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Lesotho high school learners' understandings of the nature of scientific inquiry in relation to classroom experiences

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STUDENT NUMBER: **386288**

A research report

SUBMITTED TO THE FACULTY OF SCIENCE,

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

In partial fulfilment of the requirements for the Degree of

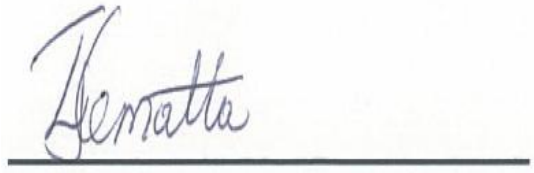
MASTER OF SCIENCE IN SCIENCE EDUCATION

SUPERVISOR: Prof. Vhurumuku Elaosi

OCTOBER 2011

DECLARATION

I declare that, apart from the sources acknowledged, this research report is my own unaided work. It is being submitted in partial fulfilment for the degree of Master of Science in Science Education to the University of the Witwatersrand, Johannesburg, and has not been previously submitted for any degree or examination at any other university.



Lieketseng Justinah Lematla

10th day of October 2011

DEDICATION

This work is dedicated to **My God** for the strength and wisdom He gave me from the beginning to the end of this course.

It is also dedicated to my mother **'Mampesa Lematla**, my husband **Atang Mphata** and my twin girls **Tlotliso** and **Tlotlisang Mphata**.

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LIST OF ACRONYMS

NOSI: Nature of scientific inquiry

NOS: Nature of science

LUSSI: Learners' understanding of science and scientific inquiry

PSI-S: Principles of scientific inquiry- students

COSC: Cambridge Overseas School Certificate

MOET: Ministry of Education and Training

OR: Open-ended responses

LR: Likert responses

ECOL: Examination Council of Lesotho

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Lesotho High School learners' understandings of the nature of scientific inquiry in relation to classroom experiences

Abstract

This study investigates learners' understandings of the nature of scientific inquiry (NOSI) in relation to their classroom experiences. Using the constructs of nature of scientific inquiry; inquiry-based teaching and learning; and principles of scientific inquiry as theoretical lenses, the study empirically explored learners' (n = 120) understandings of the nature of scientific inquiry which were captured through a questionnaire called Learners' understanding of science and scientific inquiry (LUSSI) and interviews and their perceptions of classroom inquiry (their experiences of inquiry were elicited through a questionnaire called Principles of scientific inquiry- student (PSI-S) and interviews). The participants were one hundred and twenty learners, 60 from each of two schools in an Education District in Lesotho. Eight learners, four from each school participated in the interviews. At the centre, the investigation sought to understand whether there was any relationship between learners' perceptions of their experiences of scientific inquiry and their understandings of the nature of scientific inquiry. As a result, this study was guided by the following questions: what are learners' understandings of the nature of scientific inquiry? What are learners' perceptions of their experiences of scientific inquiry? Are learners' understandings of NOSI in any way related to their experiences of scientific inquiry? Typological approach was used to analyse the qualitative data and descriptive statistics for analysing the quantitative data. The results of this study suggest that learners hold less informed understandings of the nature of scientific inquiry and that learners are experiencing closed-inquiry in their science classroom. The results also show that other learners' experiences of scientific inquiry are not related to their understandings of the nature of scientific inquiry. It was recommended that teachers should engage learners in inquiry activities rather than always carrying out teacher-demonstrations. It is also recommended that further studies should be done in Lesotho to examine the relationship between learners' understandings of NOSI and their perceptions of their classroom experiences.

Key words:

Scientific inquiry; understandings of nature of scientific inquiry; inquiry teaching and learning; learners' perceptions of scientific inquiry; nature of science; constructivism.

CHAPTER 1

INTRODUCTION TO THE STUDY

1. Introduction

This study investigated Lesotho High School learners' understandings of the nature of scientific inquiry and their relationship to learners' experiences of scientific inquiry as assessed through learners' perceptions. The development of learners' understandings of the nature of scientific inquiry (NOSI) is an important science education curriculum goal (Wong & Hodson, 2008; Schwartz, Lederman & Crawford, 2004). Scientific inquiry refers to the processes through which scientific knowledge is developed and validated, including "… the conventions and ethics involved in the development, acceptance, and utility…" of that knowledge (Schwartz al., 2004, p. 611). The NOSI is about the ideas, beliefs, views, perceptions and assumptions concerning scientific inquiry, harboured by an individual.

