachers' understandings of NOS aspects are discussed and compared with the learners' understanding of the same NOS aspects. The conceptual framework is wrapped up by a discussion of the nature of scientific knowledge and the nature of scientific inquiry. Previous studies of both pre-service and in-service teachers' understandings of the NOS are clearly discussed and elucidated followed by the learners' understanding of NOS.A discussion of studies comparing pre-service and in-service teachers with learners' understandings of the NOS then follows followed by a brief discussion of previous studies on NOS understandings in South Africa. Finally, is the chapter summary which gives a summary of the whole chapter.

2.1 Conceptual framework

A precise definition of the nature of science has been an intriguing issue amongst many in the science education circles for a long time. As mentioned earlier, this is because of the multifaceted nature of NOS which many have defined it in different ways to suit their lines of thought or ideas (Lederman, Abd-El-Khalick and Schwartz, 2002, Abd-El-Khalick and Lederman, 2000a, 2000b). The historians, sociologists, philosophers of science and even scientists have all different perceptions of what is and what is not the nature of science. Lederman (1999) argues that the perceptions of the NOS are dynamic and

tentative just like scientific knowledge considering the differences among the philosophers of science on NOS for the past fifty years.

Lederman (1992) and Lederman, Abd-El-Khalick, Bell and Schwartz (2002) claimed consensus on a NOS definition which refers NOS to the epistemology of science, science as a way of knowing or the principles and beliefs inherent to the development of scientific knowledge. Bell (1998) concurs with this definition and adds that NOS is the key principles and ideas which describe science as a way of knowing as well as the characteristics of scientific knowledge. This definition restricts NOS to only the characteristics of scientific knowledge but does not consider the processes in which the scientific knowledge is generated, scientific inquiry. The exclusion of scientific inquiry in most NOS definitions have resulted in most people conflating NOS with scientific Inquiry without realising that the two aspects of science are different but they overlap and interact with each other.

Lederman et al. (2014) have headed the critique of Lederman's (1992) definition of NOS and have suggested the inclusion of scientific inquiry in the definition of NOS. This has resulted in a new conception of NOS which is made up of the nature of scientific knowledge, NOSK, and the nature of scientific inquiry, NOSI. Lederman et al. (2014) states that NOS refers to the characteristics of *scientific knowledge* that are necessarily derived from how the knowledge is developed, *scientific inquiry*. This recent definition fuses both NOSI and NOSK to make NOS.

In the current study, an understanding of some aspects of the NOSK and some aspects of NOSI will be compared between Grade 11 learners at a public school in Gauteng and Pre-service teachers, Bachelor of Education undergraduates at a university in the same province. The understandings of the NOSK aspects, particularly the tentativeness of scientific knowledge, the social and cultural embeddedness of scientific knowledge, and the differences between theories and laws and the NOSI aspects, the myth of the scientific method and the differences between data and evidence were compared between the two cohorts mentioned above.

Researches on teachers' and learners' understanding of the NOS have been much prioritised in the last few decades with the major aim of improving the teaching and learning of science. Many of these studies have been an assessment of an understanding of the NOS aspects namely the nature of scientific knowledge and the nature of scientific inquiry of both primary and secondary learners (Moss, Abrams and Robb,2001, Bell, Blair, Crawford and Lederman,2003,Gaigher,Lederman and Lederman,2014) pre-service teachers or university undergraduates (Akerson, Morrison and McDuffie, 2006, Irez, 2006,Akerson and Donnelly,2008) and a comparative of the teachers' and learners' understanding (Lederman ,1992, Dogan and Abd-El-Khalick,2008). The evaluation of the learners' and teachers' understanding of the nature of science have been done using instruments such as multiple choice questionnaire items, open ended questionnaire, structured and unstructured interviews developed by science education researchers on NOS.

For example, the Views of Nature of Science, VNOS, questionnaire developed, revised and improved by Lederman, Abd-El-Khalick, Bell and Schwartz (2002) which assess the understanding of the nature of scientific knowledge and Views about Scientific Inquiry, VASI, questionnaire (Lederman, Lederman, Bartos, Bartels, Meyer and Schwartz,2014) which assess the aspects of scientific inquiry. Aldridge, Taylor and Chen (1997) developed Beliefs about Science and School Science Questionnaire, BASSSQ, which is used to identify individuals' views about what occurs in science, Views About What Occurs in Science Questionnaire, (VAWOSQ) and what should occur in school science, Views About What Should Occur in School Science Questionnaire, VAWSOSSQ.

Responses to the questionnaire items have been assigned different scale terms or Likert scale measures to assign a bad, good or better understanding of the nature of science aspect. For example, Lederman et al. (2002) assigned *naïve* view and *informed* view for a *bad* and *good* view respectively of a NOS aspect in the VNOS questionnaire while Akerson and Donnelly (2008) coded *inadequate* view for a misconception, *adequate* for a developing view and *informed* for a fully developed understanding of the NOS aspect of the same questionnaire. Other codes that have been used by other researchers for good understanding of the NOS aspect are *acceptable, sophisticated, proper* or *contemporary* with a bad understanding of the NOS aspect being coded *improper, unacceptable* or *misinformed*. In the BASSSQ, Aldridge et al. (1997) used a Likert type response scale to

identify teachers' beliefs about science and school science. After the administration of questionnaires in most researches on NOS, follow up interviews are done for the participants to validate their questionnaire responses and to clearly explain their views using their own words. Research has generally shown that both teachers and learners hold naïve views of the NOS aspect regardless of whatever instrument is used to assess the understanding.

There have been more studies on pre-service, in-service teachers' and learners' understanding of the nature of scientific knowledge aspects compared to the nature of science inquiry aspects. Lederman et al. (2014) argues that this may have been due to a lack of a readily available instrument to assess the understanding of the aspects, the issue of conflation of scientific inquiry and the nature of science or the misconception of doing of inquiry to develop an understanding of scientific inquiry.

The most investigated aspects of the nature of scientific knowledge, NOSK, have been the tentative, theory laden, empirical, the imaginative and creativity nature while the nature of scientific inquiry, NOSI, aspects have been mainly restricted to the myth of the experimentation and the myth of the scientific method. It is clear from literature that learners and teachers hold naïve conceptions about the aspects of the NOS (Lederman,1992, Schwartz, Lederman and Crawford,2004, Bell, Lederman and Abd-El-Khalick,2000,Khishfe,2014) because they hold constructivists, absolutists or empiricists views about the aspects (Kang,2005).For instance Khishfe and Lederman (2007) and Abel and Smith (1994) reported that learners do not recognise that scientific laws and scientific theories are two distinct types of knowledge. The misconception among learners is that they consider laws to be more superior to theories and that theories graduate to become laws. Maybe this is caused by the ways in which school science curricula presents laws and theories in syllabi and textbooks. Laws are more emphasised and sometimes accorded chapters in textbooks, for example Newton's laws of motion or Mendel's Genetic laws compared to theories.

Similarly, Akerson and Donnelly (2008) demonstrated using the, views of the nature of science, VNOS, questionnaire and follow up interviews that pre-service teachers believed that laws were facts and theories were not and that laws were a better form of scientific evidence. Other researchers like Sarkar (2010) found out those in-service teachers in

Bangladesh held traditional views that scientific theories are less stable than scientific laws because laws are proven and theories are not.

Akerson, Morrison and McDuffie (2006) used surveys, VNOS and interviews and found many pre-service teachers believed that scientific laws were a lesser type of knowledge compared to theories and laws can be proven and theories strive to become laws. Research has shown that both pre-service teachers and learners have difficulty in comprehending the differences between theories and laws. However, the teachers' conceptions of theories and laws vary from naïve, developing to informed while most of the learners have naïve or uninformed.

Regarding the tentativeness of scientific knowledge, Irez (2006) using face to face interviews and internet interviews and analysing the data by cognitive maps, found out that Turkish pre-service teachers held absolutists views of science which were a result of their failure to distinguish between laws and theories. Their belief was that laws are facts and once established are true or certain and cannot be changed. In contrast, Akerson and Donnelly (2008) found out that out of the 21 pre-service teachers assessed using VNOS on their understanding of the tentativeness of scientific knowledge 17 held adequate views on this aspect. The teachers believed that science will change if there is new information to add on. Moss, Abrams and Robb's (2001) examination of 20 pre-college students' understanding of the tentativeness of scientific knowledge found out that most learners believed that scientific knowledge does not expire but evolves over time. The learners affirmed through interviews that theories play major roles in scientific knowledge progression and that data is used to test theories which could result in new understandings. According to Khishfe (2008), most of her grade 7 learners research participants did not believe that scientific knowledge would ever change and just like Moss et al.'s (2001) participants who viewed change in scientific knowledge as the addition of new knowledge.

Pre-service teachers and high school learners have differing naïve views about the tentativeness of scientific knowledge with most of them having an absolutist view believing that scientific knowledge is absolute, certain and truthful. However, a more informed view would suggest that scientific knowledge is dynamic and subject to change in the event of new evidence and explanations. Abd-El-Khalick, Bell and Lederman (1998)

employed the VNOS and follow up interviews to assess 14 pre-service teachers', enrolled for a Master's programme in teaching, understanding of the empirical nature of scientific knowledge. As expected, using their prior experiences in science, all the participants articulated that science is empirically based and this makes it different from other inquiry disciplines such as religion and philosophy. The pre-service teachers all agreed that scientific knowledge is generated through empirical observations and experimentation. Similarly, in Akerson and Donnelly's (2008) investigation, the pre-service teachers acknowledged that science is empirically based but unfortunately believed that scientists used one single method in their data collection. The pre-service teachers in this investigation would be considered to have developing views on the empirical nature of scientific knowledge in that they have adequate views on the empirical nature of scientific knowledge but inadequate views on how scientists work.

Bell, Lederman and Abd-El-Khalick (2000) did a follow-up study on Abd-El-Khalick, Bell and Lederman's (1998) investigation and found out that the intervention programme emphasised on the latter's results, bore fruit, with all the participants acknowledging that science is empirically based and that scientists use a variety of methods in their data collection. In most researches on the understanding of NOS, pre-service teachers have generally shown adequate or informed views on the empirical nature of scientific knowledge acknowledging that this makes science different from other ways of knowing. The pre-service teachers appreciated that question about natural phenomenon and how things are answered by science through empirical observations and experimentation.

Researches on learners' conceptions of the empirical nature of scientific knowledge (Khishfe, 2008, Khishfe, 2002, Kang, Scharmann and Noh 2004, Moss, 2010, Sadler, Chambers and Zeidler, 2007, Dogan and Khalick, 2008) have shown that learners hold mixed conceptions about this aspect. Moss (2001) used articles on *Global Warming* to assess 14 to 17 years olds' understanding of data and evidence consequently assessing their understanding of the empirical nature of scientific knowledge on a large-scale project in high schools in the United States of America. The argument by Moss (2001) is that for learners to fully appreciate the empirical nature of science, they must understand what data is and how it is used.

The research findings showed that 80 % of the participants could at least identify data in the articles hence showing some basic understanding of the empirical nature of scientific knowledge.

Khishfe and Abd-El-Khalick (2002) and Khishfe (2008) used similar questionnaires and interview schedules to assess grade 6 and grade 7 learners' understanding of the empirical nature of scientific knowledge respectively.84 % of the grade 6 learners and 50 % of the grade 7 learners expressed naïve conceptions of the empirical nature of scientific knowledge. Most of the learners in both grades equated knowing with seeing and failed to understand that scientific knowledge could be produced through indirect evidence. Though not proven through research, but using my many years' experience teaching science, I believe this misconception of seeing is believing amongst many learners arise from school science curricula and textbooks which over-emphasize and exaggerate the role of experimentation in science. Research has shown that generally, both pre-service teachers and learners hold naïve conceptions about the empirical nature of scientific knowledge regardless of the contexts in which the aspect is assessed. However, research has also shown that pre-service teachers have a better understanding of the empirical nature of science compare to learners (Abd-El-Khalick, 2001, Dogan and Khalick, 2008, Akerson, Abd-El-Khalick and Lederman, 2000).

There is dearth of research on learners' or teachers' understandings of the nature of scientific inquiry. Most studies on learners' and teachers' understanding of NOS have particularly assessed the nature of scientific knowledge, NOSK aspects excluding the nature of scientific inquiry, NOSI aspects because many people often conflated NOS and scientific inquiry and failed to distinguish between the two (Lederman,1998,Abd-El-Khalick,2013).The most notable nature of scientific inquiry aspect that has been included in most researches as an aspect of the nature of scientific knowledge is the myth of the scientific method (see for example, Akerson and Donnelly,2008, Chen,2006, Irez,2006,Bayir,Cakici and Ertas,2014).Incidentally, in some instruments such as Views on Science and Education questionnaire, VOSE, (Chen,2006) and VNOS-B questionnaire (Lederman, Abd-El-Khalick, Bell and Schwartz,2002) the myth of the scientific method is represented as a NOS aspect but more aligned to the nature of scientific knowledge.

Gaigher, Lederman and Lederman (2014) used the Views about Scientific Inquiry, VASI (Lederman et al., 2014), questionnaire to assess South African Grade 10 learners' understanding of the 8 aspects of the nature of scientific inquiry. According to the researchers, the findings revealed that most of the Grade 10 students displayed an excellent understanding of the aspects of the nature of scientific inquiry assessed. However, Gaigher et al. (2014) showed that many learners were unable to distinguish between investigation and experiments eventually leading to the conclusion that there is a single scientific method followed by all in science. Similarly, according to Bell, Blair, Crawford and Lederman (2003), an 8-week science apprenticeship program improved learners' abilities in the various processes of scientific inquiry but did not do much in improving their understanding about the nature of scientific inquiry.7 out of the 10 learner apprentices did not show much difference in their pre-and post-apprenticeship responses to the questionnaire items on the scientific method. They still believed in the existence of a single scientific method which is followed by scientists when they carry out their work.

The literature on teachers' and learners' conception of NOSI shows the misconception of the existence of the scientific method which surprisingly is also common among natural and social scientists. For example, Bayir, Cakici and Ertas (2014) using interviews guided by VNOS (Schwartz and Lederman, 2002) reported a common belief of the existence of a universal scientific method among natural scientists and social scientists with high academic positions such as professors, associate professors and assistant professors in Turkey. Astonishingly, 74 % of the scientists acknowledged the existence of the scientific method and that it should be used when doing science. Dudu (2014) found out that South African grade 11 science teachers' understanding of the myth of the scientific method were naïve in that they believed scientists can use all other methods in their investigations but need the scientific method to verify and confirm results. These research findings show that this aspect of the nature of scientific inquiry, the myth of the scientific method, is grossly misunderstood by many across the academic spectrum from primary school student's right up to professors.

The perception of NOS has changed lately with many researchers advocating for the inclusion of the nature of scientific inquiry in the definition of NOS (Lederman 2004, McCommas and Olson, 1998). This has resulted in the revision of the Lederman (1992) definition of NOS to the Lederman (2006) which now refers NOS to the characteristics of scientific knowledge that are necessarily derived from how the knowledge is developed, scientific inquiry. Hence the NOS construct comprises of two aspects, the nature of scientific knowledge, NOSK and the nature of scientific inquiry, NOSI. Research has generally shown that pre-service teachers and learners hold mixed but mostly naïve views about the aspects of the nature of science.

2.2 The Nature of scientific knowledge

Lederman, Antik and Bartos (2014) argue that there the shortening of the phrase *nature of scientific knowledge (NOSK)* to *nature of science (NOS)* in the 1980s has caused some confusion amongst many researchers in science education even up to now. What is referred in most literature as the nature of science aspects are actually the nature of scientific knowledge aspects. Conceptions of the nature of science have changed lately and the two are now viewed from different perspectives. The seven aspects of NOSK are discussed below.

2.2.1 Tentativeness

Even though scientific knowledge is reliable and durable, it is never absolute or certain (Lederman, 1992, Abd-El-Khalick and Schwartz, 2002). All scientific knowledge which includes facts, theories and laws is tentative that is, subject to change in the event of new evidence or new ways of thinking. Technological advances and new interpretations of theories can result in changes in scientific claims as new evidence, explanations or theories replace old ones (Lederman,1992,2004).

2.2.2 Theory-Laden and Subjective

By it being a human activity, there is subjectivity in science. Lederman (2002) states that scientific knowledge is theory-laden yet partly subjective and Bell (1998) affirms this by arguing that intuition, personal beliefs and societal values all play significant roles in the development of scientific knowledge. Scientists are people and it is difficult to completely

avoid bias on human factors such as beliefs, gender, prior knowledge, training experiences and social contexts when they work. Scientists' personal values and beliefs can influence the way the carry out their investigation and their interpretation of results. According to Popper (1992) in Lederman et al. (2002), observations are never neutral in science, but are guided by theoretical perspectives from previous questions or problems.

2.2.3 Empirical Nature

Scientific knowledge relies a lot on empirical evidence derived from observations of natural phenomena (Lederman, 1998, Abd-El-Khalick, Waters and Lee, 2008). Experimental evidence is required for scientific claims to be established. Lederman (2004) asserts that observations are descriptive statements about natural phenomena that are accessible to the senses or extensions of the senses. Besides heavy reliance on empiricism, science is also inferential. Scientists observe and then reach conclusions based on the evidences from the observations and logical reasoning.

2.2.4 Theories and Laws

Research has shown that this aspect of the nature of scientific knowledge poses a lot of problems to both teachers and students in the science classroom. Both find it difficult to differentiate the between the two. According to Schwartz et al. (2002) laws describe relationships observed or perceived of phenomena in nature while theories are well supported explanations of natural phenomena. The usual misconception amongst many people is that there is relationship between theories and laws whereby the former becomes the latter if there is supporting evidence (Lederman. Antik and Bartos, 2014). Scientific laws are in most cases misrepresented as being of higher status than theories. Laws and theories are two different kinds of knowledge which are not interchangeable. In some, if not most cases, theories are used to explain laws, for example the kinetic molecular theory explains gas laws for example Boyle's law.

2.2.5 Observations and inferences

Science is empirical and requires evidence for claims to be justified. Scientists observe and infer in the generation of scientific knowledge. Lederman (2004) states that observations are descriptions of natural phenomena directly accessible to the senses or

extensions of the senses while inferences are conclusions based on evidences from observations and logical reasoning. Inferences are conclusions, deductions or interpretations which try to explain the causes of one's observation

2.2.6 The Social and Cultural Embeddedness of scientific knowledge

Science is a human activity influenced by the society and culture in which it is practised. It is affected and affects the social and cultural aspects in which it is embedded (Lederman, Abd-El-Khalick, Bell and Schwartz, 2002). Social elements such as social fabric, power structures, politics, language, socio-economic factors, philosophy and religion play major roles in the way in which scientific knowledge is generated. It is the values of a culture that determines what science and how the science is conducted, interpreted, accepted and utilised (Schwartz et al., 2004, Hodson and Wong, 2014). There have been some cultures which have been more dominant in their contribution to science than others. For example, there is a misconception amongst students, teachers and even the public that all scientists are white old men with long grey hair and beard and are always dressed in white laboratory coats. This misconception results from the Western culture domination of science by white males in the mid-nineteenth century.

2.2.7 Creative and Imaginative

Scientific knowledge is partly a product of human imagination and creativity (Khishfe, 2002). Most people believe science is objective, rational and orderly not realising that scientists use various methods including imagination and creativity in inventing theories, explanations and laws which are part of scientific knowledge. For example, imaginativity and creativity played major roles in coming up with the structure of atoms.

2.3 The Nature of scientific inquiry

The eight aspects of the *nature of scientific inquiry, NOSI*, which Feuer, Towne and Shavelson (2002) refers to as a set of epistemological or the guiding principles of scientific inquiry are discussed below.

2.3.1 Scientific investigations all begin with a question but do not necessarily test a hypothesis

According to NRC (2000), a scientific investigation involves asking and answering a question and comparing the answer with what the scientists already know. Science is sparked by questions from observations of organisms, objects and events in the natural world, general curiosity about nature or a response to works done by other scientists. All investigations do not necessarily have to formally state a hypothesis as is usually prescribed in school science.

2.3.2 There is no single set or sequence of steps followed in investigations (The myth of the scientific method)

There is a common perception especially in school science, that there is a recipe like stepwise procedure that all scientists follow when they do science (Lederman et al., 2002) because of the over-emphasis and over reliance on experimental design. Hence the myth of the scientific method which most people believe is used by all scientists in the generation of scientific method (Abd-El-Khalick and Lederman, 2000b, Bell and Lederman, 2003, McCommas et al., 1998). Scientists' choice of method to use in an investigation is usually guided by the question they are trying to answer.

2.3.3 Inquiry Procedures Are Guided by the Question Asked

Scientists design different methods or procedures that can answer the proposed question (NRC, 2000). The question at hand guides the how of doing the investigation. The procedures of experimental design usually referred to as the scientific method are not always fit to answer certain questions in science maybe because of their limitations.

For example, in an investigation, there may be need for control of variables which is impossible in astronomy or unethical when studying people. In science, questions drive and determine the methods used to answer those particular questions.

2.3.4 All Scientists Performing the Same Procedures May Not Get the Same Results

Scientific data do not stand alone but can be interpreted in various ways but with respect to each individual scientist. Osborne, Collins, Ratcliffe, Miller and Duschl (2003) in

Lederman et al. (2014) reiterate that scientists working on the same data may legitimately come to different conclusions or interpretations. Scientists can work on a similar question using similar approaches or methods but reach different conclusions. This is because of the scientists' prior knowledge and experiences in science, theoretical frameworks and content which differ from scientist to scientist hence the subjective nature of science

2.3.5 Inquiry Procedures Can Influence Results

The research procedures or approaches for a scientific investigation have so much influence on the outcome or results. The way the scientists set their variables, collect and analyse data impact heavily on their conclusions. Two scientists using different approaches on a similar question can come up with different results and conclusions.

2.3.6 Scientific Data Are Not the Same as Scientific Evidence

Scientific data have different purposes in a scientific investigation. However, many people including science teachers and students face difficulty in distinguishing between the two. The difference between data and evidence according to Lederman et al. (2014) is that data are observations gathered by scientists during the course of the investigation in the form of numbers, descriptions, photographs, samples while evidence by contrast is a product of data analysis procedures and subsequent interpretation directly linked to a particular question and a related claim.

2.3.7 Explanations Are Developed from a Combination of Collected Data and What Is Already Known

Scientists work within a science community of practice with its values, beliefs and norms (Lave and Wenger, 2000). As such, scientists strive to work consistently within accepted scientific principles of the science community. Consequently, investigations are guided by current knowledge and conclusions, informed by previous investigations and accepted scientific knowledge (Lederman et al., 2014).

2.4 Literature Review

2.4.1 Studies of teachers' understanding of nature of science

Previous research on teacher's understanding of the NOS have assessed mostly the NOSK aspects and excluded the NOSI aspect mainly because of the conception of NOS at the time. As previously mentioned, the shortening of NOSK to NOS in the 1980s has resulted in some confusion with most researchers assessing the NOSK instead of the purported NOS in their researches. The new conception of NOS comprises of two major aspects, NOSI and NOSK (Lederman, Antik and Bartos, 2014, Lederman et al., 2014). The NOSK aspects have been over researched with very little done on NOSI.

Research on pre-service teachers' understanding of NOS has shown that interventions such as science courses or other types of instruction slightly improve their conceptions of NOS but only for a short period (Akerson, Morrison and McDuffie, 2006, Bell, Lederman and Abd-El-Khalick, 2000, Abd-El-Khalick, 2006). For example, Akerson et al. (2006) investigated the influence of a science methods course with explicit reflective instruction in NOS on 19 pre-service teachers' understanding of NOS at a Western University in the USA. The participants who were enrolled for a master's degree in teaching in elementary education participated in an intensive semester of instructional activities designed to explicitly cover the seven aspects of NOS emphasised in literature (Lederman and Abd-El-Khalick,1998).Just like many other researchers on NOS in the 1990s and 2000s, Akerson et al. (2006) did not take into cognisance of the modern day conception of NOS, but considered the seven aspects to be of NOS instead of NOSK (Lederman, Antik and Bartos,2014).

As previously mentioned, this confusion about NOS and NOSK continues even up to today with many people not realising that the latter is an aspect of the former. NOS comprises of two aspects, NOSI and NOSK.

Data was collected using VNOS-B questionnaire (Lederman, Abd-El-Khalick, Bell and Schwartz, 2002) in conjunction with follow up semi-structured interviews. The data was collected pre-and post the science methods course as well as 5 months later which will be referred to as post. The researcher believes that the data collected 5 months; post the course was a true reflection of whether those science methods influenced the pre-service

teachers' understanding of NOS aspects. Through, experience the researcher has observed that data collected immediately after instruction is to some extent biased. This is because sometimes the ideas will still be fresh in the participants' minds or that some participants give their maximum concentration in the courses to be able to do "well" in the questionnaires and interviews. The data collected post instruction the science methods course shows a good and retained understanding of the nature of science aspects.

Akerson et al.'s (2006) analysed pre-instruction, post instruction and post post instruction interview transcripts and corresponding VNOS-B questionnaire responses and generated profiles for each individual participant's views of the NOS. The profiles showed that there were substantial improvements of the pre-service teachers understanding of the target NOS aspects. The researcher suggests that the substantial improvements in the understanding of NOS in the post science methods course could have been due to the explicit nature of instruction, the duration of the course which was a semester long or the academic level of the participants or any other factors. However, Akerson et al.'s (2006) found out that the post post science course interview and questionnaire data revealed that most pre-services teachers did not retain their new learnt concepts of NOS but retained to their original naïve understandings. For instance, in one of the extracts from the interview transcripts, one pre-service teacher asserted that laws were "facts" and theories were "conjectures". This showed that some of the participants had not retained their understanding of the NOSK aspects 5 months after the science course even though they had shown a good understanding just after the science course.

As mentioned earlier, the researcher believes that this evaluation after such a long time after instruction gives a true reflection of the effect of the NOS science course on the pre-service teachers' understanding of the NOS aspects.

Dudu (2014) explored five Grade 11 South African teachers' understanding of three NOSI tenets. The teachers were from five metropolitan high schools in Gauteng province in South Africa. The three NOSI aspects investigated were: (1) scientists use a variety of methods to conduct scientific investigations (2) scientific knowledge is socially and culturally embedded; and (3) scientific knowledge is partly the product of human creativity and imagination. Arguably, of the three NOSI aspects mentioned by Dudu

(2014), the researcher considers that out of the three, only one is an aspect of NOSI while the other two are aspects of NOSK according to recent literature on NOS (Lederman et al., 2014). The aspect "scientists use a variety of methods to conduct scientific investigations" is the only aspect of NOSI in the study while the other two are aspects of NOSK. The researcher believes that Dudu's (2014) research should have been titled "*Exploring South African high school teachers' conceptions of nature of science: a case study"*. This is because the research explored the two aspects of the NOS namely NOSK and NOSI.

The five participants were all experienced physical science teachers at higher secondary school level with a minimum qualification of a Bachelor's degree in Education or Science. Dudu (2014) used a Probe's questionnaire and semi-structured interviews as instruments to collect data. The Probe's questionnaire items were adopted from the following instruments, (Views of Science and Technology), VOST questionnaire (Aikenhead and Ryan, 1992), VNOS-A, (Lederman and O'Malley, 1990) and VNOS-B, (Lederman and Abd-El-Khalick, Bell and Schwartz, 2002). Each probe was related to each NOSI aspect to be investigated and it provided contexts for respondents to ponder on their NOSI conceptions. Semi-structured interviews were done as follow-ups to validate the responses made on the Probe instrument. An analysis of the Probe's questionnaire (Dudu, 2014, page 10) showed that this instrument was skewed and unreliable. This is because the multiple choices responses restricted participants to only but three responses of which the two were either a Yes or No and the other one an invalid explanation one. For example, Probe 1 responses were as below;

Choice A. Scientists use one method to conduct investigations

B. No, scientists use a variety of methods to conduct investigations

C. I have another view which I will explain

The researcher believes that for such a questionnaire most participants will restrict their options to either A or B which are more of Yes or No options and would not want to involve themselves in explanations, option C. Much more could have been done to improve the structure and quality of the questionnaire, for example increase the number of options and rephrasing them.

Dudu's (2014) analysis of data was more qualitative as he linked the participants' responses of the questionnaire items to their interview verbatim. The research findings

showed that the teachers held informed views of all the three aspects of NOSI investigated. For example, Dudu (2014) reports that four out of the five participants held informed views of the NOSI aspect; "*scientists use a variety of methods to conduct scientific investigations"*. The teacher who held naïve views qualified their misconception through interviews by stating that scientists employ a variety of methods but for confirmation of results they must use a common logical step by step method. Akerson and Donnelly (2008) would argue that this teacher neither holds naïve nor informed views of this NOSI aspect, but developing views.

An analysis of Dudu's (2014) paper shows that much more could have been done to improve the credibility and validity of his claims. Firstly, his sample of five participants was too small for him to suggest exploring "*South African teachers'* "conceptions of NOSI. Secondly his research, instrument, the probes questionnaire needed to be further revised and developed to make it more reliable and valid. Lastly, the author needed to make more consultations on literature on NOS, NOSI and NOSK.

2.4.2 Studies of learners' understanding of nature of science

Much research on learners' understanding of NOS has focused less on primary school learners (Khishfe, 2008, Walls, 2012, Khishfe and Abd-El-Khalick, 2002,) and more on secondary school students, (Kang, Scharmann and Noh, 2004, Moss, Abrams and Robb, 2001, Khishfe, 2012, Sadler, Chambers and Zeidler, 2004) for various reasons. One of the reasons according to Walls (2012) is that the primary school learners are too young to be capable of conceptualising the NOS aspects. Schwartz and Lederman (2002) reiterate that the aspects of NOS are more relevant to the more traditional science content recommended for K-12 science education and should be taught together with the science subject matter.

Bell, Blair, Crawford and Lederman (2003) investigated the impact of an 8-week science apprenticeship programme of an 8-week science apprenticeship programme on a group of high ability secondary school learners' understanding of the NOS at a North-West University in the USA. In this study, ten volunteers, six females and four males were purposely selected based on their prior participation in previous science apprenticeships programmes. In this programme, the participants were involved in authentic science experiences working with mentors such as scientists and laboratory workers. The

participants were expected to be actively involved in a research project and presenting their research results at a conference at the end of the programme.

Bell et al. (2003) report that most of the components of science inquiry skills outlined in NSES (NRC,1996) were emphasised in the apprenticeship for example, dealing with collecting data, constructing and testing explanations and communicating results. The participants' research covered a breadth of life sciences and physical sciences topics. The authors report that one of the major aims of the programme was to provide the participants with authentic science research experiences which would help them make choices about their future science careers. The researcher believes that this was a worthwhile programme as it provided opportunities for the learners to see and experience authentic science at work enabling them to make choices for the future. Many learners in South Africa and other developing countries are not given such opportunities and end up making wrong choices and eventually dropping out of the science career studies.

The data collection instruments included VNOS-B questionnaire (Lederman, Abd-EL-Khalick, Bell, Schwartz and Akerson, 2001), semi-structured interviews, observations, and laboratory and field notes from mentors. The data was collected before and after the apprenticeship programme to generate in-depth profiles of the participant's pre-and post the science apprenticeship experiences. The many different data sources enabled triangulation of data hence validating each participant's understanding of NOS. The profiles of the participants were compared pre-and post the apprenticeship programme to determine if there was any change in the understanding of the NOS.

The research results were presented in three sections; the first section was on understanding of NOSK, the second section was on the understanding of NOSI, and the third was on the participants' mentors' views of their role in the development of the apprenticeship programme. The analysis of VNOS-B questionnaire responses and follow up interviews before the apprenticeship programme showed that the students' understanding of the NOS and NOSI aspects were inconsistent with those identified in the current reform documents and the post programme data showed there were a few changes in the students' understanding of NOS.

The participants' initial conceptions of NOS were like those reported in previous investigations (Lederman, 1992, Akerson, Morrison and McDuffie, 2006, Bell, Lederman and Abd-El-Khalick, 2000) in that they were naïve, incomplete or inconsistent with the contemporary views. For example, Bell et al. (2003) report that even though most learners appreciated the empirical nature of scientific claims, there was so much confusion on data, evidence, laws and theories. From an excerpt of the interview transcripts, one student reiterated that *"laws don't change because they are facts"* while another on said that *"a scientific law is definite and nothing is named a law unless scientists agree that there is no question to it being true"* The post apprenticeship data showed very little changes in the participants' understanding of the NOSK.

Bell et al. (2003) remark that even though the participants developed increased levels of expertise in various processes of scientific inquiry (doing science), most of them did not show an improved understanding of the NOSI aspects. The learners improved their ability of doing science because their involvement in authentic science experiences, but still held their naïve or incomplete views about NOSI. For example, most learners held to the misconception of the scientific method even after the science experiences as one participant asserted in the interviews that "*if a scientist was trying to determine something, then they would always use the scientific method because that's the way you find a conclusion"*

In this study the assumption was that learners would come to understand NOSK and NOSI by doing science or by engaging them in authentic scientific experiences. The results revealed that the learners improved their science inquiry skills but not their understanding of science inquiry. These findings show that there is need for explicit instruction for learners to have a better understanding of NOSI and NOSK compared to the implicit instruction used in this study. Many science teachers and researchers hold the misconception that learners will understand science by doing science (Abd-El-Khalick, 2000a, Khishfe and Abd-El-Khalick, 2002, Abd-El-Khalick, 2014) contrary to these research findings which have shown that doing science and understanding about science are two different things altogether. Scientists, learners and teachers can be experts in science inquiry skills but showing very little understanding of the nature of scientific inquiry. Bell et al. (2003) argue that there is need for science teachers to provide for both implicit and explicit instruction for the educational outcome of the

understanding of NOS to be achieved. Abd-El-Khalick (2014) asserts that there is need to teach with and about NOS (Abd-El-Khalick, 2014) for students to develop informed conceptions of NOS.

Gaigher, Lederman and Lederman (2014) investigated 105 South African Grade 10 learners' knowledge about NOSI. The Grade 10 learners were purposively selected from seven different schools in one of the largest cities in South Africa. The schools were of different status ranging from private suburban to poor township. Unfortunately, Gaigher et al. (2014) did not elucidate much more on their sample of participants in terms of age, gender and their distribution from the seven different schools. The instrument used to collect the data was the Views about Scientific Inquiry (VASI) questionnaire revised and expanded by Lederman et al. (2014). The questionnaire was administered at the beginning of the academic year and the return rate was 15-42 across all the seven schools which was a good. Each of the VASI questionnaire item assessed a NOSI aspect even though the participants' responses revealed information about more than one aspect. The questionnaire responses were coded and a scoring rubric was developed during the coding process. The questionnaire responses were analysed by five experienced US researchers and one South African researcher. The researcher believes that there was need for another instrument such as an interview for validating responses from the questionnaire items. This could have made the results of this study more valid and reliable

The research findings showed that South African learners showed an excellent understanding of the assessed NOSI aspects. Gaigher et al. (2014) equated this degree of understanding of the NOSI aspects by the South African students to that obtained by other students after explicit instruction internationally. The researcher strongly believes that there was some anomaly in these research results. It is quite amazing that without any explicit pre-instruction on the NOSI aspects the South African learners exhibited a much better understanding compared to other learners internationally who would have undergone a pre-instruction course on NOSI. The implications of these findings are that the standards of teaching and learning science in South Africa have suddenly gone up contrary to research (Dudu and Vhurumuku, 2012, Mji and Makgatho2006).

Gaigher et al. (2014) also found out that the socio-economic status, SES, also influenced the learners' understanding of the NOSI aspects. Their research findings showed that learners from higher socio-economic backgrounds showed a better understanding of the NOSI aspects compared to students from impoverished backgrounds. Dogan and Abd-El-Khalick (2008) also came to similar conclusions on their research on Turkish learners' understanding of NOSI aspects.

The analysis of every question related to a particular NOSI aspect showed that most South African learners held well informed views on the NOSI aspects assessed according to Gaigher et al. (2014). As a practising science teacher, the researcher found these results to be too good to be true. There has not been much literature on NOSI aspects but more on the NOSK aspects and the researcher wonders where these South African learners learnt and very much familiarised with the NOSI aspects. Lederman, (2014) reiterates that there is a dearth of research on NOSI aspects. Contrary to many other research findings on learners' understanding of the NOSI aspect," there *is no single scientific method"* (Khishfe, 2008, Bell et al., 2003, Khishfe and Abd-El-Khalick, 2002), 57 % of the South African learner participants showed well informed views on this aspect. The difference between data and evidence which most learners and teachers struggle to differentiate was again well done by South African learners with only 13.3 % of the participants holding naïve views about this aspect. These were very unusual results compared to other research findings.

Gaigher et al. (2014) argue that their study was mainly to establish a baseline of the learners' knowledge about scientific inquiry and the data they collected did not show how the understanding developed. Surprisingly, literature (Dudu and Vhurumuku, 2012, Mji and Makgatho, 2006, Ramnarain, 2010) has shown that there are very little inquiry activities that are done in South African schools. So, where did this well-developed understanding of the NOSI aspects come from? The authors argue that this understanding may have been developed through explicit instruction without necessarily engaging the students in inquiry experiences. The question is how many teachers in South Africa engage in explicit reflective instruction with the demands of the syllabi, the department and the examinations.

2.4.3 Studies comparing learners' and teachers' understanding of nature of science

Research comparing two different cohorts has been very limited. For example, Bayir, Cakici, and Ertas (2014) compared natural and social scientists understanding of the NOS and Arinho de la Rubia, Lin and Tsai (2014) did a cross-cultural comparison of undergraduate student views of NOS. Researches comparing high school learners and in-service and/or pre-service teachers have also been limited.

Dogan and Abd-El-Khalick (2008) compared Turkish Grade 10 learners' and science teachers' conceptions of the NOS aspects on a large scale national study. The sample was large and representative and comprised of 2087 learners and 378 science teachers. The teacher participants were 55 % female and all aged between 23 and 56. They had varying teaching experience ranging from 1to 21 years.80 % of the teachers held Bachelor's degrees,14 % Master's and 1 % PhD. The students were selected from 63 schools with different socio-economic-status, SES, from 21 cities across Turkey. Random samples of students from the participating schools were selected using the Cochran formula, Cochran (1977) in Dogan and Abd-El Khalick (2008). All the students' participants were in Grade 10 and studied either biology, physics or chemistry or both or all the three.

The major aim of the study was to assess the learners' and the teachers' understanding of the interactions between science –technology and society, the characteristics of scientists and the epistemology of science. The researcher believes that there were too many things to assess in one paper or research. The researcher suggests that Dogan and Abd-El-Khalick (2008) should have broken their research into three researches; one to assess STS, the other to assess scientists and the last one to assess the epistemology of science. This could have allowed for more detailed information for each of the assessed aspects. Also, the blending of STS and NOS could have resulted in confusion amongst some of the participants.

This study was guided by the following research question *"what are grade 10 Turkish students and science teachers' conceptions of some important aspects of NOS"* which is like one of the research questions of the present study. A questionnaire comprising of 14 modified items from the Views of Science-Technology-Society, VOSTS questionnaire (Aikenhead, Ryan and Fleming, 1989) was used to collect data. The NOSK aspects referred

to as NOS aspect in this study included in the 14 items are the theory driven nature of scientific knowledge, the tentativeness nature of scientific knowledge, the relationship between scientific constructs and reality, the myth of the scientific method, differences between laws and theories and observations and inferences. The researcher considers that this instrument with only 14 items had too much to assess at one given time since it had to assess all the NOS aspects mentioned above, STS and scientists. There was need to increase the number of items in the questionnaire say to about 25 to clearly assess all the aspects in question in an orderly fashion. The questionnaire was administered to the learner participants under the supervision of a teacher for 45 minutes. The teacher participants completed the questionnaire individually in their own spare time, unfortunately the authors did not indicate the time they were given to complete the questionnaire.

The data was analysed by a team of researchers who had particular roles to play in the analysis. One of the teams coded each of the responses from the VOSTS questionnaire as either naïve, has merit or informed. The responses were computed and statistically and qualitatively analysed. Generally, the results indicated that both teachers and learners did not hold consistent views across the targeted NOS aspect. Their views were fluid, incoherent and inconsistent.

For instance, Dogan and Abd-El-Khalick (2008) report that all learners and teachers held at least a naïve view on hypothesis theories and laws. There was a general belief amongst both teachers and learners that hypothesis, theories and laws are hierarchically interrelated with a hypothesis becoming a theory and a theory to a law depending on the evidence available. Comparatively most learners, 68.2% and teachers, 72.9 % held informed views of the tentative nature of scientific knowledge. However, the informed views about the tentativeness of scientific knowledge were tainted by the beliefs that through repeated testing theories would become laws and in turn laws can be proven to be correct. This view is inconsistent with the tentative view of scientific knowledge.

The research results also showed that in 8 out of the 14 items in the VOSTS questionnaire, the teachers' views were virtually identical to the students'views.45, 8 % of the teachers compared to 44.2 % students' participants ascribed to the idea of the single universal step-by-step *"scientific method "*while 17 % and 10 % of the learners and teachers

respectively held informed views about the same aspect of NOS. Most of the students and teachers believed that scientific models are copies of reality because research and scientific observations have shown them to be true. The researcher finds these results to be very disturbing as he expects the teachers to have a better understanding of NOS compared to the students. Abd-El-Khalick and Lederman (2000b) stress that teachers should have well informed understandings of NOS to be able to teach NOS concepts.

Surely all the teacher participants in the study have at least a Bachelor's degree and the researcher expects them to have a much better understanding of the NOS aspects compared to the student s they teach. The teachers should have covered some content on NOS at high school and at university and are expected to have a better understanding compared to the Grade 10 learners. The Grade 10 learners seem to have knowledge about NOS aspects compared to the teachers who are teaching them. This does not add up at all. The researcher believes that there should be a significant difference between the students and the teachers' understanding of the NOS aspects. It is impossible to expect the teachers to teach the science content they do not understand or have a similar understanding as the students they are supposed to teach.

Dogan and Abd-El-Khalick (2008) like Gaigher et al. (2014) found out that the socio-economic status, SES, of a school and in turn of an individual has influence on their views of the NOS. According to these researchers' learners from a higher SES showed a better understanding of the NOS aspects compared to leaners from a lower socio-economic status. Dogan and Abd-El-Khalick (2008) argue that learners from schools with higher socio-economic status, with more educated parents living in cities and regions with higher hold more informed views of NOS aspects compared to those with less educated parents living in regions of lower SES. The researcher believes that learners from a higher SES have a better access to information compared to learners from a lower SES.

2.5 Rationale for comparing Pre-service teachers' and Grade 11 learners' understanding of nature of science

The present study compares Pre-service teachers' and Grade 11 learners' understanding of the NOS aspects for the following reasons. Firstly, the researcher was motivated by studies that have examined high school learners' and pre-service teachers' understanding of the NOS mostly in the Western world. Most of the researches had separately assessed the learners and the pre-service teachers' conceptions of NOS and very few had compared the two groups' understanding. This interested the researcher to compare the Grade 11 learners and the Pre-service teachers in the South African context. Secondly regarding literature, the researcher assumed that there was no significant difference in the understanding of NOS between the grade 11 students and the pre-service teachers. This assumption guided the third research question.

Thirdly the researcher wanted to find out if the university science methods courses had had influence on the Pre-service teachers' understanding of NOS compared to Grade 11 learners' experiences of NOS which receives little attention in most school science curricula (Abd-El-Khalick, Bell and Lederman,1998).Fourthly, the researcher believed that Pre-service teachers would soon be practising in science classrooms and this research was interested in finding out if these teachers were any different from the Grade 11 learners they would be soon teaching in terms of their understanding of NOS. Akerson, Morrison and McDuffie (2006) argue that it is impossible for teachers to teach appropriate views of NOS without holding appropriate views themselves. Hence the need to assess the Pre-service teachers' understanding of NOS before they are full time teachers so that remedial action is taken if needed. Lastly, the researcher has compared Pre-service teachers and Grade 11 learners because the Grade 12 learners are protected from participating in research or extra-curricular activities because they are preparing to write their final examinations.