It has been suggested that learners can best learn about NOSI if they are involved in "authentic inquiry" activities that are explicitly designed to develop their understandings of NOSI (Wong & Hodson, 2008). Authentic inquiry means practicing science in ways similar to what professional scientists do in their daily endeavours. Wong and Hodson (2008) suggest a variety of strategies for developing learners' NOSI understandings through authentic inquiry. These activities include giving learners opportunities to: ask questions; design and plan investigations; solve problems; formulate hypotheses, decide which observations to make and how to record them; independently interpreting data; communicating results; and engaging in discourse among themselves and with the teacher as well as seeking alternative explanations to problems, and applying information to solving novel problems. There is an underlying assumption that engaging learners in authentic inquiry can lead to their developing desirable or informed understandings of NOSI. This is particularly so if such development is done through explicit strategies specifically designed to promote learners NOSI understandings (Lederman, 2007). While this is so the exact nature of the relationship between involving learners in authentic inquiry and their understandings of NOSI is not clearly understood. The way learners experience and perceive their classroom experiences might be entirely different from the way they perceive or understand scientific inquiry, i.e. their understandings of NOSI (Vhurumuku, 2010a).

1.1 Rationale for the study

There is an abundance of research literature from all over the world showing that, learners' understandings of the NOSI are generally inadequate (Lederman, 1992; Lederman, 2007). Equally many researchers have assessed learners' perceptions of their classroom learning environments (Lang, Wong, & Fraser, 2005; Fraser, 1998). This research line has concentrated on associations between learners' perceptions of their learning environment and such factors as: learners' attitudes to the subject and achievement; and teacher-learner interactions. Little effort has gone into determining the relationship between learners' understandings of NOSI and their perceptions of their classroom experiences. A survey of the literature shows that no such research has been done in South Africa and in Lesotho.

Understandings of learners' ideas about NOSI and their perceptions of classroom experiences are important for both curriculum development and the crafting of pedagogical strategies which might enhance the teaching and learning of science at the high school level. This is critical for the development of scientific literacy among high school learners. An understanding of NOSI is a constitutive component of scientific literacy (Laugksch, 2000). Scientific literacy is an important curriculum goal in contemporary science education. Moreover, as learners talk about their classroom experiences of scientific inquiry, they may reflect on what science is, how it interacts with society and influences their daily lives. For Lesotho, the results and recommendations coming out of this study may enlighten policy makers, curriculum developers, and teachers about the status quo *vis a vis* learners' understandings of NOSI and classroom pedagogical practices. The results of this study are important in that they can help reform science for both science teaching and curriculum development in Lesotho. This is especially so given that learners perceptions of classroom experiences can be taken as reliable indicators of teacher practices (Fraser, 1998).

1.2 Context of the study

Lesotho is one of the countries which value the importance of developing learners' understandings of scientific inquiry. As part of scientific literacy, learners' understanding of NOSI is considered to be critical for national progress and development (Schwartz al., 2004). So important is this that the government of Lesotho has invested heavily in encouraging young citizens to undertake studies in Science at both school and university level. For many

years, the Lesotho government has been giving scholarship to qualifying post high school learners to study at university level in such fields as; Medicine, Health Science, Information Technology and Actuarial Science (Mahao, 2003; Thahane, 2003). Despite this effort, the number of learners studying science related fields at the National University of Lesotho continues to be low (Mahao, 2003; Thahane, 2003). Mahao (2003) has attributed these low numbers to poor learner performance in science related fields at school level.

The development of learners' understandings of NOSI is an explicit goal in the Lesotho Ordinary (O) level science syllabus. This syllabus is designed for both learners who will be leaving school after Form E and those who will go on to study science at tertiary level. For the majority of learners this is their last encounter with a formal education in science before leaving school. Learners are therefore expected to be scientifically literate (including understanding of NOSI) as a result of going through this syllabus. In Lesotho, Forms D and E are the last two years of High School. These years are aimed at preparing learners for the Cambridge Overseas School Certificate (COSC) Examinations at the O-level (Mahao, 2003) as well as develop learners into scientifically literate citizens. Learners who wish to continue with studies in science at university or college level are encouraged to register and sit for the COSC examinations (Ministry of Education and Training (MOET), 2005). For these learners, the *core curriculum* consists of: English Language -allocated five periods per week (a period is 40 minutes long) ; Mathematics -allocated seven periods per week; Biology -allocated five or six periods per week; and Physical Science (Chemistry and Physics) -allocated eight periods per week (MOET, 2005). At the end of each year, promotions from Form D to Form E level are determined by obtaining good examination grades in all of the core curriculum subjects and the learners' performance in the course work during the year. All COSC examinations are organized and administered by the Examinations Council of Lesotho (ECOL).