2.6 Previous studies on nature of science in South Africa

There are some many published studies on in-service teachers' understanding of NOS in South Africa but very few on pre-service teachers', students, or other groups of people's understanding of NOS. For example, Gaigher et al. (2014) investigated Grade 11 learners' knowledge about scientific inquiry while in the same year Dudu (2014) explored South African teachers' conceptions of the nature of scientific inquiry. Vhurumuku (2013) investigated the impact of explicit instruction on undergraduates' understanding of the NOS. Ogunniyi (2006) explored the effect a semester long NOS course on two science teachers' understanding of NOS. Dekkers (2006) and Dekkers and Mnisi (2003) investigated how inquiry and reflection contributes to the teachers' and learners' understanding of the NOS and the teachers' understanding of NOS respectively. There is need for more research on pre-service teachers' and learners' understanding of NOS in South Africa.

2.7 Chapter summary

This chapter looked at the conceptual framework guiding the research which is the NOS construct. NOS was defined and discussed from different science education researchers' perspectives. The NOSI and NOSK aspects to be compared between the Grade 11 learners and Pre-service teachers were identified and briefly discussed. The Pre-service teachers' understandings of the NOSI and NOSK aspects were discussed and compared and related to the learners' understandings of the same aspects. The NOSK and NOSI aspects were then discussed separately to clearly show the difference between the two. After the conceptual framework, a literature review of previous studies on teachers' understanding of NOS, students' understanding of NOS and a comparison of teachers' and learners' understanding then followed. The chapter ended with a discussion on the rationale of comparing Pre-service teachers and Grade 11 learners and a brief discussion of previous studies on NOS done in South Africa.

Chapter Three

Research methodology

3. Introduction

Research in most cases is guided by some philosophical assumptions which usually determine the approaches and strategies to be employed by the researcher as well as the instruments to be used in data collection. The aim of a research is always to get answers to the research questions. For this study the research questions are stated in in Chapter One as:

1. What are the Grade 11 learners' understandings of nature of science?
2. What are the pre-service teachers' understandings of nature of science?
3. To what extents are the High School Grade 11 learners' and Bachelor of Education pre-service teachers' understanding of nature of science different?

To understand how data was collected for answering the above research questions, it is important to briefly consider the following issues: the philosophical assumptions guiding the study; the research paradigm; and principles about sampling and sampling procedures. Additionally, in this chapter the data collection procedure is described as well as issues related to research rigour and data analysis. The chapter will end by giving a summary and some concluding remarks.

3.1 Research design

Research design refers to a plan, architectural blueprint or guide for data collection, analysis and interpretation (Opie, 2004; Adams and Schvaneveldt, 1991; Thomas, 2009). It guides the ways in which the research is carried out in terms of the best approaches to be used and the appropriate methods of data collection, analysis and interpretation. This study used a combination of quantitative and interpretivists qualitative approaches to explore and determine the differences in NOS understandings between Grade 11 learners and third year B.Ed. Pre-service teachers. The quantitative approaches used rely on

producing frequencies, numbers and percentages (Collins, 2010; Wilson, 2008). A non-parametric statistical analysis as well as figures, graphs and numbers are used to present data. These quantitative positivistic approaches were chosen for this study because they can easily lead to comparison. In the case of this study a comparison of the understandings of the NOS between the Grade 11 Science learners and the third-year B.Ed. Pre-service teachers. Quantitative data from the questionnaire responses was analysed using graphs, figures, tables and Mann-Whitney U test to compare the two groups' views of the selected NOS aspects.

Qualitatively, the interpretivists epistemological assumption is based on the premises that reality is socially constructed (Mertens, 2005). All human activities might have meaning and need to be interpreted and understood within the contexts of social experiences. In this study, it is assumed that the Grade 11 learners' and the B.Ed. Pre-service teachers' understandings of NOS are based on their different experiences in the academic social contexts at school and university respectively. Therefore, these participants' understandings of the NOS might be part of their summation of experiences in science education. Guba and Lincoln (1994) advise that this can best be done through interactions between and among the researcher and participants. For the present study, the ideal data collection approach was judged to be through interviews. This approach is in line with constructivists or interpretivist paradigm.

In order to assess and compare the Grade11 learners' and B.Ed. Pre-service teachers' understandings of the selected NOS aspects, this study utilised items selected from a Likert-type questionnaire called Views About What Occurs in Science Questionnaire, VAWOSQ,(see, Appendix 1) as well as a semi-structured interview schedule (see, Appendix 2).The VAWOSQ was considered an appropriate tool for collecting data for this study because of its convenience in terms of time, cost and administration(McMillan ,2006).Questionnaire data can be obtained quickly and easily by a single researcher at very low costs. Many issues and questions can be addressed in one questionnaire and there is also assurance of anonymity. In previous studies on teachers and learners' understanding of NOS, questionnaires have been successfully used (Lederman 2007). For this reason, this study chose to adopt the VAWOSQ to explore and compare the Grade 11 learners' and the B.Ed. Pre-service teachers' understandings of NOS.

Questionnaire data in previous research on NOS have been triangulated with interview data (see for example, Ceyhan and Turk, 2015; Macaroglu, Tasar, Cataloglu, 1998). Semi-structured interviews were also used in this study to allow for interviewees to offer responses without being influenced by a set of given responses (Cohen, Manion and Morrison, 2006) and to allow the researcher to probe respondents and gain more in-depth information (Opie, 2004). Interviews have the advantage that they allow for openness and honest. At the same time, they help obtain data directly to answer the research questions.

Data from the VAWOSQ were quantitatively analysed by considering the scores for each item on the questionnaire. As mentioned earlier, the Likert-type scale on each item on the questionnaire ranged from 1 to 5. For some items on the, a high score meant informed views. In other words, the higher the score, the better the understanding of the NOS aspect. However, some items were reverse scored, to consider the fact that the lower the score the more informed the view of the respondent was on the item. The quantitative analysis of the VAWOSQ data is done is done using a statistical package the Mann-Whitney U test. Through doing this, a comparison could be made of Grade 11 learners' and the Pre-service teachers' understanding of selected NOS aspects.

Data from the semi-structured interviews were analysed through a typological analysis. According to (Hatch, 2002) a typological analysis involves division of data into groups or categories based on pre-determined typologies generated from theory, literature or common sense. In the case of the present study the categorization aimed to determine whether the response was informed, mixed or naive. This included interpretive analysis. The quantitative data from the questionnaires was triangulated with the qualitative data from the interviews to validate the findings. As mentioned earlier, this study sought to explore and compare Grade 11 learners' and B.Ed. Pre-service teachers' understanding of NOS. The research design has been discussed above; Figure 3.1 gives an outline of the research design and methodology;

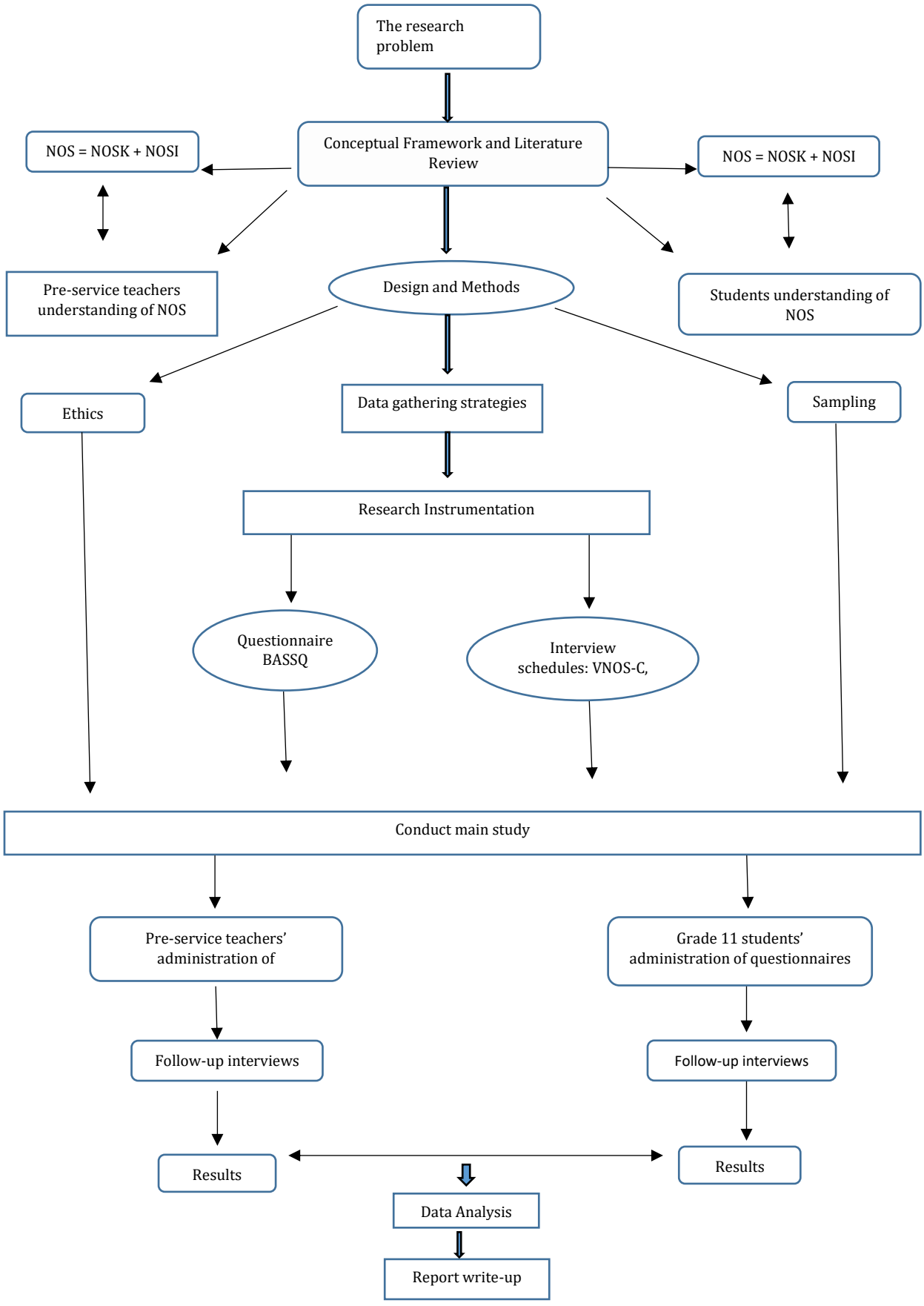


Figure 3.1: An outline of the Research Design and Methods

3.2 Participants sampling

3.2.1 The learner sample

Ten Grade 11 learners (studying either Physical Sciences or Life Sciences or both) were conveniently sampled from school A where the researcher is a teacher. The participants were conveniently selected because of their willingness to participate. The sampling can therefore be described as convenient. Due to financial and time constraints, it was not practical to choose a random sample which is more representative of the entire population (Gall, Gall and Borg, 2003) and appropriate for this study. Hence convenience sampling was used. Critiques of convenience sampling, however, argue that it may result in sampling bias. Shenton (2003) argue that the use of convenient sampling may result in the loss of trustworthiness of the data collected and eventually the credibility of the research findings.

In this study, several measures were taken into consideration to reduce sampling bias and improve on the trust and confidence of the data collected. Firstly, even though the convenient sample of the Grade 11 learners were from the school were the researcher is a teacher, all the participants were chosen on voluntary basis. The Grade 11 learners were given opportunities to accept or refuse to participate in the study for a long time. This was to ensure that only those who genuinely chose to participate would be involved in the data collection sessions. The Grade 11 learner participants were also given the freedom to withdraw from the study at any point they felt like.

Secondly, the Grade 11 learner participants who volunteered to participate were from other physical science and life science classes not taught by the researcher hence indirectly related. The researcher intentionally chose volunteers from other teachers' classes to avoid biases in the data collection process. The researcher believed that participants from other teachers' classes were not directly related to the researcher and therefore had the freedom of contributing their ideas without fear of embarrassing themselves or losing credibility in front of their teachers. The researcher strongly emphasised that the exercise was not for assessment purposes and that there were no wrong or right answers but to get the participants, ideas and opinions over NOS concepts.

Thirdly, the data collection sessions were done professionally at the convenience of all the Grade 11 participants. The researcher agreed with the participants for a convenient day where they were free to participate in the data collection procedures. Before each data collection session, the researcher briefly explained about the study and reiterated that this was a voluntary exercise and participants had the freedom to continue participating or not. The researcher believes that this gave the participants a less tense and more relaxed atmosphere even though they did the sessions under examination conditions. The researcher believes that under such conditions the data collected was more authentic.

Lastly but not least, triangulation was also used to improve the credibility of the collected data. Two methods of data collection were employed. Data from the Views About What Occurs in Science Questionnaire, VAWOSQ, was corroborated with the interview data to check for any inconsistencies or anomalies. For example, the follow up interviews after the administration of the VAWOSQ were for the participants to verify, confirm and explain their ideas much further using their own words. In so doing, the researcher wanted to ensure that the Grade 11 participants had willingly and honestly given their ideas without fear or favour of the researcher who also is a teacher at the school.

Only 10 Grade 11 participants were considered by the researcher because they were convenient and easy to work with. The 10 participants were conveniently available with no travelling costs for the researcher. Data from the 10 participants was not too much and the researcher was comfortable working with it. Of the 10 participants, 4 were males and 6 were females. Of this sample six were studying Physical Sciences only; and four both Physical Sciences and Life Sciences. It is important to emphasize that the learners who volunteered to participate were generally enthusiastic about learning science and were excelling academically in the subjects and looked forward to pursue careers in science. The Grade 11 learners were aged between 16 and 18 years. Of the 10 learner participants 1 was white, 2 were Indians and the rest blacks. English was the first language for 3 participants and the second or third for the other 7 participants. However, all the learners came from relatively good socio-economic backgrounds. Most of them stayed within the vicinity of the school. They had access to many educational resources such as libraries, internet, textbooks and tablets.

3.2.2 The Pre-service teachers sample

The ten Pre-service teachers were third year undergraduates studying full time for a Bachelor in Education degree programme. They were conveniently sampled from University A where the researcher is studying. These participants were easily accessible to the researcher and showed willingness to participate. As noted, all the Pre-service teachers were in their third year of studies and were majoring in Physical Sciences. Six are males and 4 are females. Two of the sampled students are English first language speakers. The Pre-service teachers had done many courses in Physical Sciences (Physics and Chemistry) and Science Teaching Methods courses in the previous two years. All the 10 Pre-service teachers had gone for teaching experiences for at least five times (each period being three weeks) at various schools in the province. They were all above 18 and had done very well academically in all their courses in their first and second year at university. They all seemed to be enjoying their studies and looked certain to completing their courses and move into the next teaching practice session. The researcher chose 10 Pre-service teacher participants because they were convenient and easy to work with and to make the comparison with the Grade 11 learner participants much easier.

3.3 Research instruments

As mentioned, the instruments used in this study to assess the Grade 11 learners' and the B.Ed. Pre-service teachers' understanding of the selected NOS aspects were the VAWOSQ (Appendix 1) and the semi-structured interview schedule (Appendix 2) on NOS. This section describes and explains these two instruments.

3.3.1 The Views About What Occurs in Science Questionnaire (VAWOSQ)

A questionnaire is a data gathering instrument that elicits from the respondents'answers or reactions to pre-arranged questions in a specific order (Adams and Schvaneveldt, 1991). It is a tool for obtaining information, ideas, views and opinions about a particular issue of interest. Mention has been made of the fact that questionnaires have been used to study individuals' understanding of NOS around the world. As noted this was the basis of using the VAWOSQ developed by Aldridge, Taylor and Chen (1997) to assess the Grade 11 learners' and Pre-service teachers' understanding of NOS. The VAWOSQ questionnaire is a Likert-type questionnaire which asks respondents' views of NOS items on a 5-point

scale ranging from *Almost Never; Seldom; Sometimes; Often;* to *Almost Always* with respective scores of *1; 2; 3; 4* and *5.* The scoring for some of the items is done in reverse such that a low score implies an acceptable understanding of the NOS item. For example, item 9 was scored in the reverse order. This item is:

Item 9	*Almost Never*	*Seldom*	*Sometimes*	*Often*	*Almost Always*
Scientific investigations follow the scientific method	1	2	3	4	5

Item 9 scored in the reverse order meaning that a score of *1* is assigned as 5 which, suggests an informed understanding of the nature of scientific investigations. To say *Almost Never* implies an informed position. Another example of an item from the VAWOSQ is item 12, which reads:

Item 12	*Almost Never*	*Seldom*	*Sometimes*	*Often*	*Almost Always*
Scientific knowledge is *tentative*	1	2	3	4	5

For this item, a respondents' choice of *4* or *5* meant agreeing with the informed view that scientific knowledge is *Often* or *Almost Always* tentative. A choice of *1* meant that, the respondent had the view that scientific knowledge is *Almost Never* tentative which is a naïve view.

Aldridge et al. (1997) refer to the inquiry process as a measure of the teacher's beliefs about the processes involved in gaining scientific knowledge and epistemological status as a measure of teacher's beliefs about the status or certainty of scientific knowledge. Lederman et al. (2014) posit that the science inquiry process can also be referred to as NOSI and the epistemological status as Nature of Scientific Knowledge (NOSK). The VAWOSQ comprises of 40 items, 20 of which are for the NOS aspects while the other 20 are for the nature of school science. Of the VAWOSQ items only 20 items were used for this study. Ten for NOSI and 10 for NOSK.

According to Aldridge et al. (1997), the VAWOSQ went through rigorous reliability, validity, integrity and viability tests. It was first piloted to 10 experienced school science teachers in Australia to test for ambiguity and problems in the questionnaire items. For testing validity, the BASSQ was administered to 27 junior high school science teachers in Australia and the results statistically analysed. Six of the 27 junior high school science teachers were further interviewed to determine the conceptual integrity and viability of the VAWOSQ. The VAWOSQ has been used in previous studies for example by Seyan and Turk (2013) to assess Pre-service teachers' understanding of NOS in Turkey (Macaroglu, Tasar, Cataloglu, 1998) and to assess Pre-service elementary school teachers' understanding of NOS and NOSK. It has also been used by Buck (2003) to assess teachers and students at a high school in Nevada, USA. On the African continent, it has also been used successfully in Zimbabwe by Vhurumuku (2004) to assess High school learners and teachers' understandings of NOS and NOSK.

3.3.2 Semi-structured interview schedule

Semi-structured interviews were used in this study because they allow for interviewer to follow up with carefully and properly planned questions to cover the research questions (Opie, 2004). This approach ensures a greater interest by the interviewees and can simultaneously produce rich and detailed answers. However, semi-structured interviews are less controlled by the interviewer, more flexible and do not usually have predetermined answers (Kvale, 1996). Similar questions are asked to all the participants making it easier to analyse data in terms of trends, patterns, events or opinions. The interview schedule used in this study consisted of selected items from the Views of the Nature of Science Form C, VNOS-C (Abd-El-Khalick, Bell, and Lederman, (1998) and Views about Scientific Inquiry, VASI schedule (Lederman et al., 2014). The items chosen for this study have been used in similar studies (for example, Akerson, Abd-El-Khalick and Lederman, 1999; Morrison, Raab and Ingram, 2007; Irez, 2006; Lederman et al., 2014; Gaigher et al., 2014). Three aspects of NOSK and two aspects of NOSI were assessed in this interview schedule as a follow up to the VAWOSQ questionnaire responses. The NOSK aspects probed were on; differences between theory and law, the social and cultural embeddedness of scientific knowledge, and the tentativeness of scientific knowledge. The NOSI aspects used are on; the scientific method, and the differences between data

and evidence. Some examples of the items used in the interview schedule are given below (Appendix 2):

1.The *"scientific method"* is often described as involving the steps of making a hypothesis, identifying variables (dependent/independent), designing an experiment, collecting data, reporting results. Do you agree that to do good science, scientists must follow the scientific method?

- **YES**, scientists must follow the scientific method
- **NO,** there are many scientific methods

• If **YES** (you think all scientific investigations must follow a standard set of steps or method), describe why scientists must follow this method; and

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

3.4 Validity and reliability

As mentioned earlier, this study involved the use of mixed methods and there was need to consider the trustworthiness and validity of qualitative and quantitative data respectively. The researcher needs to get assurance that the research findings are to be believed and trusted. Bickman and Rog (1998) reiterate that all possible biases or errors that could distort or cloud the research findings must be minimised so that the research findings can be referred to as the best approximations to the truth (Mouton, 1996). Guba (1981) in Shenton (2004) propose four criteria to be considered in qualitative research for trustworthiness of a study namely credibility, transferability, dependability and confirmability. On the other hand, also four criteria are used to validate quantitative data and these are internal validity, generalisability, reliability and objectivity (Shenton,2004). The major ideas in validating a study are to confirm whether the study findings are well founded. Opie (2004) refers to validity as the degree to which a method, test or tool measures what it is supposed to measure.

In this study, several measures were taken to enhance trustworthiness of the qualitative data and the validity of the quantitative data of the study. The research tools used, that is, the VAWOSQ and the interview schedule were pre-tested for validity. The VAWOSQ was first piloted on a group of 10 experienced school science teachers studying at postgraduate level to check for ambiguity or problems in the questionnaire items. It was further piloted on a group of 7 Junior High School science teachers who commented on its validity and assured the researcher that the items could be understood by the intended respondents. The VNOS-C items were also piloted on the same group. However, it is noteworthy that the items had previously been used on college undergraduates, graduates and Pre-service teachers (for example, Lederman, Abd-El-Khalick, Bell and Schwartz, 2002). Equally, the VASI items used in this study were first initially given to two in-service teachers to ascertain their understanding. This is despite the fact the items have been used many times in several similar studies (for example, Irez, 2006; Akerson, Hanson and Cullen, 2007; Abd-El-Khalick, 2004; Kang, Scharman and Noh, 2004). Additionally, it is important to note that the use of the interview was necessary to triangulate the VAWOSQ findings. During this process two colleagues studying for a Master's Degree in Science Education helped. The researcher found this useful when it came to eliminate discrepancies and interpretations of the findings. Discussions of the interpretations by the researcher with these colleagues led to some meaningful changes of earlier assumptions. It helped in the re-interpretation of the responses. This aided the process of categorizing and re-categorisation of the interview responses using a predetermined coding system.

3.5 Ethical issues

This study involved human participants in a social setting and thus there was need to consider ethical issues. The researcher had to adhere to research ethics to make the research credible. Ethical guidelines which included policies regarding informed consent, confidentiality, anonymity, caring and privacy were followed in this study. Cohen et al. (2000) warn that researchers must balance between their profession in pursuit of knowledge and their participants' rights and values which can be potentially threatened by the research. To fulfil the research ethical obligations, the researcher first applied to the Gauteng Department of Education, GDE, for the permission to carry out the study. After getting the GDE approval letter (Appendix 15), the researcher then applied for

permission from the School of Education Human Research Ethics Committee at the University for Ethical Clearance of research involving human participants. Copies of the Clearance letters are found in Appendixes 13, 14 and 15.

3.6 The data collection procedure

3.6.1 Administration of learner questionnaires and conducting learner interviews

Weeks before carrying out the study, the 10 Grade 11 participants were given pre-notification letters (Appendix 7) telling them about the study and their roles. The learners who were 18 and above were given consent forms (Appendix 9) to sign and those below 18 were given the forms to take home for their parents or guardians to sign to either allow them or disallow them to participate in the research. The researcher explained to the participants that this was a voluntary exercise and those who did not want to participate were free not to do so. The researcher also emphasized that the exercise was for research purposes and did not contribute to their assessment. The participants were assured of confidentiality and anonymity. The participants were told that they would not disclose their identities but would use given codes to identify themselves. The researcher also assured that only he and the participants would be at the venues where the questionnaire responses and interviews were to be done.

It was only the researcher and his supervisor who would have access to the questionnaires and the audio-taped recordings of the interviews.

3.6.2 Administration of the VAWOSQ and interviewing of learners

Administration of the VAWOSQ

The VAWOSQ was administered to the learners on 15 October 2015 in the afternoon after school. All the 10 Grade 11 participants met with the researcher at the school A's in the All-Purpose Room. This room is used by the school for various activities including examinations. The researcher first thanked the participants for their time and their willingness to participate in the study. He then briefed them about the purpose of study and what they were expected to do, that is, answer questions from the VAWOSQ (Appendix 1). The participants sat according to the codes they were given by the researcher with their desks about a metre apart just like under examination conditions.

They were told to write the given codes as their identities. The researcher then told the participants to ask any questions they had in mind before attempting the questions from the questionnaire. The researcher did not put any time restrictions for the participants to complete the questionnaire. It took about 30 minutes for all the participants to respond to the 20 questionnaire items. Some participants had problems with meanings of words like *tentative, intuition and perspectives*. The researcher had to explain the meanings of the words.

Interviewing of learners

The interviews were carried out in the researcher's office after school hours over a period of three days. The researcher used the interview schedule (Appendix 2) as a guideline. Using the codes given to the participants, the researcher managed to identify each of the Grade 11 learners and their respective responses to the questionnaire items. Each participant was interviewed individually by the researcher for about 10 to 15 minutes. The interview session for each Grade 11 learner was audio recorded for verbatim transcription. In the interviews, the participants were asked questions according to the interview schedule. However, there were diversions here and there from the interview schedule depending on the nature of the responses given by the Grade 11 participants and flowing up and probing.

3.6.3 Administration of the VAWOSQ and interviewing of Pre-service Teachers

Administration of the VAWOSQ

At university A, the Pre-service teachers responded to the questionnaire items on 30 October 2015. The researcher was given 30 minutes' time from one of the Science Methods courses to administer the questionnaire. The researcher briefly explained to the Pre-service teachers about the study and their roles as participants. The researcher emphasised that he was to get their opinions about NOSK and NOSI and this had nothing to do with their academic assessment. It was emphasized that the items in the questionnaires had no wrong or right answers. As was done with the Grade 11 learners, the 10 Pre-service teachers were also assigned codes for anonymity purposes. The researcher told the participants that they were free to ask any questions related to the exercise if they needed to. Otherwise, the questionnaire was administered under typical

examination conditions. It took between 15 and 30 minutes for all the participants to respond to questionnaire items. At the end of the questionnaire sessions at university A, the researcher thanked all the participants for their time and effort and went on to talk about the interviews, which he emphasized were to be voluntary and were to follow after the questionnaire items were analysed. The researcher reiterated that the interviews were to give the participants further opportunities to elaborate or expand on their responses to the questionnaire items.

Interviewing Pre-service teachers

The researcher made individual appointments with the Pre-service teachers for the interview sessions. The interview sessions were carried out with the Pre-service teachers on three different days. Each individual interview session lasted for 20 minutes unlike the Grade 11 learners' interview sessions. The Pre-service teachers elaborated more on their responses than did the Grade 11 learners. Each interview session was audio-recorded for verbatim transcription.

3.7 Data analysis

According to Hatch (2002), data analysis involves a systematic search for meaning. It involves processes of organising and interrogating data in ways that allow for ease interpretation. The two sources of data for this study were the VAWOSQ responses and the interview transcripts derived from the semi-structured learner and pre-service teacher interviews.

3.7.1 Analysis of the VAWOSQ data

As noted, the VAWOSQ (Appendix 1) comprised of two sections, the process of scientific inquiry, NOSI, with 10 items and the certainty of scientific knowledge, NOSK, with 10 items. Coding of the participants' responses was based on a Likert-type response scale with item scores *1,2,3,4,5* respectively for the responses *Almost Never, Seldom, Sometimes, Often and Almost Always.* The scoring for items *6, 8, 11, 14, 16, and 19* was in *reverse*. For the items scored in reverse order, scores of *1* and *2* were considered informed views, *3* mixed views and *4* and *5* naïve views. For the rest of the items scores of *4* and *5* meant informed views, a score of *3* mixed views while *1* and *2* showed naïve views. For example,

for *item 18* on the section of certainty of scientific knowledge, NOSK, a score of 4 or 5 meant that the participant had informed views of the NOS tenet, the social and cultural embeddedness of scientific knowledge, a score of 3 meant mixed views *(not sure*) while a score of 1 or 2 meant naïve views.

On the other hand, for item 9, for example, a score of 1 or 2 on the Likert-scale showed a more informed view of the scientific method. Participants who chose these two lower scores believed that scientists do not follow a specific scientific method in their investigations while those who chose higher scores believed otherwise. Generally, a higher total score for everyone meant a better understanding of the NOS tenets assessed.

To compare the differences in the understanding of the NOS between the Grade 11 learners and the Pre-service teachers, the Mann-Whitney U test (Winter and Dodou, 2010) was applied to the VAWOSQ data. The Mann-Whitney U test was considered ideal for this comparison because the data was the Likert-type scale which was non-continuous or non-parametric. It is used to compare differences between two independent groups when the when data is either ordinal or continuous, but not normally distributed. The ranks for the Grade11 learners and the Pre-service teachers were summed up to get T_1 and T_2 respectively. The number of participants $n_1 = n_2 = 10$ was for both groups. The hypothesis was stated as given below;

> ***H_0**: There is no difference in the understandings of NOS of Grade 11 learners and Pre-service teachers.*
>
> ***H_1:** There is a difference in the understandings of NOS of Grade 11 learners and Pre-service teachers*

To test the null hypothesis, the Mann-Whitney U test was performed for a two-tailed test with significance level set at .05. The Mann-Whitney U test calculator was used to compare the medians of the Grade 11 learners and Pre-service teachers. This enabled the researchers to be able to accept or reject the null hypothesis. (see Appendix 5)

3.7.2 Analysis of semi-structured interview data

Qualitatively learner and Pre-service teacher interview data were analysed through a combination of typological analysis (Hatch, 2002) and interpretive analysis Denzin and Lincoln (2002) using predetermined categories of naïve mixed or informed understandings as done by Abd-El-Khalick and Lederman (2000) and Abd-El-Khalick (2003). The unit of analysis was an understanding of the NOS aspects. Each respondent's answer to question item was read and re-read several times before categorization and interpretation could be done. Responses were read and re-read and categorised as naïve, mixed or informed. Some illustrative responses then selected for data presentation with meanings attached to the data. An ambiguous point of view was coded as mixed. The three predetermined codes stated above were attached to words, phrases or sentences as shown in two participants' the response below.

> PST 4: If scientists *do not follow* (naïve) a *set of steps* (naïve*)* or method that is *standard*, (naïve) then we risk not being able to *replicate the experiment* (mixed).

The response above had words and phrases that were coded naïve and mixed and this resulted in categorising the whole response as naïve.

> Learner 2: *Scientific technology* is always *changing* (informed). Thus, *new discoveries* (informed) are constantly *made* (informed) and these discoveries may contribute to a *scientific theory being changed* (informed).

Thus, Learner 2's response was categorized as more informed compared to PST 4. Even though he could not clearly express himself, the response showed that the learner fully appreciated that scientific knowledge is always dynamic. An understanding of the following aspects was assessed in the interviews; the scientific method, differences between data and evidence, tentativeness of scientific knowledge; differences between law and theory and the social and cultural embeddedness of scientific knowledge.

3.8 Chapter Conclusion

In this chapter the research methods and design were discussed. The data collection procedure was described. Issues about validity were highlighted. The research instruments were described and explained together with the sample and the sampling procedures. Ethical principles were pointed out. The chapter ended with an outline and description of the data analysis procedure. In the next Chapter (Chapter 4), the findings of the study are presented and discussed.

Chapter Four

Results and discussion

4. Introduction

In this chapter, the research results are presented and discussed to answer the three research questions which were stated in Chapter One. These questions are:

1. What are the Grade 11 learners' understandings of nature of science?
2. What are the Pre-service teachers' understandings of nature of science?
3. To what extent are the High School learners and Bachelor of Education Pre-service teachers' understanding of nature of science different?

The chapter ends with a summary.

4.1 Grade 11 learners' understanding of nature of science

The VAWOSQ and the semi-structured interview schedules were used to assess the Grade 11 learners' understanding of the NOS. The questionnaire results showed that most of the Grade 11 learners held naïve and mixed views compared to informed views on most of the NOS aspects assessed. As Figure 4.1 shows, of the 20 questionnaire items on NOSI and NOSK, participants showed the following: only on 37% of items were their views informed. Responses to 63 % of the items were naïve and mixed which both can be described as misunderstandings of the NOS aspects in question.

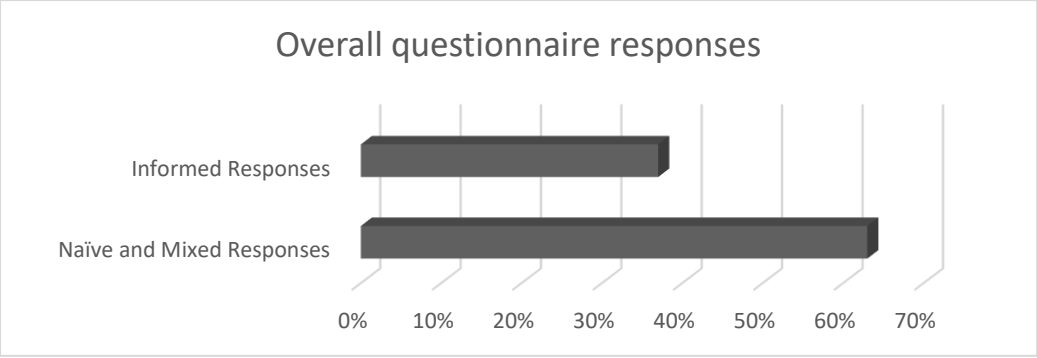


Figure 4.1 Grade 11 learners; responses to VAWOSQ Items (n=10)

As Figure 4.1 shows, the Grade 11 learners chose responses which can be classified as naïve and mixed responses, that is, 67%, compared to informed responses, 33% in their responses to the 20 VAWOSQ items. It was noted in Chapter 3 that mixed and naïve both imply a misunderstanding or misconception of the NOS aspect assessed. From these results, it can be suggested that the Grade 11 learners did not have adequate understandings of most of the assessed items. This is further evidenced by the fact that none of the ten assessed Grade 11 learners showed informed understandings of all 20 VAWOSQ Items**.** This situation is clearer when one looks at Figure 4.2. Figure 4.2 shows the total numbers of each participant's naïve and mixed compared to the informed responses.

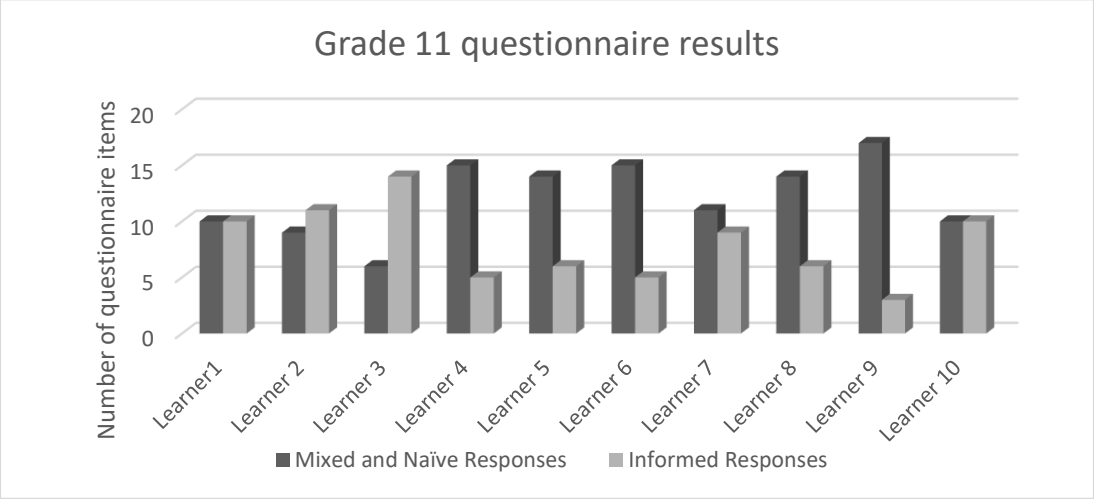


Figure 4.2 Individual Grade 11 learners' views on the 20 VAWOSQ items

Figure 4.2 shows that 60 % of the Grade 11 learner participants showed less informed responses compared to mixed and naïve responses combined. These results show that most of the Grade 11 learners did not understand most of the NOS aspects assessed. It can be said that they either had complete misconceptions or naïve understandings. For example, Figure 4.2 shows that Learner 9 can be described as showing gross misunderstandings of the assessed NOS aspects as 17 of his responses were either naïve or mixed. For this learner, only for 3 items were the understanding informed. Follow up interview with Learner 9; generally, agree with the VAWOSQ results. A typical example was when the Learner 9 was asked about the use of the scientific method in investigations. His interview response was:

> **Learner 9:** *Yes! All the scientists follow the scientific method. This standard method must be followed so that other scientists can also verify their findings. If a standard method is used, scientists can verify findings without the help of the scientist who discovered the findings.*

Clearly, this learner strongly believed in the infallibility of the scientific method. The VAWOSQ results also show that 80 % of the Grade 11 learners held inadequate understandings about the use of the scientific method by scientists. On the use of the scientific method, the interview results revealed learners' understandings to be mostly vague and incorrect.

As Figure 4.2 shows 40 % (only 4 learners) had informed understanding on at least five of the NOS aspects assessed. Only two learners (Learner 1 and 3) showed adequate understandings on at least half the assessed NOS aspects to be described as informed. The rest of the learners were either mixed or naïve. While the learner responses to the VAWOSQ can be described as normal and expected a much clearer picture comes out when their interview responses are considered. Clearly, the sampled Grade 11 learners failed to support their VAWOSQ responses in the interviews. This led the researcher to speculate that some guess work in responding to the VAWOSQ items was involved. For example, Learner 4 showed that she held the informed view that scientists do not necessarily follow the scientific method but, when her interview response is considered the opposite appeared to be true. This is what she said:

> **Learner 4:** *Scientists are able to understand the experiment if a scientific method has been drawn up. Also, future scientists will be able to comprehend a given experiment if a scientific method is followed and understood.*

A similar result was obtained with for example, Learner 3. She similarly showed that she had informed views on the social and cultural embeddedness of scientific knowledge. However, when the interview results on understanding of the same NOS aspect was considered a completely different picture came out. This is what she said:

> **Learner 3:** *Science is universal due to the fact that it is not based around subjective or biased decision making, for example the Big Bang theory. Everything is factual and can be understood in global measures.*

These apparently contradicting responses raise issues about the validity of the VAWOSQ items. It could point towards interviews being more reliable data sources in judging leaner understandings of NOS. This is further evidenced by the fact that on being probed Learner 3 showed gross misunderstanding of the social and cultural embeddedness of scientific knowledge. To the extent that it could be suggested that interview responses failed to fully corroborate VAWOSQ results. This might add credence to the doubts raised about the validity of the VAWOSQ. Perhaps, learners did not fully comprehend the NOS aspects in the VAWOSQ.

However, while this is the case, it is interesting to look at learner responses to Item 14 of the VAWOSQ. The item deals with the issue of whether *scientific knowledge can be proven*. The results on this item are shown in Figure 4.3:

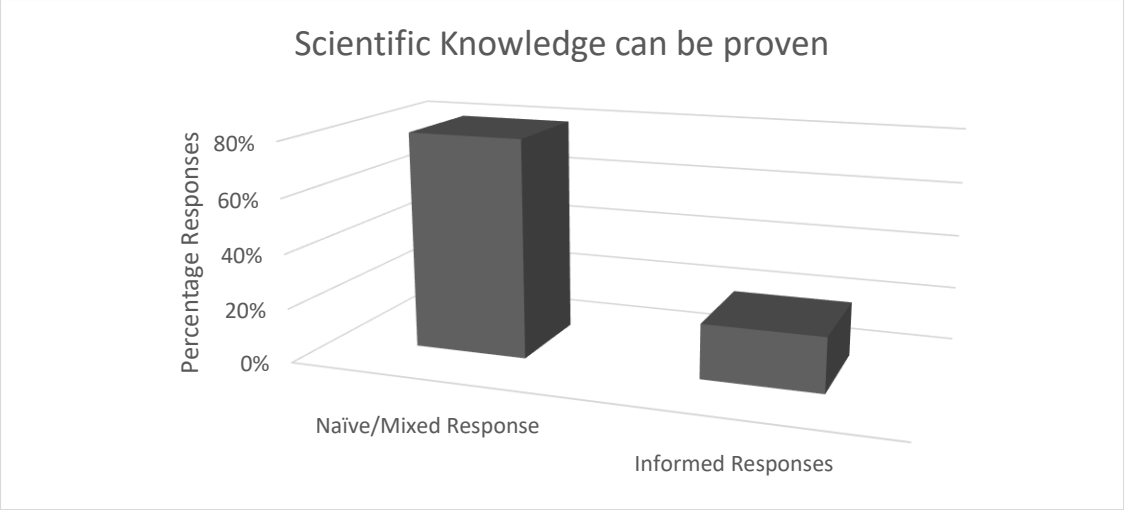


Figure 4.3: Grade 11 learners' responses on "Scientific knowledge can be proven"

Irrespective of the misgivings mentioned about VAWOSQ, Figure 4.3 shows that the misconception that *scientific knowledge can be proven* was prevalent amongst the sampled Grade 11 learners. Only two out of the ten Grade 11 learners showed informed views of this NOS aspect. The rest believed that *Almost Always* scientific knowledge can be proven. This is not a surprising finding as it is in line with what was found by for example, Abd-El-Khalick (2005) in similar studies in the USA, focusing on college students. Abd-El-Khalick (2005) found that the most of the sampled college students believed that scientists prove hypothesis and theories by conducting experiments. It therefore cannot be taken as a surprise that the Grade 11 learners in the present study may have had similar views. At the same time this could explain why this NOS aspect

(*scientific knowledge can be proven)* could have been completely misinterpreted and misunderstood by the sampled Grade 11 learners.

An interesting finding about learners'views on the aspect, *scientific knowledge is tentative* came out as shown in Figure 4.4. Half of the Grade 11 learners showed an informed understanding while the other half exhibited either naïve or mixed views.

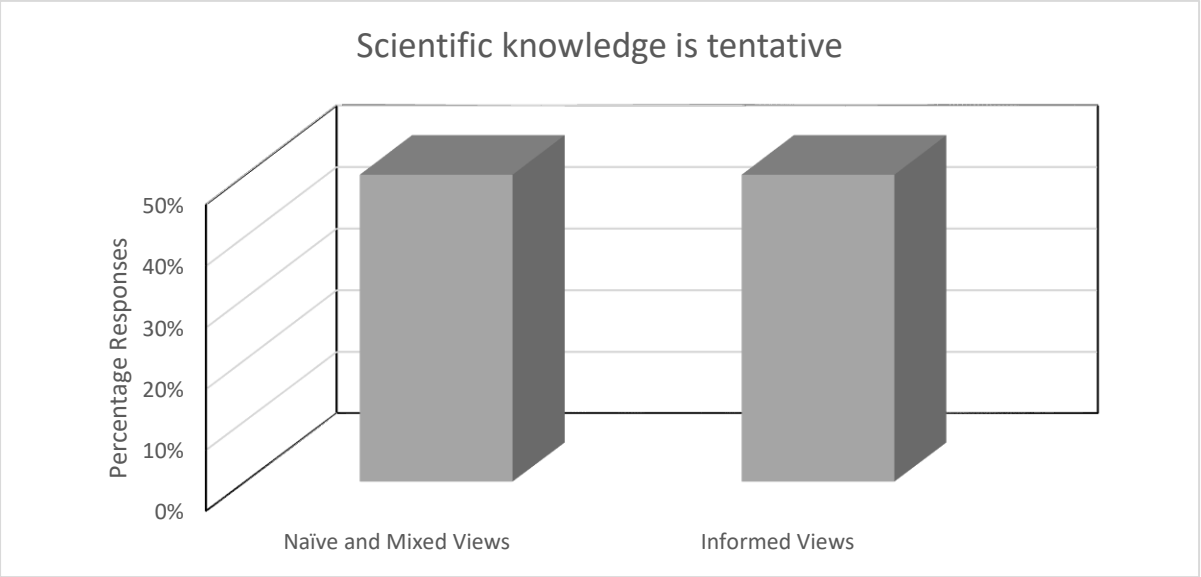


Figure 4.4: Grade 11 learners' responses on the tentativeness of scientific knowledge.

More interestingly, on the tentativeness of scientific knowledge, even though the VAWOSQ results produced a 50% naïve or mixed responses to 50% informed responses, the interview results showed that the sampled Grade 11 learners had generally, a good understanding of this NOS aspect. For example, three of the learners who were interviewed acknowledged that scientific knowledge is dynamic. Learner 3 confirmed his informed VAWOSQ response by saying:

> **Learner 3:** *Scientific knowledge is always changing. As a result, new discoveries are constantly made and these discoveries may contribute to a scientific theory being changed.*

In the same vein, Learner 7 also showed an informed understanding of the tentativeness of scientific knowledge in the interview and argued:

Learner 7: *New information is gathered years after the initial theory was put forward with the advancement of technology. This new information can change the aspect of a common theory thus changing it.*

Overall, on this NOS aspect, that is, *scientific knowledge is tentative* the VAWOSQ results corroborated the interview results.