In their teaching of science, Lesotho teachers are expected to use the inquiry approach and develop learners' skills in critical thinking as well as involve learners in authentic scientific activities (MOET, 2005; Cuevas, Lee, Hart and Deaktor, 2005). These include giving learners opportunities to ask questions, experiment, process and interpret data, and engage in problem-solving. Ntoi (2007) has recommended that when implementing the Lesotho O-level science syllabus teachers should use: constructivist oriented learner-centred approaches; involve learners in investigative practical activities and experiments and projects that require

design, analysis and synthesis of information. The use of inquiry in teaching and learning therefore is an important science education curriculum goal in Lesotho.

1.3 The aim of the study

The major aim of this study was to investigate Lesotho Form D learners' understandings of NOSI, their perceptions of classroom experiences (in terms of the extent to which they are experiencing scientific inquiry) and the nature of relationship between these two variables. The study was guided by the following questions:

1. What are learners' understandings of the nature of scientific inquiry?
2. What are learners' perceptions of their experiences of scientific inquiry?
3. Are learners' understandings of NOSI in any way related to their experiences of scientific inquiry?

1.4 Theoretical framework

This study is informed by the theory on inquiry teaching and learning, the nature of science (NOS) and the nature of scientific inquiry (NOSI). The NOS refers to an individual's ideas, beliefs, views, perceptions and assumptions about scientific knowledge – the facts, principles, laws and theories making up the body of knowledge called science (Vhurumuku and Mokeleche, 2009). It is important to note that for this study the focus is on NOSI and not on NOS. The NOS focuses on individuals' understandings of the nature of scientific knowledge whereas the NOSI focuses on understandings of the scientific process, i.e. the processes through which scientific knowledge is developed and validated (Vhurumuku, 2011). It is suffice to mention that, for science, inquiry teaching and learning are innately linked to the theory of constructivism (Shiland, 1999).

In this section theoretical aspects of scientific inquiry, learning and teaching and NOSI are discussed. The aspects of scientific inquiry relevant to this study are teased out. The basic tenets of NOSI selected for the study are identified and described. By tenets it is meant the ideas, principles, opinions or doctrines about the scientific process that are generally believed or held to be true by members of the science education community (Vhurumuku, 2010b). The concept of perceptions of inquiry is operationalized.

1.4.1 Scientific inquiry, learning and teaching

Inquiry has been associated with constructivism (Hinrichsen, Jarrett and Peixotto, 1999; Shiland, 1999). Both inquiry and constructivism have traces to Dewey's philosophy. According to Dow (1999), inquiry has its deeper roots in the Socratic inquisitiveness of Athenian times. It can be understood as the search for truth or knowledge by questioning which Socrates and his disciples sought to do. Another view of inquiry (Hinrichsen et al, 1999; Windschilt, 2003), takes it to be synonymous with the scientific process and enterprise. According to this view, science is man's endeavour to understand the nature of *nature* through inquiry and discovery. Inquiry is said to start from something that is intriguing, that raises questions, something not understood, and that does not fit expectations or that which the learner wants to know (Exploratorium, 1996). The process of inquiry involves using tools, collecting data, analyzing data, processing answers and explanations, prediction and communication of results as well as identifying assumptions and use of logical and critical thinking (Songer, Lee & McDonald, 2003).

Anderson (2002) identifies three types of inquiry namely: scientific inquiry; inquiry learning; and inquiry teaching. As already mentioned, in this study scientific inquiry is taken to mean the processes through which scientific knowledge is developed and validated and the NOSI as the ideas, beliefs, views, perceptions and assumptions concerning the nature of scientific inquiry, harboured by an individual. According to Anderson (2002) inquiry learning is an active process during which learners are engaged in both knowledge and skills acquisition. This type of inquiry is said to be similar to scientific inquiry because learners partake in the "same" activities done by scientists in their search for new knowledge. During inquiry learning, learners use tools, collect data, analyze data, process answers and explanations, predict and communicate results as well as identify assumptions and use of logical and critical thinking (Songer et al., 2003). Inquiry teaching is a teaching strategy or approach during which the teacher organizes for and executes learners' practice of inquiry. Crawford (2000) points out that this process involves cognitive interactions between the teacher and the learner. Instead of the teacher being a knowledge transmitter, the learner and the teacher collaborate to develop conceptual understanding through shared learning experiences. This has been called collaborative inquiry and has its roots in the theory of constructivism.