Generally, however, it can be said that the results point towards the sampled Grade 11 learners having little or no understanding of most of the NOS aspects assessed. This is what the VAWOSQ and interview results appear to indicate.

4.2 Pre-service teachers' understanding of nature of science

Figure 4.5 shows the performance by all the 10 Pre-service teachers on the VAWOSQ items. Of the 20 questionnaire items on NOSI and NOSK (collectively on NOS), the following results were obtained: only on 44 % of items were their views informed. Responses to 56 % of the items were either naïve or mixed. To the extent that the sampled Pre-service teachers can be described as, showing misunderstandings on the NOS aspects. The VAWOSQ results showed that most of the Pre-service teachers held either naïve or mixed views compared to informed views.

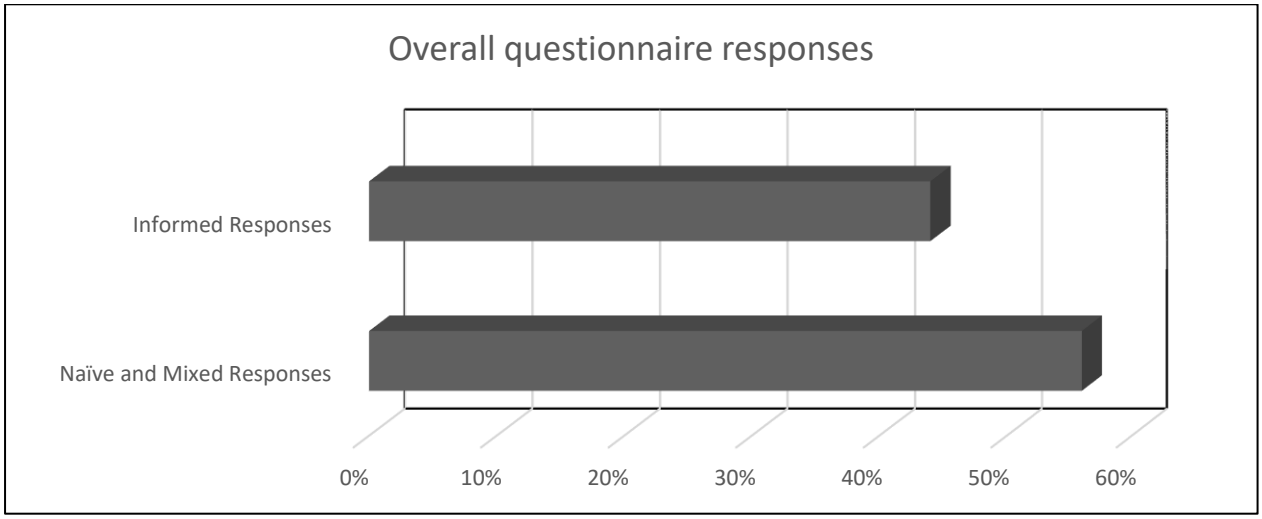


Figure 4.5 Pre-service teachers; responses to VAWOSQ Items (n=10)

As Figure 4.5 shows the total percentage of naïve and mixed responses is larger than the percentage of informed responses. As mentioned earlier, mixed or naïve responses, according to the predetermined coding system discussed in Chapter 3, both imply a misunderstanding or misconception of the NOS aspect assessed. From these results, it can be suggested that the Pre-service teachers did not hold informed views or held inadequate understandings on most of the assessed NOS items. This is further evidenced by the fact that none of the ten assessed Pre-service teachers showed informed

understandings of all 20 VAWOSQ Items**.** This situation is clearer when one looks at Figure 4.6. which shows the total numbers of each participant's naïve plus mixed compared to the informed responses.

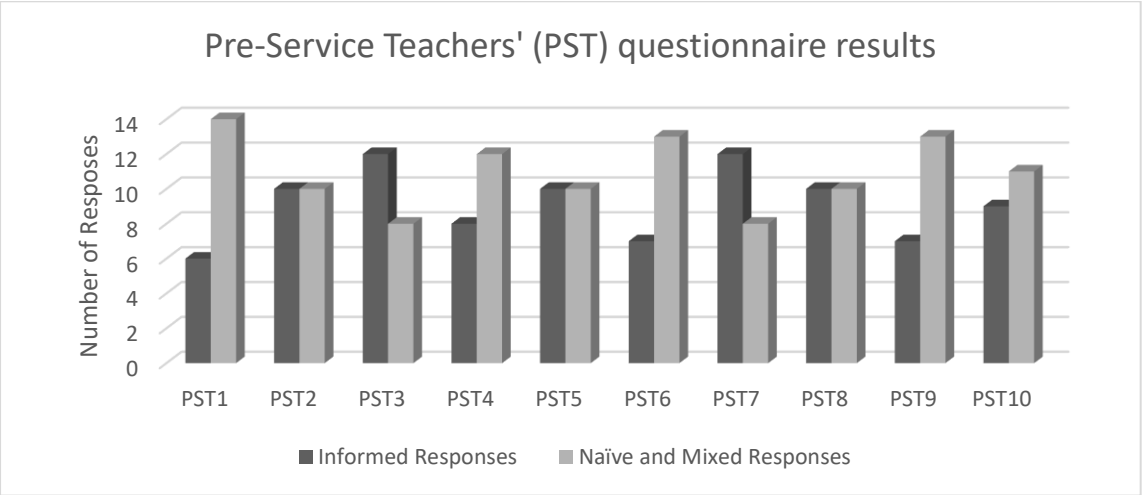


Figure 4.6 Pre-service teachers' responses on the 20 VAWOSQ items

Figure 4.6 shows that none of the 10 Pre-service teachers held informed views of all the 20 VAWOSQ items assessed. Only 20 % (2 Pre-service) of the learner teachers held informed views compared to naïve and mixed. From this, it can be said that most of them did not understand the NOS aspects assessed. For instance, Figure 4.6 shows that PST 1 had the least understanding, as adjudged from the questionnaire items. Follow up interviews for the PST 1 agree with the VAWOSQ result. Clearly, this Pre-service teacher held misconceptions on most of the NOS aspects assessed. For example, PST1 suggested that scientists *Almost Always* follow the scientific method in their investigations in the questionnaire and he confirmed his misconception in the interview by saying:

> **PST1:** *If scientists do not follow a set of steps or method that is standard, then we risk not being able to replicate the experiment. This then makes the experiment unreliable*

PST 1 believed that the scientific method is a standard method with a set of steps to be followed *almost always* by scientists when they carry out their investigations. This is a misconception which 90% of the Pre-service teacher participants exhibited in both the VAWOSQ and interview responses. This was particularly clear for Pre-service teachers PST4 and PST 7. For these two Pre-service teachers, the VAWOSQ results corroboration with the interview results was clearly outstanding.

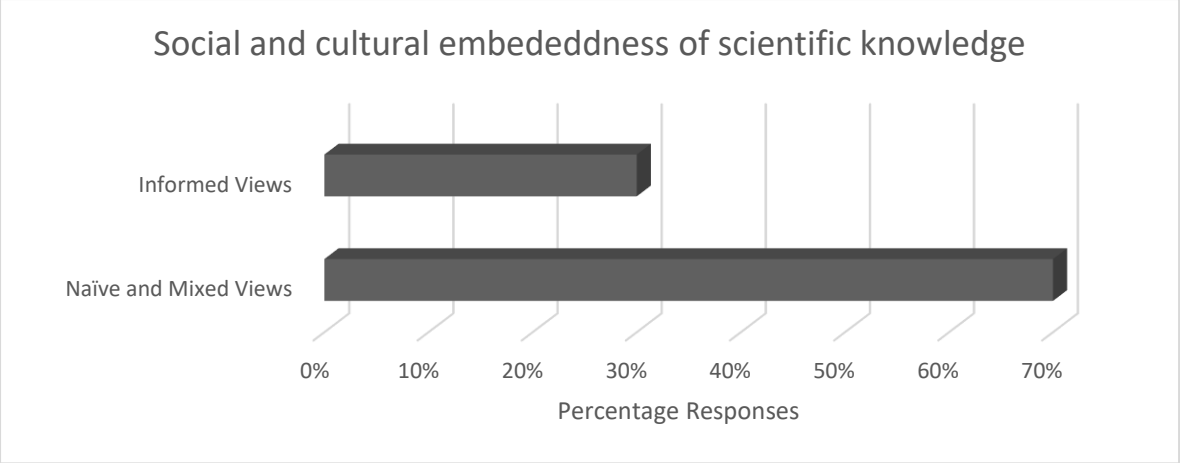


Figure 4.7: Pre-service teachers' views on the social and cultural embeddedness of scientific knowledge.

Figure 4.7 shows results on the NOS aspect: *social and cultural embeddedness of scientific knowledge*. On this aspect 70 % of the Pre-service teachers showed inadequate understandings. On this aspect, Pre-service teachers showed mixed and naïve views, in both the VAWOSQ and the interviews. Typical examples were PST 5 and PST 8 who confirmed their misconceptions on the social and cultural embeddedness of scientific knowledge by saying:

> **PST5:** *In a sense, I believe that science is universal. If something is an acid in one country, it will still be an acid in another.*
>
> **PST8:** *I believe science is universal. This is because the same data will be gathered if the same method is used anywhere in the world. Science is the same throughout the world.*

It is however possible that these two Pre-service teachers had different interpretations on this NOS aspect. PST5's response had more to do with science as a discipline whereas PST8's had more to do with the scientific process and not scientific knowledge. It could also be said PST8's understanding of this NOS aspect was more to do with the application of the products of science rather than the nature of the scientific knowledge while PST 5's interpretation was on science, society and culture relationship. Nevertheless, both these two participants showed that they did not understand the NOS. This is unlike PST 7 who clearly showed an informed view on the social and cultural embeddedness of scientific knowledge and argued:

PST 7: *Science reflects social and cultural values. People investigate certain scientific concepts based on society and their culture, for example Americans investigated nuclear bombs because of the society that wanted to inflict harm on Hiroshima and Nagasaki. The discovery of beriberi could be attributed to the societal needs of the time.*

To a large extent, PST 7 was correct to suggest that people do investigations based on their culture and society implying that science investigations are contextual. Scientific investigations lead to the generation of scientific knowledge based on societal needs and cultural values and attitudes.

The Pre-service teacher sampled in the study had gross misconceptions on the NOS aspect, scientific knowledge can be proven as shown in Figure 4.8 from the VAWOSQ results.

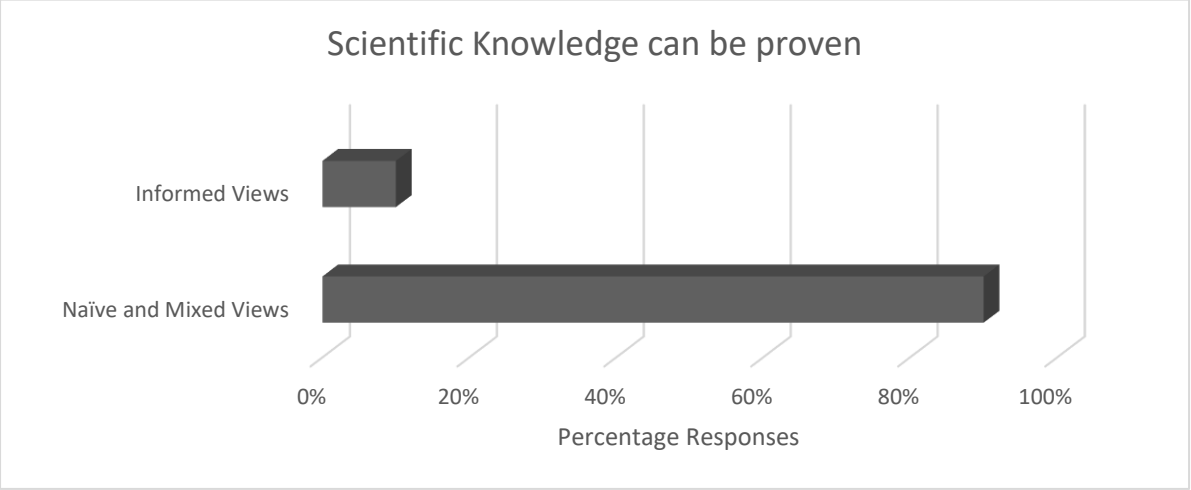


Figure 4.8: Pre-service teachers' views on scientific knowledge can be proven

As shown in Figure 4.8, most of the Pre-service teachers (90%) held naïve and mixed views believing that scientific knowledge can be proven. In their questionnaire responses on this NOS aspect, most of the Pre-service teachers confirmed their misunderstanding by choosing the option *Almost Always,* scientific knowledge can be proven. It can be argued that any participant who chose this option had a misconception. Scientific experiments and investigations are carried out not to prove, but to corroborate (Popper, 1972). As alluded to, research points to many people be it teachers, learners or college students harbouring the belief that by carrying out investigations and experiments,

scientists are trying to prove theories, facts and hypothesis (McCommas, 1996). The Pre-service teachers'misconception here is therefore not surprising.

Overall, the Pre-service teachers showed misunderstanding of most of the NOS aspects assessed in both the VAWOSQ and the interviews. However, there was one NOS aspect, *the tentativeness of scientific knowledge*, where they remarkably showed a good understanding in the VAWOSQ as shown in Figure 4.9.

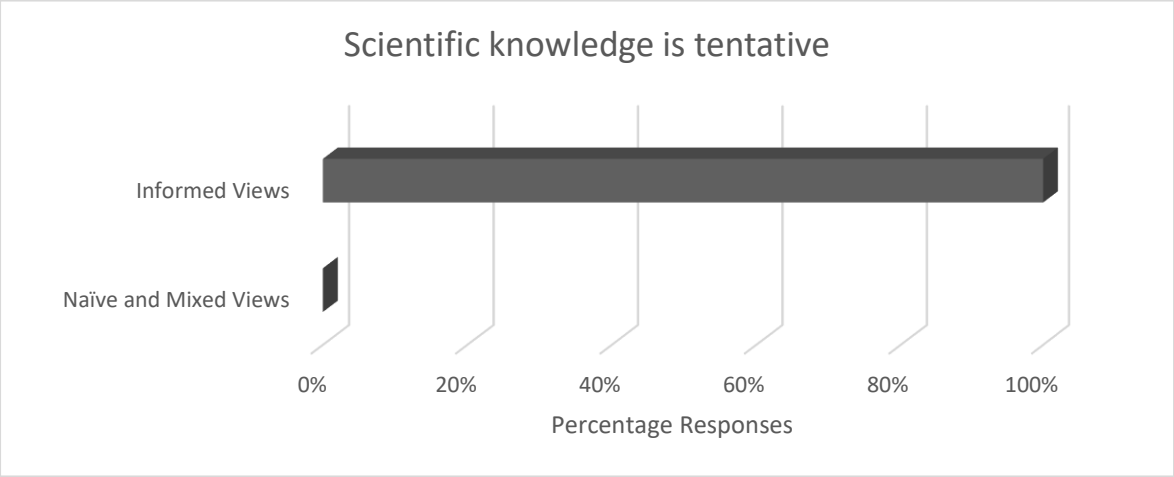


Figure 4.9: Pre-service teachers' views on the tentativeness of scientific knowledge

All the Pre-service teachers had informed views for this NOS aspect. These questionnaire results corroborated with the interview results with three interviewees, for example, showing a good understanding of the tentativeness of scientific knowledge. For example**,** PST 7 argued;

> **PST 7:** *Yes. More information about a specific theory could be found thus changing the original idea or concept of the theory due to recent discoveries.*

PST 7 acknowledges that scientific knowledge is tentative by saying "yes" and further argues that in the event of new information or discoveries, the original idea might change.PST 7 like the other interviewees in his group understood this NOS aspect well even though he had difficulties expressing himself clearly.

From the discussion, above, it can generally be concluded that the Pre-service teachers did not have a good understanding of most of the NOS aspects assessed. They showed adequate understanding only on two out of the twenty NOS aspects assessed. The VAWOSQ results triangulate with the interview results.

4.3 Comparison of Grade 11 learners' and Pre-service teachers' understanding of nature of science

In section 4.1 and 4.2 Grade 11 learners' and Pre-service teachers' understandings of the NOS were presented and discussed respectively. The questionnaire and the interview results were evidence enough to show the two groups' levels of understanding of the NOS. This section discusses and compares the differences in the understanding of NOS between the two groups.

As mentioned in Chapter 3 this study employed both quantitative and qualitative approaches to answer the research questions. Accordingly, to compare the Grade 11 learners' and Preservice teachers' understanding of the NOS both approaches were used. Quantitatively, the Mann-Whitney U test was employed on the VAWOSQ data to ascertain whether there was a difference in the understandings of the two groups. The hypotheses tested were as follows: (see Appendix 5)

The null hypothesis H_0 asserts that the medians of the Grade 11 learners' scores and the medians of the Pre-service teachers' scores are identical which implies that their understanding of NOS is similar.

H_0: There is no difference in the understandings of NOS of Grade 11 learners and Pre-service teachers.

H_1: There is a difference in the understandings of NOS of Grade 11 learners and Pre-service teachers

To test the null hypothesis, the Mann-Whitney U test was performed for a two-tailed test with significance level set at .05. The U-value was 41. The critical value of U at $p < .05$ was 23. The result was not significant at $p < .05$. This led to failure to reject the null hypothesis, that there is no difference in the understandings of NOS of Grade 11 learners and Pre-service teachers (see Appendix 5) This result is further corroborated when a plot of a comparison of median scores for each item on the VAWOSQ is done as shown in Figure 4.10.

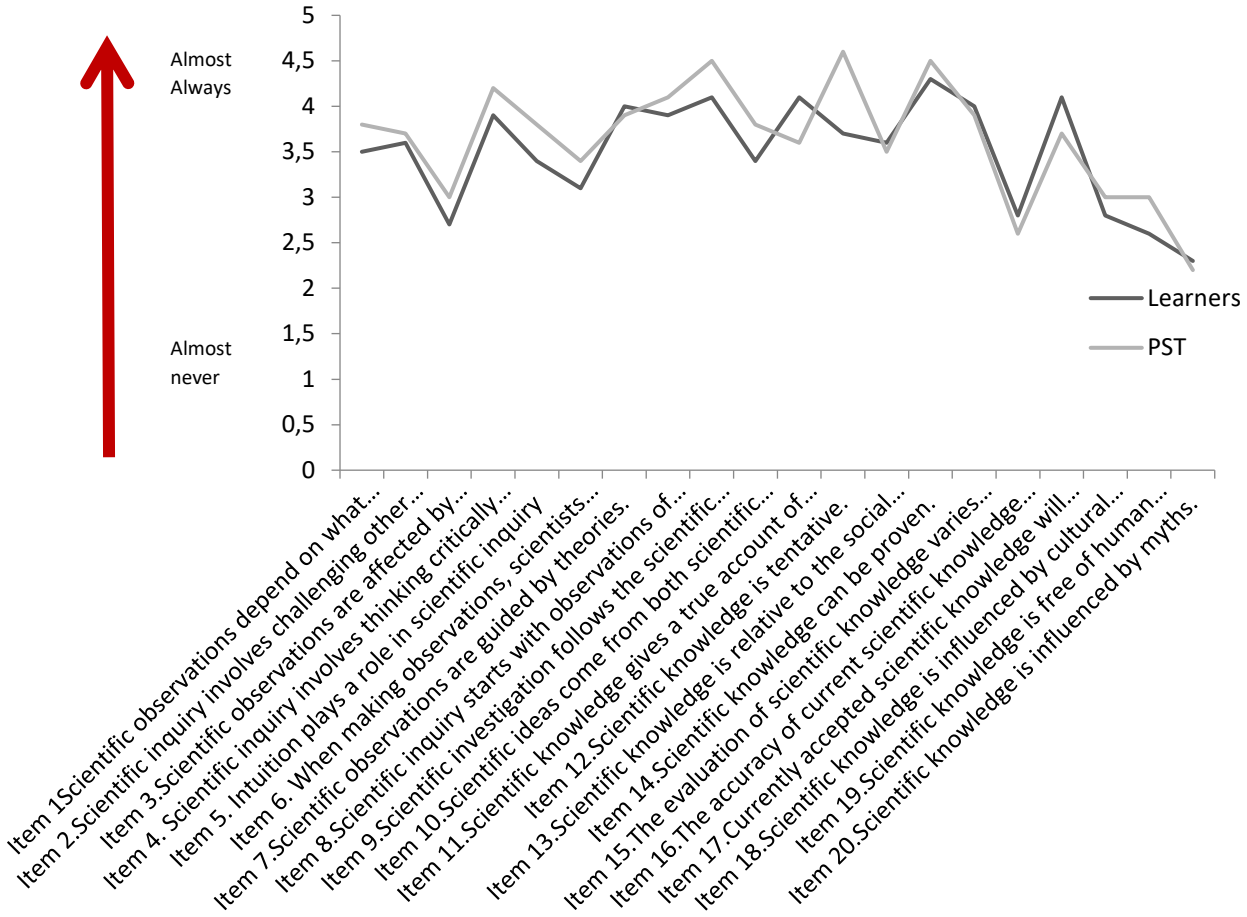


Figure 4.10: Comparison of median scores for each item on the VAWOSQ (n=10)

Figure 4.10 shows that there was not much difference in the performances of the two groups on each item. Thus, overall, the Mann–Whitney U test and the graph show that Grade 11 learners' and Pre-service teachers' understandings based on the VAWOSQ were not very different from each other.

Follow-up interview results, after the administration of the VAWOSQ further confirmed that there was not much of a difference in the understanding of the NOS aspects between the two groups. Their responses to most of the NOS aspects assessed in the interview showed similar understandings. For example, exploring the two groups' understandings of the NOS aspect: *there is only one scientific method* resulted in the following respective responses:

PST 7*: If scientists do not follow a set of steps or method that is standard, then we risk not being able to replicate the experiment. This then makes the experiment unreliable. However, I do believe that you do not always need to follow the steps in a set order.*

Learner 3: *All scientists use the scientific method. The scientific method covers all the aspects of an investigation. It helps plan the procedure and information of the experiment and allows scientists to understand the outcome of their experiments with clear conclusion.*

PST 7 and Learner 3 both held naïve understandings about the scientific method and there was no difference in their understanding of this NOS aspect.

Furthermore, when the two groups were assessed on their understanding of another NOS aspect, *the social and cultural embeddedness of scientific knowledge* their responses were not very different from each other. Clearly, both groups exhibited mixed and naïve responses. The extracts below are illustrative:

PST 5: *I believe science is universal. This is because the same data will be gathered if the same method is used anywhere in the world.*

Learner 4: *Science is universal since it is not based around subjective or biased decision making, for example the Big Bang theory. Everything is factual and can be understood in global measures.*

Learner 4 and PST 5 misinterpreted the NOS aspect and asserted that science is universal (a misunderstanding) and then went on show this in their explanations which were clearly misconceptions. From these responses, one could undoubtedly see that there was no difference in understanding of this NOS aspect between the two participants from the two groups.

The interview results also showed that both the Grade 11 learners and the Pre-service teachers held informed views on the *tentativeness of scientific knowledge*. Both groups' interviewees demonstrated their appreciation and acknowledgement that scientific knowledge and ideas have changed overtime by saying the following:

PST 7: *Yes. More information about a specific theory could be found thus changing the original idea or concept of the theory due to recent discoveries.*

Learner 3: *Scientific knowledge is always changing. As a result, new discoveries are constantly made and these discoveries may contribute to a scientific theory being changed.*

Learner 3 clearly asserts that scientific knowledge is dynamic while PST 7 affirms this by saying that "Yes" scientific knowledge changes overtime due to new discoveries. It is evident that there was no difference in the understanding of the tentativeness of scientific knowledge between the two learners. Both groups showed a relatively good understanding of this NOS aspect.

Overall the evidence from the Mann-Whitney U test, comparison of median scores of VAWOSQ data, as well as interview data show that there was no significant difference in the understandings of the assessed NOS aspects between the Grade 11 learners and the Pre-service teachers.

4.4 Discussion

This study sought out to compare differences in the understanding of the NOS between Grade 11 High school learners and the university Pre-service teachers. The results from the study show that both the Grade 11 learners and the Pre-service teachers had little understandings of the assessed NOS aspects and there was no significant difference in their conceptions. The two groups exhibited similar understandings and misunderstandings of the NOS aspects. These findings are not really surprising as there is a plethora of similar studies which have produced similar results (Lederman, 1992). However, most of these studies have compared in-service teachers with pre-service teachers (Bayir, Cakici and Ertas, 2014) and very few studies have compared Pre-service teachers and high school learners

The present findings indicate that there is no significant difference in understanding the NOS between high school learners and Pre-service teachers. It was expected that Pre-service teachers would show some significantly better understandings compared to the Grade 11 learners. However, the findings show that they have similar understandings. These findings suggest that there is no clear development of the NOS understanding as

learners' progress from high school to university. Palmquist and Finley (1997) suggest that most Pre-service teachers enter the teaching programs at university tightly clung to their mixed and naïve views of the NOS. At university, Pre-service teachers are expected to cover science education teacher courses which emphasize the inclusion of the NOS and how to teach about NOS (Mathews, 1990, Ogunniyi, 1983, Dagher, 1997). As McCommas (1998) notes, school science instruction, NOS is not very well emphasized in science lessons. This can explain why the Grade 11 learners had little understandings of NOS. The lack of any differences in the understandings of the NOS between the Grade 11 learners and the Pre-service teachers is however completely surprising because of the differences in which NOS instruction is expected to be treated and emphasized at the respective science education levels. Questions arise over the revealed no difference in understandings of the NOS between high school learners and Pre-service teachers. It could be that university teacher education programmes are not doing enough to develop Pre-service teachers' NOS understandings.

The findings of the current study show that both the Grade 11 learners and the Pre-service teachers exhibited little or no understanding of the assessed NOS. In Chapter 1, it was mentioned that an adequate understanding of the NOS is a central component of scientific literacy which is a fundamental goal of science education (AAAS, 1989, NRC, 1996) in many countries. The results of the present study however, suggest that there is still much to be done to help learners, in-service teachers and pre-service teachers develop adequate understandings of the NOS for envisaged goals of science education to be achieved in South Africa. As Abd-El-Khalick and Lederman (2000) advice teachers' understandings of NOS should be addressed first if there is any hope of developing adequate understandings of NOS for the learners.

While this is so, some issues could have affected the validity the present results. Firstly, the samples for both the Grade 11 learners and the Pre-service teachers are too small ($n_1=n_2=10$) and come from the same school and same university making it difficult to generalise the findings. Second, the samples might not be representative of the population groups making the validity of the findings to be questionable and perhaps unreliable. A third issue is about the research instruments themselves which might have impacted the validity of the research findings. Chen (2006) argues that these traditional instruments such as open-ended questionnaires or Likert type are written from the

perspective of experts and respondents may fail to understand and interpret the test items. It is possible that the items used here were not appropriate for the study samples. The very nature of the Likert type VAWOSQ instrument could have warded responses them into making wrong choices. It is suffice to mention that both groups of participants were not familiar with this type of multi-choice responses to Likert type questions. The participants' choices on the VAWOSQ could have been guess work thereby grossly affecting the validity of the research findings. The semi-structured interview questions which were adopted from Views of the Nature of Science, VNOS (Lederman et al. 2002) may have been misleading and could have failed to clearly address the South African context (Deng, Chen, Tsai and Chai,2011). For example, the questions on the NOS aspect: *social and cultural embeddedness of scientific knowledge* appears to have been misinterpreted by all the participants in the interviews. This may have been due to ambiguity of language (Chen, 2006) as some of the participants were second language speakers. For these participants, the question items might have been quite complex.

While this might be the case, the findings here are consistent with those reported in many other studies that have assessed learners, in-service teachers and pre-service teachers' views of the NOS (Lederman, 1992; Dogan and Abd-El-Khalick, 2008; Abd-El-Khalick, 2005; Moss, 2010; Abd-El-Khalick and Akerson, 2004) in other parts of the world. For example, Lederman (1992) reports studies that compared in-service teachers' and learners' understanding of the NOS and describes similar findings. Similarly, Palmquist and Finley (1997) and Irez (2006) assessed pre-service teachers' beliefs about the NOS and Bell et al. (2003), Khishfe (2007) and Moss (2010) assessed high school learners' understanding of the NOS and produced similar findings. Thus, it can still be argued that the Pre-service teachers and the high school learners sampled in the present study had little understandings of NOS.

Interestingly, the present findings are inconsistent with the findings of the research study also done in South Africa by Gaigher, Lederman and Lederman (2014). Their study found that South African Grade 10 high school learners had excellent understanding of the NOSI aspects. In their descriptions of their findings, Gaigher et al. (2014) equated this degree of understanding of the NOSI aspects by the South African students to that obtained by other students after explicit NOSI instruction internationally. The findings of the present study are inconsistent with this as they show that South African Grade 11 learners

exhibited little understandings of NOS aspects. It is quite difficult to explain why there is so much a difference in the results between the present study and that of Gaigher et al. (2014). However, it needs be noted that the standards of science education in some South African schools are poor (Mji and Makgatho, 2006). Perhaps with explicit instruction on the NOSI South African learners can exhibit good understanding of NOS. This could explain the positive results found by Gaigher et al. (2014).

This findings here suggest that there is need to pay attention to ways in which NOS is represented and addressed in both the school curricula and the science education teacher programs in South Africa .Teachers' understanding of NOS should be given priority (Abd-El-Khalick and Lederman,2000) since they are considered to be the primary intermediary of science curriculum Dogan and Abd-El-Khalick (2008).Science teacher education programs should emphasize and include formal and explicit NOS instruction so that teachers can be taught how to teach about NOS (Abd-El-Khalick,2014). McCommas, Clough and Almzroa (1998) and Lederman (1992) argue that teachers must have a good understanding of NOS which to enable them to translate this into classroom practice. Pre-service teachers and practicing teachers should be aware that the NOS instruction is an important instructional objective that should be considered in every lesson in terms of behaviours, activities, attitudes and decisions. McCommas et al. (1998) argue that science education programs in many universities do not value NOS instruction and so the produced teachers, in most cases, do not know how to teach about NOS in their science teaching (Abd-El-Khalick, 2014). While the South African secondary school science curriculum emphasizes the inclusion of NOS in science learning various factors can impeded the inclusion of NOS instruction in the classroom. This is a possible explanation of the current findings. Some of the factors such as lack of teacher expertise, lack of resources and too much emphasis on content knowledge for the purposes of the examination might impede teachers teaching about NOS. The consequences are that at the end of school and even university, many students will be scientifically illiterate because they lack a basic understanding of NOS. There is need for all the stakeholders in science education to value the importance of NOS instruction from primary to tertiary education for the goal of scientific literacy to be achieved.

4.5 Chapter summary

This chapter first discussed and described the Grade 11 learners' understanding of NOS followed by the Pre-service teachers' understandings. A comparison of the two groups' understandings of the same NOS aspects then followed. A discussion of the research results was done. The next chapter looks at the conclusions and recommendations coming out of this study. It also highlights some of the limitations of the present study.

Chapter 5

Conclusion, implications and recommendations

5. Introduction

The aims of this study were to investigate the Grade 11 learners' understanding of the NOS; the Pre-service teachers' understandings of the NOS and to find out if there were any differences in the understanding of NOS between the two groups. Chapter 4 has presented and discussed the research results coming up with the following conclusions;

1. Grade 11 learners have little or no understanding of the NOS

2. Pre-service teachers have little or no understanding of the NOS

3. There is no significant difference in the understanding of the NOS between the Grade 11 learners and the Pre-service teachers

These conclusions are discussed separately below

5.1 Grade 11 learners' understanding of nature of science

The findings of this study revealed that most Grade 11 learner participants have little or no understanding of the NOS. The VAWOSQ response results showed that for most of the 20 NOS aspects assessed, the Grade 11 learners performed very badly as shown by their scores. For example, the NOSK item 14, *scientific knowledge can be proven*, virtually all the Grade 11 learner participants showed misconceptions. They believed that repeated experimentation can lead to proving scientific knowledge which is a naïve view. The Grade 11 learner participants' questionnaire responses on item 9, the *scientific method* corroborated with their interview responses. All but only one of the Grade 11 learner participants exhibited naïve views on the use of the scientific method by scientists in their investigations. Similarly, the interview responses also showed gross misconceptions of the same aspect as most of the participants believed that the scientific method is a standard method which all scientists must use when they carry out investigations. Generally, the interview responses confirmed the Grade 11 learners' misunderstandings of the NOS aspects as most of them could not explicitly explain their questionnaire responses.

These findings corroborate with the findings of other researchers in similar studies such as Moss (2010), Bell, Blair, Crawford and Lederman (2003), Abd-El-Khalick (2005), Khishfe and Abd-El-Khalick (2002) and Meichtry (1993). Kang et al. (2004) assessed grade 10 high school learners' views on the NOS and the findings showed that the participants had mild to gross misconceptions of the NOS aspects assessed. Contrary to these studies research findings are the findings by Gaigher, Lederman and Lederman (2014) which showed that South African learners displayed very good understanding of the NOSI aspects like that obtained after explicit instruction in international studies. As a practising teacher of science in South Africa, the researcher believes that there could be other factors that could have manipulated these research findings. For example, Gaigher et al. (2014) may be purposefully selected a particular sample of students to get the required result. Generally, as mentioned above, there is a plenty of research evidence that show that students all over the world hold naïve views on most NOS aspects. South Africa is no exception.

5.2 Pre-service teachers' understanding of NOS

The other finding for this study also showed that most the Pre-service teacher participants held misconceptions on most of the NOS aspects assessed. The VAWOSQ response results show that the Pre-service teachers' average performance for the NOS aspects was well below par. The Pre-service teachers had inaccurate understandings on more than 50 % of the items on the questionnaire. For example, the Pre-service teachers showed a poor understanding of item 3, which inquired whether scientists' observations were affected by their values and beliefs. Most of the Pre-service teachers chose the options *Almost Never* or *Seldom* that scientists observations are affected by their values and beliefs cementing their misconception that science is always objective. Also for item 14 on the VAWOSQ, most Pre-service teacher participants believed scientific knowledge can be proven. McComas et al. (1998) argues that this misconception roots from experiments and investigations in textbooks which purportedly always want to answer a question or prove a theory or hypothesis.

The interview responses, on the scientific method corroborated with the VAWOSQ response results. Most of the Pre-service teacher participants held inaccurate understandings on the use of the scientific method as most of them chose the option, *Almost Always* that scientific investigations follow a step-wise method. Follow up

interview responses revealed that the Pre-service teacher participants had gross misconceptions on the *scientific method* exemplified by one of them who suggested that the scientific method must be followed by scientists for them to be able to repeat the experiment and to compare results. However, one of the Pre-service teachers responded very well on the scientific method and suggested that scientists use several methods depending on the circumstance. These research results showed that the participant Pre-service teachers held misconceptions on many NOS aspects and these results are like other results by Akerson and Donnelly (2008), Vhurumuku (2013), Palmquist and Finley (1997) Bell, Lederman and Abd-El-Khalick (2000), Irez (2006) Bell and Smith (1994) and Akerson and McDuffie (2006).

5.3 Comparison of the Grade 11 learners' and Pre-service teachers' understanding of nature of science

The research findings have also revealed that there was no significant difference in the understanding of the NOS aspects between the Grade 11 high school learners and the Pre-service teachers. The statistical analysis, The Mann-Whitney U Test results showed that there was no significant difference at 5 % significance level between the two groups. These statistical results were corroborated with the interview results and further confirmed that there was no significant difference in the understanding of NOS between the two groups. Follow up interviews on item 9, on VAWOSQ, the scientific method also showed that that the two groups exhibited similar understandings. Generally, both groups' participants believed that the scientific method is a *"standard method"* which must be followed by all scientists. On the social and cultural embeddedness of scientific knowledge, both the Grade 11 learner participants and the Pre-service teacher participants misunderstood the NOS aspect and talked about the universality of science. There was no difference in the understanding of the tentativeness of scientific knowledge as both groups showed relatively good understandings in both the VAWOSQ and the interview responses. All the interviewed participants from both groups acknowledged and appreciated that scientific knowledge was tentative even though they said it in many ways. The statistical analysis done on the VAWOSQ data corroborated with the interview results showed that generally there was no significant difference in the understanding of the NOS between the Grade11 learners and the Pre-service teachers.

There is very little research comparing Pre-service teachers and students but there is a lot comparing in-service teachers and students. Research evidence (Lederman, 1992, Dogan and Abd-El-Khalick, 2008, Akerson and Donnelley, 2008) has generally shown that there is not much of a difference in the understanding of the NOS between in-service teachers and students. The research findings in this study are in line with the previous research results comparing in-service teachers and students.

5.4 Conclusion

Even though generalising these results might pose problems due to insufficient statistical power such as sample size, these research findings can be very useful to several stakeholders in science education in South Africa. The research findings show that there is still a lot to be done for the country to attain the major goal of science education, scientific literacy. Both the Pre-service teacher and Grade 11 learner participants showed very little understanding of the NOS which is a basis for one to be considered scientific literate. Teachers need to be aware that the teaching of science with NOS (Abd-El-Khalick, 2014) should be considered a primary goal in science education. Pre-service teachers' understanding of NOS should be addressed in their teacher training programs. Lederman (1999) is of the view that the NOS should be considered an important instructional objective in the implementation of every instruction in the science lesson. Curriculum planners should present NOS explicitly in the science curriculum from primary right up to tertiary level. The researcher believes that for teachers to seriously incorporate NOS in their teaching, an assessment of NOS understanding should equally be done just like an assessment of science content knowledge. The CAPS (DoE,2011) science curriculum in South Africa should be further revised to include as many aspects of directly related to science content knowledge. This may improve the learners' understanding of NOS and science in general simultaneously increasing the levels of scientific literacy amongst South African citizens.

5.5 Implications and Recommendations

The results for this study have significant implications in improving scientific literacy in South Africa which is one of the major goals in science education. A good understanding of the NOS results increased rates of scientific literacy. Evidence from the research has shown that both the high school learner and the pre-service learner participants held mostly naïve views on the NOS. The research findings emphasise the importance of a concerted effort to help improve the situation. Pre-service teachers will soon be practising in the classroom and cannot be expected to teach what they do not understand (Palmquist and Finley, 1997) hence there is need to help them internalise the instructional importance of NOS in their future teaching. McComas et al. (1998) reiterate that science teaching methods courses at universities and colleges should concentrate more on improving pre-service teachers' conceptions of science which is anticipated also to have a domino effect on their students' conceptions. The relevant authorities at universities should take a cue from this study and help the pre-service teachers to make NOS instruction an integrated and meaningful component of science teaching (Abd-El-Khalick, 1998).

Pre-service teachers should understand the reasons behind and the importance of including NOS for them to be able to pay attention to NOS in their instructional decisions in the classroom (Lederman, 1999, Meichtry, 1993, Dogan and Abd-Khalick, 2008). To improve the pre-service teachers' conceptions of NOS, there is need for explicit attention of NOS in science methods courses and extensive training on teaching and assessing the NOS content. Science educators and curriculum developers may also take heed of these research findings because most of them pay little or no attention to NOS evidenced in their instructional decisions with ramifications on the learners' understanding of NOS. The researcher with many years' experience as a high school science teacher believes that most teachers are unaware of the importance of an understanding of NOS in their teaching hence the pay little attention to it.

Science educators in South Africa, like in most countries in the world, concentrate more on teaching and learning of science content basically for their learners to pass examinations which is a misconstrued goal of science education. It is high time science educators become aware of the importance of an understanding of NOS because of its

significance in scientific literacy. As mentioned earlier, the CAPS (2011) documents for GET and FET phases emphasise the importance of NOS in the learning and teaching of science in South Africa. Unfortunately, the researcher believes that the CAPS (2011) documents are more science content laden with very little or nothing on NOS content. Since most educators faithfully follow the CAPS (2011) curriculum, the researcher believes that they will not include NOS content in their teaching because of its absence in the curriculum document. For students to achieve better understandings of NOS there is need for curriculum developers to include a lot of NOS content in the curriculum. An understanding of NOS should also be assessed just like an understanding of the science content.

5.6 Recommendations for further research

Previous studies have focused more on assessing teachers' and learners' understanding of the nature of science (Lederman, 1992, Meichtry,1993, Abd-El-Khalick and Lederman, 2000, Akerson and Donnelly,2008) using instruments such as questionnaires and interview schedules. In almost all the studies, it has been found out that both teachers and students mostly held inadequate views on the nature of science aspects. The researcher believes that the instruments used in assessing the participants' understanding of NOS are complicated and too advanced for the teachers and learners. The jargon, the wording and the concepts in the questionnaires and interview schedules are beyond the comprehension of most of the participants. In conducting this study the researcher has observed that most of the participants do not understand the items in the questionnaires or interview schedules and end up resorting to guess work. There is need to research further in better ways to assess the participants' understanding of NOS. The researcher believes that the currently used questionnaire and interview schedules can be revised further so that they can be user-friendly to all the participants. Further research can also be done to find the most effective ways to assess participants' understanding of NOS.

5.7 Reflections

Carrying out this research has been an eye opener to me as a physical science teacher. Over my many years teaching science at secondary school level, I had never considered the importance of an understanding of the nature of science. My primary goal of teaching science before undertaking this research was to make learners science literate and not scientific literate (Lederman, Antik and Bartos, 2014) which is the desired goal of science education. There is much more to learning and teaching the discipline science than just mastering the facts, theories and laws.

References

AAAS: (1993). *Benchmarks for science literacy: Project 2061*.Oxford University Press, New York

Abd-El-Khalick & Lederman (2000). Improving science teachers' conceptions of nature of science: critical review of the literature. *International Journal of Science Education*, 22(7), 665-85

Abd-El-Khalick, F. (2001). Embedding nature of science instruction in pre-service elementary science courses: Abandoning scientism, But …. *Journal of Science Teacher Education, 12*(3), 215–233.

Abd-El-Khalick, F. (2003). Socio-scientific issues in pre-college science classrooms: The primacy of learners' epistemological orientations and views of nature of science. In D. L. Zeidler (Ed.), The role of moral reasoning in socio-scientific issues and discourse in science education (pp. 41–61). Dordrecht, The Netherlands: Kluwer.

Abd-El-Khalick, F. (2004). *Over and over and over again: College students' views of nature of science.* In L.B. Flick & N.G. Lederman (Eds.), Scientific inquiry and nature of science: Implications for teaching, learning, and teacher education. (pp. 389–425). Dordrecht, The Netherlands: Kluwer.

Abd-El-Khalick, F. (2005). Developing deeper understandings of nature of science: The impact of a philosophy of science course on preservice science teachers' views and instructional planning. *International Journal of Science Education*, 27, 15–42.

Abd-El-Khalick, F. (2006, April). Developmental patterns in secondary school students' epistemological views. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Francisco, CA.

Abd-El-Khalick, F. (2013). Teaching *with* and *About* Nature of Science, Science Teacher Knowledge Domains. *Science and Education,* 22, 2087-2107

Abd-El-Khalick, F. (2013). Teaching with and About Nature of Science, and Science Teacher Knowledge Domains. *Science and Education*.22, 2087-2107

Abd-El-Khalick, F., & Akerson, V. L. (2004). Learning about nature of science as conceptual change: Factors that mediate the development of pre-service elementary teachers' views of nature of science. *Science Education,* 88(5), 785–810.

Abd-El-Khalick, F., & BouJaoude, S. (1997). An exploratory study of the knowledge base for science teaching. *Journal of Research in Science Teaching*, 34, 673–699.

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of the nature of science: A critical review of the literature. *International Journal of Science Education, 22* (7), 665–701.

Abd-El-Khalick, F., & Lederman, N. G. (2000). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching*, 37(10), 1057–1095.

Abd-El-Khalick, F., & Lederman, N. G. (2000a). Improving science teachers' conceptions of the nature of science: A critical review of the literature. *International Journal of Science Education, 22*(7), 665–701.

Abd-El-Khalick, F., & Lederman, N. G. (2000b). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching, 37*(10), 1057–1095.

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82*(4), 417–436.

Abd-El-Khalick, F., BouJaoude, S., Duschl, R.A., Hofstein, A., Lederman, N.G., Mamlok, R., Niaz, M., Treagust, D., &Tuan, H. (2004). Inquiry in science education: *International perspectives. Science Education,* 88(3), 397–419.

Abd-El-Khalick, F., Waters, M., & Le, A. (2008). Representation of nature of science in high school chemistry textbooks over the past four decades. *Journal of Research in Science Teaching,* 45(7), 835–855.

Abell, S. K., & Smith, D. C. (1994). What is science? Preservice elementary teachers' conceptions of the nature of science. *International Journal of Science Education*, 16(4), 475– 487.

Achieve. (2013). *Next Generation Science Standards*. Retrieved 10 June 2015, from http://www.nextgenscience.org

Adams, G.R., & Schvaneveldt, J.D. (1991). *Understanding Research Methods. (*2nd Ed). New York: Longman

Aikenhead, G., & Ryan, A.G. (1992). The development of a new instrument: ‘‘Views on science–technology–society’’ (VOSTS). *Science Education*, 76, 477–491.

Aikenhead, G., Ryan, A., & Fleming, R. (1989). *Views on science–technology–society (from CDN.mc.5). S*askatoon, Canada: Department of Curriculum Studies, University of Saskatchewan

Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. Journal of *Research in Science Teaching*, 37(4), 295– 317.

Akerson, V. L., Morrison, J. A., & McDuffie, R. A. (2006). One course in not enough: Preservice teachers' retention of improved views of nature of science. *Journal of Research in Science Teaching,* 43, 194–213.

Akerson, V., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching, 37*(4), 295–317.

Akerson. L. V. & Donnelly, L.A. (2008). Relationships among Learner Characteristics and Pre-service Elementary Teachers' views of the Nature of Science. *Journal of Elementary Science Education*, 20 (1), 45-58

Aldridge, J., Taylor, P.C., & Chen, C-C. (1997). *Development, Validation and use of the beliefs about science and school questionnaire* (BASSSQ). Paper presented at the annual meeting of the National Association for Research on Science Teaching, Chicago, IL

American Association for the Advancement of Science, AAAS. (1993). *Benchmarks for scientific literacy.* New York, NY: Oxford University Press

Arinho de la Rubia, L.S., Lin, T-J. & Tsai, C-C. (2014). Cross-Cultural Comparisons of Undergraduate Student Views of the Nature of Science. *International Journal of Science Education,* 36(10), 1685-1709

Bartos, S.A., & Lederman, N.G. (2014). Teachers Knowledge Structures for Nature of Science and Scientific inquiry: Conceptions and Classroom Practice. *Journal of Research in Science Teaching*, 59 (9),1150-1184

Bayir, E., Cakici, Y. & Ertas, O. (2014). Exploring Natural and Social Scientists Views of Nature of Science. *International Journal of Science Education*, 36(8), 1286-1312

Bell, J. (2010). *Doing Your Research Project.* London: Open University Press

Bell, R. L., & Lederman, N. G. (2003). Understandings of the nature of science and decision making on science and technology issues. *Science Education, 87*(3), 352–377

Bell, R. L., Lederman, N. G., & Abd-El-Khalick, F. (2000). Developing and acting upon one's conception of the nature of science: A follow-up study. *Journal of Research in Science Teaching, 37*(6), 563–581

Bell, R.L. (1998). Teaching the Nature of Science: Three Critical Questions. Retrieved 13 March 2012 from http://www.ngsp.com/Portals/o/downloads/SCL22-0449A_AM_Bell.pdf

Bell, R.L., Blair, L.M., Crawford, & Lederman, N. G. (2003). Just Do It? Impact of a Science Apprenticeship Program on High School Students' Understandings of the Nature of Science and Scientific Inquiry. *Journal of Research in Science Teaching*, 40(5), 487-509

Bell, R.L., Lederman, N.G., & Abd-El-Khalick, F. (2000). Developing and Acting upon One's Conception of the Nature of science: A Follow-Up Study. *Journal of Research in Science Teaching*, 563-581

Bell. (1999). *Doing your Research Project*. Buckingham: Open University Press

Buck, P.E. (2003). Authentic Research experiences for Nevada High School teachers and students. *Journal of Geoscience Education*, 51(1), 48-53

Cakici, Y., & Bayir, E. (2012). Developing children's views of the nature of science through the role-play? *International Journal of Science Education*, 34(7), 1075-1091

Campion, M. A., Campion, J. E., & Hudson, J. P., (1994). Structured Interviewing: A Note on Incremental Validity and Alternative Question Type. *Journal of Applied Psychology*, 79 (6), 998-1002

Chen, S. (2006). Development of an instrument to assess views on nature of science and attitudes teaching science. *Science Education*, 90, 803-819

Chisholm, L. (2005).*'The state of Curriculum Reform in South Africa: The issue of Curriculum C2005'*in Southall, R., Habib, A., & Daniel, J., (Eds), *State of the Nation*. (HSRC, Pretoria)

Cohen, L. & Manion, M. (1994). *Research Methods in Education*. London: Routledge

Cohen, L., Manion, L. & Morrison, L. (2002). *Research Methods in Education. London*: Routledge Falmer

Cohen, L., Marion, L., & Morrison, K. (2000). Research Methods in Education (5th ed.). London: Open University Press.

Collin, H. (2010). *Creative Research: The Theory and Practice of Research for the Creative Industries*. New York. AVA Publications

Creswell, J. W. (2003). *Research design: Qualitative, quantitative and mixed approaches* (2nd Ed.). Thousand Oaks, CA: Sage.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods*

Creswell, J.W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research.* (4th Ed.). Boston: Pearson

Dawson, G. (1991). *Science Vision: An Inquiry based videodisc science curriculum.* Tallahassee, FL, Florida State University

De Boer, G.E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching*, 37(6), 582-601

De Winter, J. C. F., & Dodou, D. (2010) Five-Point Likert Items: t test versus Mann-Whitney- Wilcoxon. *Practical Assessment, Research and Evaluation,* 15(11), 1-12

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

Dekkers, P., & Mnisi, E. (2003). The nature of science – do teachers have the understandings they are expected to teach? *African Journal of Research in Mathematics, Science and Technology Education, 7*, 21-34

Dempster, E.R. & Reddy, V. (2007). Item readability and science achievements in TIMSS 2003 South Africa. *Science Education*,91(6),906-925

Deng, F., Chen, D.T., Tsai, C.C. & Chai, C.S. (2011). Students' Views of the Nature of Science: A critical review of research. *Science Education*, 95 (6), 961-999

Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 105-117) Thousand Oaks, CA: Sage

Department of Education, DoE, South Africa. CAPS (2011), Pretoria

Department of Education, Government of South Africa. (2002). *Revised National Curriculum Statement for Grades R-9 (schools) – Natural Sciences.* Government Gazette, Vol. 443, No. 23406. Pretoria.

Dogan, N., & Abd-El-Khalick, F. (2008). Turkish Grade 10 students' and science teachers' conceptions of the nature of science: A national study. *Journal of Research in Science Teaching*, 45(10), 1083-1112

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, 23, 5–12

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science*. Bristol: Open University Press.

Dudu, W.T. (2014). Exploring South African high school teachers' conceptions of the nature of scientific inquiry: A case study. *South African Journal of Education*, 34 (1), 1-19

Dudu, W.T., & Vhurumuku, E. (2012). Teachers' practices of inquiry when teaching investigations: A case study. *Journal of Science Teacher Education*, 23,579-600

Duschl, R. (1990). *Restructuring science education*. New York: Teachers College Press.

Feuer, M.J., Towne, L., & Shavelson, R.J. (2002): Scientific Culture and Educational Research. *Educational Researcher*, 3 (8), 28-39

Gaigher, E., Lederman, N.G., & Lederman. (2014). Knowledge about Inquiry: A study in South African high schools. *International Journal of Science Education*, 36(18), 3125-3147

Gall M.D., Gall, J.P., & Borg, W.R. (2003). *Educational Research: An Introduction.* Boston: Pearson Education.

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In Denzin, N.K & Lincoln, Y.S. (Eds), Handbook of qualitative research. Thousand Oaks: Sage

Haidar, A.H. (1999) Emirates pre-service and in-service teachers' views about the nature of science. *International Journal of Science Education*, 21(8), 807-822

Hatch, J. A. (2002). *Doing qualitative research in education settings.* Albany: SUNY Press.

Heine, J. S., Lehman, R.D., Peng, K & Greenholtz, J. (2002). What's wrong with cross cultural comparisons of subjective Likert Scales? The Reference Group Effect. *Journal of Personality and Social Psychology*, 82 (6), 903-918

Hodson, D. & Wong, S.L. (2014). From the Horse's Mouth: Why scientists' views are crucial to nature of science understanding. *International Journal of Science Education,* 36(16), 2639-2665

Irez, S. (2006). Are we prepared? An assessment of pre-service science teacher educators' beliefs about Nature of Science. *Science Teacher Education*, 90(6), 1113-1143

Jansen, J. (1998). Curriculum reform in South Africa: a critical assessment of outcomes-based education. *Cambridge Journal of Education*, 28(3), 321-331

Johnson, R.B. & Onwuegbuzie, A.J. (2004). Mixed methods Research: A Research Paradigm whose Time Has Come. *Educational Researcher*, 33 (7), 14-26 *Journal of Science Teacher Education*, 12, 215–233
.

Kang, S., Scharman, L.C. & Noh, T. (2004). Examining Students' Views on the Nature of science. Results from Korean 6th, 8th and 10th grades. *Science Education*, 89(2), 314-334

Khishfe, R. (2012). Nature of Science and decision making. *International Journal of Science Education,* 34 (1), 67-100

Khishfe, R. (2008). The development of seventh graders' views of nature of science. *Journal of Research in Science Teaching, 45*(4), 470–496.

Khishfe, R. (2014). Explicit Nature of Science and Argumentation instruction in the context of Socio-scientific Issues: An effect on student learning and transfer. *International Journal of Science Education*, 36(6), 974-1016

Khishfe, R., & Abd-El-Khalick, F. (2002). Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching, 39*(7), 551–578

Kriek, J. & Grayson, D. (2009). A holistic professional development for South African physical science teachers. *South African Journal of Education*,29(2),185-203

Kvale, S. (1996). *Interviews: An Introduction to qualitative research*. New York: Sage

Laugksch, R.C. (2000). Scientific literacy: A conceptual overview. *Science Education, 84(1)*, 71-94

Lave. & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. New York: Cambridge University

Lederman, J.S., Lederman, N.G., Bartos, S.A., Bartels, S.L., Meyer, A.A., & Schwartz, R.S. (2014). Meaningful assessment of Learners' Understandings about Scientific Inquiry-The Views about Scientific Inquiry (VASI) Questionnaire. *Journal of Research in Science Teaching*, 51(1), 65-83

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research in science education* (pp. 831–880). Mahwah, NJ: Lawrence Erlbaum.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research on science education. Mahwah, NJ: Erlbaum.

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 learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497–521

Lederman, N. G., Schwartz, R. S., Abd-El-Khalick, F., & Bell, R. L. (2001). Preservice teachers' understanding and teaching of the nature of science: An intervention study. *The Canadian Journal of Science, Mathematics, and Technology Education*, 1(2), 135–160.

Lederman, N.G. (1992). Students' and teachers' Conceptions of the Nature of Science: A Review of the Research. *Journal of Research in Science Teaching*, 29(4), 331-359

Lederman, N.G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching*, 36, 916–929

Lederman, N.G., & O'Malley, M. (1990). Students' perceptions of tentativeness in science: Development, use, and sources of change. *Science Education*, 74, 225–239

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 learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39(6), 497–521.*

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 Learners' Conceptions of Nature of Science. *Journal of Research in Science Teaching*, 39(6), 497-521

Lederman, N.G., Antik, A., & Bartos, S. (2014). Nature of Science, Scientific Inquiry and Socio-Scientific Issues Arising from Genetics: A pathway to developing a Scientific Literate Citizenry. *Science and Education,* 23,285-302

Lin, S-Y., & Lederman, N.G. (2007). Exploring prospective Teachers worldviews and conceptions of the nature of science. *International Journal of Science Education,* 29, 1281-1307

Lineman, S.R., Lynch, P., Kurup, R., Web, P., & Bantwini, B. (2003). South African Teachers' Perceptions of the Nature of Science. *African Journal of Research in Mathematics, Science and Technology Education,* 7 (1), 35-50

Litchman, M. (2000). *Qualitative Research in Education: A user's guide.* Thousand Oaks: SAGE

Liu, S.Y., & Tsai, C.C. (2008). Differences in the scientific epistemological views of undergraduate students. *International Journal of Science Education*, 30(8), 1055-1073

Macaroglu, E., Tasar, M.F., & Cataloglu, E. (1998). Turkish pre-service elementary school teachers' beliefs about the nature of science. Paper presented at the annual meeting of the national association for research in science teaching, San Diego, CA

Makgato, M. (2007). Factors associated with the poor performance of learners in mathematics and physical science in secondary schools in Soshanguve South Africa. Africa Education Review,4(1),89-05

Matthews, M. (1998a). In defence of modest goals when teaching about the nature of science. *Journal of Research in Science Teaching*, 35(2), 161 – 174.

Matthews, M. R. (1994). *Science teaching: The role of history and philosophy of science*. New York: Routledge.

McComas, W. F., Clough, M. P., & Almzroa, H. (1998). *The role and character of the nature of science in science education. In W. F. McComas (Ed.), The nature of science in science education: Rationales and strategies* (pp. 3–39). Dordrecht: Kluwer Academic Publishers

McComas, W.F. (1996). Ten myths of science: Re-examining what we think we know about the nature of science*. School Science and Mathematics*, 96, 10–16.

McComas, W.F. (1998). *The nature of science in science education: Rationales and strategies.* Dordrecht, Netherlands: Kluwer Academic Publishers.

McComas, W.F., & Olson, J.K. (1998). *The nature of science in international science education standards documents*. In W.F. McComas (Ed.), The nature of science in science education: Rationales and strategies (pp. 41–52). Dordrecht: Kluwer.

McMillan, J. H. (2006). *Research in Education. Evidence-based Inquiry*. Boston: Pearson

McMillan, J. H., & Schumacher. (1993). *Research in Education: A Conceptual Introduction.* New York: Harper Collins College Publishers

Meichtry, Y. J. (1999). The nature of science and scientific knowledge: Implications for a preservice elementary methods course. *Science & Education*, 8, 273– 286.

Meichtry, Y.J. (1993). The impact of science curricula on students' views about the nature of science. *Journal of Research in Science Teaching*, 30(5), 429-443

Meichtry, Y.J. (1998). *Elementary science methods: Developing and measuring students' views about the nature of science*. In McComas, W.F., (Ed), The Nature of Science in Science Education: Rationales and Strategies

Mertens, D. M. (2005) *Research methods in education and psychology. Integrating diversity with quantitative and qualitative approaches*. (2nd Ed). Thousand Oaks: Sage

Millar, R. (2006). Twenty-first century science: Insights from the design and implementation of a scientific literacy approach in school science. *International Journal of science Education*, 28, 1499-1521

Mji, A., & Makgatho, M. (2006). Factors associated with high school learners' poor performance: A spotlight on mathematics and physical science. *South African Journal of Education*, 26, 253-266

Monk, M., & Osborne, J. (1997). Placing the history and philosophy of science on the curriculum: A model for the development of pedagogy. *Science Education*, 81(4), 405–424

Morrison, J. A., Raab, F., & Ingram, D. (2009). Factors influencing elementary and secondary teachers' views on the nature of science. *Journal of Research in Science Teaching*, 46(4), 384–403

Moss, D., Abrams, E., & Robb, J. (2001). Examining student conceptions of the Nature of Science. *International Journal of Science Education*, 23, 771-790

Moss, D.M. (2001) Examining student conceptions of the nature of science, *International Journal of Science Education*, 23:8, 771-790

Mouton, J. (1996). *Understanding Social Research*. Pretoria: Van Schaik

National Research Council (NRC) (2000). National science education standards. Washington, DC: National Academy Press.

National Research Council, NRC, (1996). *National Science Education Standards*. Washington DC, National Academic Press

Ogunniyi, M.B. (1983). Relative effects of a history/philosophy of science course on student teachers' performance on two models of science. *Research in Science & Technological Education,* 1, 193–199.

Ogunniyi, M.B. (2006). Effects of a discursive course on two science teachers' perceptions of the Nature of Science. *African Journal of Research in Science, Mathematics and Technology Education*, 10(1), 93-102

Opie, C. (2004). *Doing educational research*. Sage. London. Chapter 7: Presenting data. pp. 130-150.

Palmquist, B.C. & Finley, F.N. (1997). Pre-service Teachers' views of the Nature of science during a post-baccalaureate science-teaching program. *Journal of Research in Science Teaching*, 34(6), 15-42

Pomeroy, D. (1993). Implications of teachers' beliefs about the nature of science: Comparison of the beliefs of scientists, secondary science teachers, and elementary teachers. *Science Education*, 77(3), 261–278.

Ramnarain, U. (2010). A report card on learner autonomy in science investigations. African Journal Research in Mathematics, Science and Technology Education, 14, 61-72

Rannikmae, A., Rannikmae, M., & Holbrook, J. (2006). Nature of science as viewed by non-science undergraduates. *Journal of Baltic Science Education,* 2(10), 70-85

Ryan, A.G., & Aikenhead, G.S. (1992). Students' preconceptions about the epistemology of science. *Science Education*, 76, 559–580

Sadler, T. D., Chambers, F. W., & Zeidler, D. L. (2004). Student conceptualizations of the nature of science in response to a socio-scientific issue. *International Journal of Science Education, 26*, 387–409

Sarkar, A.M., (2010). Science teachers' conceptions of nature of science: The case of Bangladesh. *Asia-Pacific Forum on Science Learning and Teaching,*11(1),1-15

Shenton. A.K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information*,22,63-75

Schwartz, R. S., & Lederman, N. G. (2002). 'It's the nature of the beast': The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in Science Teaching, 39*(3), 205–236

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing views of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88*, 610–645

Schwartz, R.S., Lederman, N.G. & Crawford. (2004). Developing Views of Nature of Science in an Authentic Context: An Explicit Approach to Bridging the Gap between Nature of Science and Scientific Inquiry, *Science Teacher Education*

Scott, D. & Usher, R. (2004) *Understanding Educational Research*. New York: Routledge, New York

Sedibe, K. (1998). Dismantling apartheid education: an overview change. Cambridge Journal of Education, 28 (3), 269-282

Seyan, H.T., & Turk, G.E. (2015). An investigation of the relationship between performance in the problem-solving laboratory applications and views about the nature of science. *Procedia-Social and Behavioural Sciences*, 106, 401-410

Shank, & Brown. (2007). *Exploring Educational Research Literacy.* New York, Routledge

Silverman, D. (2000). *Doing qualitative research: A practical handbook*. London, Thousand Oaks

Thomas, G. (2009). *How to do your Research Project*. London: Sage

Thye, T.I., & Kwen, B.H (2004). Assessing the nature of Science Views of Singaporean Pre-Service teachers. *Australian Journal of Teacher Education,* 29 (2), 1-10

Tsai, C.-C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning and science. *International Journal of Science Education,* 24(8), 771–783

Van Der Horst, T. H., & McDonald, R. (1997). *OBE. A teacher's manual*. Pretoria. Kagiso.

Vhurumuku, E. (2013). The impact of explicit instruction on undergraduate students' understanding of the Nature of Science. *African Journal of Research in Mathematics, Science and Technology Education*, 14 (1), 99-111

Vhurumuku, E., & Mokeleche, M. (2009). The nature of science and indigenous knowledge systems in South Africa, 2000-2007.A critical review of research in science education. *African Journal of Research in Mathematics, Science and Technology Education*, 13 (1), 96-114

Walker, K.A. & Zeidler, D.L. (2007). Promoting discourse about socio-scientific issues through scaffold inquiry. *International Journal of Science Education*, 29(11), 1387-1410

Wallace, C.S., & Kang, N.H. (2004). Investigation of experienced secondary science teachers' beliefs about Inquiry. An examination of competing belief set. *Journal of Research in Science Teaching,* 41(9), 936-960

Walls, L. (2012). Third Grade African-American students' views of the Nature of Science. *Journal of Research in Science Teaching*, 49, 1-37

Wilson, J. (2008). *Essentials of Business Research: A guide to doing your Research Project.* Thousand Oaks: SAGE

Wong, S., & Hodson, D. (2008). From the horse's mouth: What scientists say about scientific investigations and scientific knowledge. *Science Education*, 93(1), 109-130

Yoon. S., Suh, J.K. & Park, S (2014). Korean Students' Perceptions of scientific Practices and Understanding of Nature of Science*. International Journal of Science Education*, 36 (16), 2666-2693

Appendices

Appendix 1

Views of What Occurs in Science Questionnaire (VAWOSQ)

Appendix

Your Views About What Occurs in Science

Please indicate how often, in your opinion, each practice **occurs in science.**

Process of Scientific Inquiry		Almost Never	Seldom	Some-times	Often	Almost Always
1.*	Scientific observations depend on what scientists set out to find.	1	2	3	4	5
2.	Scientific inquiry involves challenging other scientists' ideas.	1	2	3	4	5
3.	Scientific observations are affected by scientists' values and beliefs.	1	2	3	4	5
4.*	Scientific inquiry involves thinking critically about one's existing knowledge.	1	2	3	4	5
5.	Intuition plays a role in scientific inquiry.	1	2	3	4	5
6.	When making observations, scientists eliminate their beliefs and values.	1	2	3	4	5
7.	Scientific observations are guided by theories.	1	2	3	4	5
8.	Scientific inquiry starts with observations of nature.	1	2	3	4	5
9.	Scientific investigation follows the scientific method.	1	2	3	4	5
10.	Scientific ideas come from both scientific and non-scientific sources.	1	2	3	4	5
Certainty of Scientific Knowledge		**Almost Never**	**Seldom**	**Some-times**	**Often**	**Almost Always**
11.	Scientific knowledge gives a true account of the natural world.	1	2	3	4	5
12.	Scientific knowledge is tentative.	1	2	3	4	5
13.	Scientific knowledge is relative to the social context in which it is generated.	1	2	3	4	5
14.*	Scientific knowledge can be proven.	1	2	3	4	5
15.	The evaluation of scientific knowledge varies with changes in situations.	1	2	3	4	5
16.	The accuracy of current scientific knowledge is beyond question.	1	2	3	4	5
17.*	Currently accepted scientific knowledge will be modified in the future.	1	2	3	4	5
18.	Scientific knowledge is influenced by cultural and social attitudes.	1	2	3	4	5
19.	Scientific knowledge is free of human perspectives.	1	2	3	4	5
20.	Scientific knowledge is influenced by myths.	1	2	3	4	5

14

Appendix 2

Interview schedule

This schedule is for the interview of the participants after analysing the responses of the items on the BASSSQ questionnaire.

1.The ***"scientific method"*** is often described as involving the steps of making a hypothesis, identifying variables (dependent/independent), designing an experiment, collecting data, reporting results. Do you agree that to do good science, scientists must follow the scientific method?

☐ **YES**, scientists must follow the scientific method

☐ **NO,** there are many scientific methods

• If **YES** (you think all scientific investigations must follow a standard set of steps or method), describe why scientists must follow this method.

_____

_____

• If **NO** (you think there are multiple scientific methods), explain how the methods differ and how they can still be considered scientific.

_____

_____

2. Is ***"data"*** the same or different from ***"evidence"?*** Explain.

_____

_____

3. After scientists have developed a **scientific theory** (e.g. atomic theory, evolutionary theory), does the **theory ever change?**

☐ YES ☐ NO

Explain why

_____

_____

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

_____

_____

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

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

If you believe that science is universal, explain why. Defend your answer with an example

Appendix 3

Views About What Occurs in Science Questionnaire: Grade 11 learners' response data

Item	Learner scores per item									
Process of Scientific Inquiry	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**	**L10**
1.Scientific observation depend on what scientists set out to find	4	4	4	4	3	3	5	3	1	4
2.Scientific inquiry involves challenging other scientists 'ideas	4	5	4	2	4	4	4	3	2	4
3.Scientists observations are affected by scientists 'values and beliefs	3	2	4	3	1	2	4	4	1	3
4.Scientific inquiry involves thinking critically about one's existing knowledge	5	4	5	5	4	3	3	4	2	4
5.Intuition plays a role in scientific inquiry	4	3	4	5	3	3	4	3	1	4
6. When making observations, scientists eliminate their beliefs and values*	*4*	*2*	*2*	*3*	*5*	*3*	*1*	*4*	*5*	*2*
7.Scientific observations are guided by theories	5	4	4	3	5	4	4	4	3	4
8. Scientific inquiry starts with observations of nature*	*4*	*5*	*3*	*3*	*5*	*3*	*4*	*4*	*4*	*4*
*9*Scientific investigations follow the scientific method*	*5*	*5*	*4*	*3*	*5*	*3*	*4*	*4*	*4*	*4*
10.Scientific ideas come from both scientific and non-scientific sources	3	5	4	4	5	2	2	3	4	2
Certainty of scientific knowledge (NOSK)										
*11*Scientific knowledge gives a true account of the world*	*4*	*4*	*5*	*5*	*4*	*2*	*5*	*4*	*4*	*4*
12.Scientific knowledge is tentative	4	5	5	3	5	3	3	3	2	4
13.Scientific knowledge is relative to the context in which it is generated	4	4	5	4	3	3	3	4	2	4
*14*Scientific knowledge can be proven*	*5*	*5*	*4*	*5*	*5*	*3*	*3*	*4*	*4*	*5*
15.The evaluation with scientific knowledge varies with changes in situations	4	4	4	5	5	3	5	3	4	3
*16*The accuracy of current scientific knowledge is beyond question*	*3*	*1*	*3*	*4*	*1*	*2*	*3*	*4*	*3*	*4*
17.Currently accepted scientific knowledge will be modified in the future	5	5	5	3	3	3	4	5	3	5
18.Scientific knowledge is influenced by cultural and social attitudes	4	2	4	3	2	2	3	5	1	2
*19*Scientific knowledge is free of human perspectives*	*3*	*3*	*3*	*3*	*4*	*2*	*1*	*3*	*2*	*2*
20.Scientific knowledge is influenced by myths	2	3	4	2	3	1	2	3	2	1
Median Score	**4**	**4**	**4**	**3**	**4**	**3**	**4**	**4**	**4**	**4**

Item

Higher score means more informed view: 1

Lower score means more informed view: *6**

Key

Categories

Naïve

Developing

Informed

Appendix 4

Views About What Occurs in Science Questionnaire (VAWOSQ): Pre-service Teacher (PST) Response Data

Item	Pre-Service Teacher (PST) Scores									
Process of Scientific Inquiry	**PST 1**	**PST 2**	**PST3**	**PST4**	**PST 5**	**PST6**	**PST 7**	**PST 8**	**PST 9**	**PST 10**
1.Scientific observation depend on what scientists set out to find	3	4	4	4	4	2	5	5	4	3
2.Scientific inquiry involves challenging other scientists 'ideas	3	3	3	4	3	3	4	4	5	5
3.Scientists observations are affected by scientists 'values and beliefs	1	2	5	2	2	4	5	3	3	3
4.Scientific inquiry involves thinking critically about one's existing knowledge	4	5	4	3	5	4	4	4	4	5
5.Intuition plays a role in scientific inquiry	4	3	4	5	5	2	5	5	3	2
6. When making observations, scientists eliminate their beliefs and values*	*3*	*4*	*2*	*4*	*1*	*5*	*3*	*4*	*5*	*3*
7.Scientific observations are guided by theories	4	4	4	3	2	5	4	4	4	5
8. Scientific inquiry start with observations of nature*	*4*	*4*	*5*	*4*	*3*	*3*	*4*	*5*	*4*	*5*
*9*Scientific investigations follow the scientific method*	*5*	*5*	*4*	*4*	*3*	*4*	*5*	*5*	*5*	*5*
10.Scientific ideas come from both scientific and non-scientific sources	3	5	4	4	4	4	5	2	3	4
Certainty of scientific knowledge (NOSK)										
*11*Scientific knowledge gives a true account of the world*	*4*	*3*	*3*	*4*	*1*	*3*	*4*	*5*	*4*	*5*
12.Scientific knowledge is tentative	4	4	5	5	5	4	5	4	5	5
13.Scientific knowledge is relative to the context in which it is generated	4	4	4	3	3	2	5	4	3	3
*14*Scientific knowledge can be proven*	*5*	*3*	*4*	*4*	*5*	*4*	*5*	*5*	*5*	*5*
15.The evaluation with scientific knowledge varies with changes in situations	4	4	3	4	4	4	5	2	5	4
*16*The accuracy of current scientific knowledge is beyond question*	*3*	*1*	*2*	*5*	*2*	*3*	*2*	*1*	*5*	*2*
17.Currently accepted scientific knowledge will be modified in the future	3	4	5	4	3	3	5	4	2	4
18.Scientific knowledge is influenced by cultural and social attitudes	2	4	4	4	2	4	2	3	3	2
*19*Scientific knowledge is free of human perspectives*	*3*	*3*	*2*	*2*	*4*	*3*	*3*	*1*	*5*	*4*
20.Scientific knowledge is influenced by myths	1	2	2	3	4	3	1	2	1	3
Median Score	**3,5**	**4**	**4**	**4**	**3**	**3,5**	**4,5**	**4**	**4**	**4**

Item

Higher score means more informed view: 1

Lower score means more informed view: *6**

Key

Categories: views

Naïve

Developing

Informed

Appendix 5

Mann-Whitney *U* Test

This is a simple Mann-Whitney *U* test calculator that provides a detailed breakdown of ranks, calculations, data and so on.

The Mann-Whitney *U* test is a nonparametric test that allows two groups or conditions or treatments to be compared without assuming that values are normally distributed.

Median Scores of VAWOSQ for Grade 11 Learners and Pre-service teachers, PST

Grade 11 Learners	Median Score	Pre-service teacher	Median score
Learner 1	4	PST 1	3.5
Learner 2	4	PST 2	4
Learner 3	4	PST 3	4
Learner 4	3	PST 4	4
Learner 5	4	PST 5	3
Learner 6	3	PST 6	3.5
Learner 7	3.5	PST 7	4.5
Learner 8	3.5	PST 8	4
Learner 9	4	PST 9	4
Learner 10	4	PST 10	4

Null Hypothesis

The null hypothesis: H_0: asserts that the medians of the two samples are identical.

H_0: There is no difference in the understanding of the nature of science, NOS, of the Grade 11 learners and the Pre-service teachers

Equation

$$U = NM + \frac{N(N+1)}{2} - \sum_{x_i} Rank(x_i)$$

Result Details

Grade 11 Learner sample

Sum of ranks: 96
Mean of ranks: 9.6
Expected sum of ranks: 105
Expected mean of ranks: 10.5
U-value: 59
Expected *U*-value: 50

Pre-service teacher sample

Sum of ranks: 114
Mean of ranks: 11.4
Expected sum of ranks: 105
Expected mean of ranks: 10.5
U-value: 41
Expected *U*-value: 50

Grade 11 Learner sample and Pre-service teacher sample Combined
Sum of ranks: 210
Mean of ranks: 10.5
Standard Deviation: 13.2288

Significance Level:

- ○ 0.01
- ◉ 0.05

1 or 2-tailed hypothesis:

- ○ One-tailed
- ◉ Two-tailed

Result 1 - U-value

The *U*-value is 41. The critical value of *U* at $p < .05$ is 23. Therefore, the result is *not* significant at $p < .05$.

Result 2 - Z-ratio

Result 2 - Z-ratio

The *Z*-Score is -0.64254. The *p*-value is .52218. The result is *not* significant at $p < .05$.

Appendix 6

Information for the school principal

University of the Witwatersrand, Johannesburg, South Africa
School of Education
Marang Centre for Maths and Science Education
27 St Andrews Road
Park town, 2193
August 5, 2015
Cell: 082 799 7756
E-mail: musekiwakiz@yahoo.com

Dear Sir/Madam

Re: REQUEST FOR PERMISSION TO DO RESEARCH AT YOUR SCHOOL

I am a student at the University of the Witwatersrand studying for an MSc Science education degree. I am doing research on a comparison of the understanding of the nature of science between Bachelor of Education pre-service teachers and Grade 11 high school students. The study seeks to find out if there is a difference in understanding of the nature of science between high school students and pre-service teachers in the South African context. Previous researches have shown that both teachers (in-service and pre-service) and students hold naïve views about the nature of science.

The following research questions will guide the study:

1. What are the Grade 11 learners' understandings of the nature of science?

2. What are the Bachelor of Education pre-service teachers' understandings of the nature of science?

3. To what extent are the high school learners' and pre-service teachers' understanding of the nature of science different?

The research procedures will include learners responding to questionnaire items and doing follow up interviews with the researcher. I am aware of the ethics in human subject research and I have put in place several provisions to safeguard the learners in this project. For example, I do not intend to disrupt or inconvenience teachers in their implementation of the curriculum. The administration of the questionnaires and follow up interviews will be conducted after hours. Other ethical considerations include:

- Data collected will be used strictly for the research purposes.
- Written consent will be obtained from parents and learners (see attached)

Please be assured that teaching and learning activities will not be disrupted at all times when this research is conducted.

Please feel free to contact me at any time if you have questions or concerns about the research.

Sincerely



Kizito Musekiwa (Researcher) Date

Appendix 7

Information for Parents/Guardian

University of the Witwatersrand, Johannesburg, South Africa

School of Education
Marang Centre for Mathematics & Science Education
27 St Andrews Road
Park town, 2193
August 5, 2015

Cell: 082 799 7756
E-mail: musekiwakiz@yahoo.com

Dear Parent/Guardian/Learner

RE: INFORMATION AND REQUEST FOR PARTICIPATION CONSENT

Introduction

I am a student at the University of the Witwatersrand studying for an MSc Science education degree. I am doing research on a comparison of the understanding of the nature of science between Bachelor of Education pre-service teachers and Grade 11 high school students. The study seeks to find out if there is a difference in understanding of the nature of science between high school students and pre-service teachers in the South African context. Previous researches have shown that both teachers (in-service and pre-service) and students hold naïve views about the nature of science.

Description and Invitation

Your child is hereby invited to participate in the study. The proposed research will be carried out at your child's school. It involves your child responding to a questionnaire and being interviewed. The interview will be audio taped. I will have one interview with your child if he or she is selected at random from a group of other students.

Confidentiality

Unless you request otherwise, you/your child's name will be kept confidential at all times and in all academic writings about the study.

Time involvement

Administration of questionnaires and interviews will be conducted after normal school teaching hours.

Please be assured that teaching and learning activities will not be disrupted at all times when this research is conducted.

Volunteering to Be Part of this Research Study- Participant rights

If you have read this form and have decided to allow your child to participate in this project, kindly understand that your child's participation is voluntary and your child has a right to withdraw consent or discontinue participation at any time without penalty. Your child has the right not to answer questions. Your child's individual privacy will be maintained in all published and written data resulting from the study. Pseudonyms will be used always.

Anonymity and confidentiality

The anonymity and confidentiality of your/your child's participation is guaranteed at all times. Pseudonyms will be used and the researcher and the supervisor only will access data collected

Consent

Please complete, sign and return the form below, indicating whether you agree or do not agree to participate.

Thank you.

Yours sincerely



Kizito Musekiwa Date

(Researcher)

Appendix 8

Interview consent form (Parent/Guardian)

I ……of……

……

…… (Address) have read and understood the procedures involved in the study and what is required of my child as a participant. I willingly give the following consents:

Please put a tick in the appropriate response

I am willing to allow my child to participate in the study.

Yes No

I give consent for my child to be interviewed in the study

Yes No

I give consent for my child to be audio taped:

Yes No

The extra copy of this form is for you to keep

Thank you.

Name of learner

Signature of teacher ***Date***

Name of parent/guardian *(Please print*

Appendix 9

Questionnaire consent form (Parent /Guardian)

I, ...of……..

.....

(Address) have read and understood the procedures involved in the study and what is expected of me as a participant? I willingly give the following consents:

Please put a tick at the appropriate response

I am willing to allow my child to participate in the study

Yes No

I give consent to my child to respond to questionnaire items

Yes No

The extra copy of this form is for you to keep

Thank you.

Signature of* Parent /Guardian** ***Date

Appendix 10

Consent form for School Principal

I……of……

……. .....

(School) have read and understood the procedures involved in the study I willingly give the following consents:

Please put a tick at the appropriate response

I am willing to allow my school participate in the study.

Yes No

The extra copy of this form is for you to keep

Thank you.

Signature of School Principal ***Date***

Please print your name

Appendix 11

Information for Bachelor of Education student: Bachelor of Education: **Pre-service teacher**

University of the Witwatersrand, Johannesburg, South Africa
School of Education
Marang Centre for Mathematics & Science Education
27 St Andrews Road
Park town, 2193

August 5, 2015

Cell: 082 799 7756
E-mail: musekiwakiz@yahoo.com

Dear Student

RE: INFORMATION AND REQUEST FOR PARTICIPATION CONSENT

Introduction

I am a student at the University of the Witwatersrand studying for an MSc Science education degree. I am doing research on a comparison of the understanding of the nature of science between Bachelor of Education pre-service teachers and Grade 11 high school students. The study seeks to find out if there is a difference in understanding of the nature of science between high school students and pre-service teachers in the South African context. Previous researches have shown that both teachers (in-service and pre-service) and students hold naïve views about the nature of science.

Description and Invitation

You are hereby invited to participate in the study. The proposed research will be carried out at your university. It involves you responding to a questionnaire and being interviewed. The interview will be audio taped. I will have an interview with you if you are selected at random from a group of other participants.

Confidentiality

Unless you request otherwise, your name will be kept confidential at all times and in all academic writings about the study.

Time involvement

Administration of questionnaires and interviews will be conducted after normal university teaching hours.

Please be assured that teaching and learning activities will not be disrupted at all times when this research is conducted.

Volunteering to Be Part of this Research Study- Participant rights

If you have read this form and have decided to participate in this project, kindly understand that your participation is voluntary and you have the right to withdraw consent or discontinue participation at any time without penalty. You have the right not to answer particular questions. Your privacy will be maintained in all published and written data resulting from the study. Pseudonyms will be used always.

Anonymity and confidentiality

The anonymity and confidentiality of your participation is guaranteed at all times. Pseudonyms will be used and data collected will be accessed by the researcher and the supervisor only.

Consent

Please complete, sign and return the form below, indicating whether you agree or do not agree to participate.

Thank you.

Yours sincerely



Kizito Musekiwa Date

(Researcher)

Appendix 12

Information for the Head of School of Education: University of the Witwatersrand

University of the Witwatersrand, Johannesburg, South Africa
School of Education
Marang Centre for Maths and Science Education
27 St Andrews Road
Park town, 2193

August 5, 2015

Cell: 082 799 7756
E-mail: musekiwakiz@yahoo.com

Dear Sir/Madam

Re: REQUEST FOR PERMISSION TO DO RESEARCH AT YOUR SCHOOL

I am a student at the University of the Witwatersrand studying for an MSc Science education degree. I am doing research on a comparison of the understanding of the nature of science between Bachelor of Education pre-service teachers and Grade 11 high school students. The study seeks to find out if there is a difference in understanding of the nature of science between high school students and pre-service teachers in the South African context. Previous researches have shown that both teachers (in-service and pre-service) and students hold naïve views about the nature of science.

The following research questions will guide the study:

1. What are the grade 11 learners' understandings of the nature of science?

2. What are the Bachelor of Education pre-service teachers' understandings of the nature of science?

3. To what extent are the high school learners' and pre-service teachers' understanding of the nature of science different?

The research procedures will include learners responding to questionnaire items and doing follow up interviews with the researcher. I am aware of the ethics in human subject research and I have put in place a number of provisions to safeguard the learners in this project. For example, I do not intend to disrupt or inconvenience teachers in their implementation of the curriculum. The administration of the questionnaires and follow up interviews will be conducted after hours. Other ethical considerations include:

- Data collected will be used strictly for the research purposes.

- Written consent will be obtained from parents and learners (see attached)

Please be assured that teaching and learning activities will not be disrupted at all times when this research is conducted

Please feel free to contact me at any time if you have questions or concerns about the research.

Sincerely



Kizito Musekiwa

Researcher Date

Appendix 13

Interview consent form: Bachelor of Education student: Pre-service teachers

I ……of……

……

…… (Address) have read and understood the procedures involved in the study and what is required of me as a participant. I willingly give the following consents:

Please put a tick in the appropriate response

I am willing to participate in the study.

Yes No

I give consent to be interviewed in the study

Yes No

I give consent to be audio taped:

Yes No

The extra copy of this form is for you to keep

Thank you.

Name of Student

Signature of student ***Date***

Appendix 14

Questionnaire consent form: Bachelor of Education Student; Pre-service teacher

I, ...of……

.....

(Address) have read and understood the procedures involved in the study and what is expected of me as a participant? I willingly give the following consents:

Please put a tick at the appropriate response

I am willing to participate in the study

Yes No

I give consent to respond to questionnaire items

Yes No

The extra copy of this form is for you to keep

Thank you.

Signature of* Parent / Guardian** ***Date

Please print your name

Appendix 15

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

For administrative use:
Reference no: D2016 / 233
enquiries: Diane Buntting 011 843 6503

GDE RESEARCH APPROVAL LETTER

Date:	**21 August 2015**
Validity of Research Approval:	**21 August 2015 to 2 October 2015**
Name of Researcher:	**Musekiwa K.**
Address of Researcher:	**9 Summer Place; 150 Ferreira Street; Kenilworth; Johannesburg; 2190**
Telephone / Fax Number/s:	**011 434 2044; 082 799 7756**
Email address:	**musekiwakiz@yahoo.com**
Research Topic:	**A comparison of the pre-service teachers' and Grade 11 learners' understanding of the nature of Science.**
Number and type of schools:	**ONE Secondary School**
District/s/HO	**Ekurhuleni South**

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved. A separate copy of this letter must be presented to the Principal, SGB and the relevant District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted. However participation is VOLUNTARY.

The following conditions apply to GDE research. The researcher has agreed to and may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

CONDITIONS FOR CONDUCTING RESEARCH IN GDE

1. The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter;
2. A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB);

2015/08/24

Office of the Director: Knowledge Management and Research
9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506
Email: David.Makhado@gauteng.gov.za
Website: www.education.gpg.gov.za

Appendix 16

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

OFFICE OF THE DEPUTY REGISTRAR

15 October 2015

Ms Kizito Musekiwa
Student number: 545570

TO WHOM IT MAY CONCERN

"A comparison of pre-service teachers' and grade 11 students' understanding of the nature of science"

This letter serves to confirm that the above project has received permission to be conducted on University premises, and/or involving staff and/or students of the University as research participants. In undertaking this research, you agree to abide by all University regulations for conducting research on campus and to respect participants' rights to withdraw from participation at any time.

This notice serves as proof that the University's internal mailing system may be used as the mechanism by which potential participants can be approached.

If you are conducting research on certain student cohorts, year groups or courses within specific Schools and within the teaching term, permission must be sought from Heads of School or individual academics.

The necessary ethical clearance has been obtained.

Nicoleen Potgieter
Deputy Registrar

Private Bag 3, Wits, 2050, South Africa | **T** +27 11 717 1204/8 | **F** +27 86 553 2271 | www.wits.ac.za

Appendix 17

Wits School of Education

27 St Andrews Road,
Park town,
Johannesburg,
2193 Private Bag 3,
Wits 2050,
South Africa.
Tel: +27 11 717-3064
Fax: +27 11 717-3100
E-mail:
enquiries@educ.wits.ac.za
Website: www.wits.ac.za

04 September 2015
Student Number: 545570
Protocol Number: 2015ECE044M
Dear Kizito Musekiwa

Application for ethics clearance: Master of Science

Thank you very much for your ethics application. The Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate, has considered your application for ethics clearance for your proposal entitled:

A comparison of Grade 11 learners and pre-service teachers' understandings of NOSI

The committee recently met and I am pleased to inform you that **clearance was granted**.

Please use the above protocol number in all correspondence to the relevant research parties (schools, parents, learners etc.) and include it in your research report or project on the title page. The Protocol Number above should be submitted to the Graduate Studies in Education Committee upon submission of your final research report.

All the best with your research project.

Yours sincerely,
Wits School of Education
011 717-3416
cc- Supervisor: Professor E Vhurumuku