Various forms of teacher practices of inquiry have been suggested, for example, Sandoval (2005) mentions guided inquiry as an approach whereby learners' inquiry is guided by the teacher requiring learners to follow procedures step by step as guided by the teacher or a manual. Inquiry teaching has also been associated with such terms as problem solving and unguided discovery. It is possible to talk about the extent to which the teachers' practice is open or closed-ended, that is *open-ended inquiry* or *closed inquiry*, depending on the degree of learner centeredness of the activities (Asay & Orgill, 2010). According to Asay and Orgill (2010) in open-ended or "full inquiry" learners are given significant latitude to: (1) ask scientifically oriented questions; (2) provide evidence in responding to questions; (3) formulates explanations from evidence; (4) connect explanations to scientific knowledge; and (5) communicate and justifies explanations. In closed or "partial inquiry" the teaching and learning activities are largely teacher centred. For a long time, inquiry has been characterised as a good method for teaching and learning of science (Anderson, 2002). Essentially this characterisation includes asking such questions as: "what does it mean to teach or learn science through inquiry? What are the goals of its use?"

1.4.2 The nature of scientific inquiry

Learners' understandings of both NOS and the NOSI have been described as informed or naïve (Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2006). Learners can be described as harboring naïve NOS and NOSI views if they subscribe to such notions and beliefs as: scientific knowledge is certain and a fixed, true and "objective" representation of reality; there is one method of science which practicing scientists adhere to; an objective reality which is independent of the knower exists; and scientific observations are free from human preconceptions. Harboring informed NOS and NOSI views means subscribing to such views and ideas as: scientific knowledge is dynamic, tentative, revisionary and the result of active interaction between the knower and the known; there exist multiple truths and realities which are neither fixed nor absolute; there are several appropriate methods in science; scientific observations are theory-laden and dependent on the experience and preconceptions of the observer; and the development of scientific knowledge is based on empirical investigation as well as the creativity and imagination of scientists.

For this study, six tenets of NOSI have been selected for investigation. This selection is based on what the literature says are important NOSI tenets for high school learners to understand

(Liang et al., 2006). These tenets are: (1) the difference between observations and inferences, (2) the difference between scientific laws and scientific theories, (3) tentativeness of scientific theories, (4) social and cultural embeddedness of science, (5) the role of imagination and creativity in scientific investigations; and (6) the fact that there is no one scientific method. Briefly, the six tenets are:

Difference between observation and inference

Scientific investigations are based on observations and inferences. Observations are descriptive statements about natural phenomena that are directly accessible to the senses and about which observers can reach consensus with relative ease (Liang et al., 2006). On contrary, inferences are explanations given by scientists from their different observations and cannot be directly accessible to the senses. According to Lederman, Abd-El-Khalick, Bell and Schwartz (2002) different perspectives of scientists lead to different interpretations of the same observation.

Difference between a scientific law and a scientific theory

Scientific laws and theories are different kinds of knowledge and one does not become the other as is commonly mistakenly held (Lederman et al., 2002). Scientific theories are systems of ideas intended to explain set of unrelated observations through different investigations. While, scientific laws are verbal statements of relation that expresses essential principles of science. Scientific laws are subject to change.

Tentativeness of scientific theories

Liang et al. (2006) assert that scientific theories are subject to change. Such change can be brought by scientists reinterpreting the existing observation due to new evidence hence, may replace the existing theory with a new one. More important, theories have a major role in generating research problems and guiding future investigations (Lederman et al., 2002).

Social and cultural embeddedness of science

Science is practiced in the context of a larger social and cultural tradition and its practitioners are the product of that culture (Lederman et al., 2002). As a result, science is affected and affects the social and cultural practices in which it is embedded. These social and cultural

values determine what science is accepted, what science is to be conducted and how science should be interpreted.

The role of imagination and creativity in scientific investigations

The development of scientific knowledge involves making observations of nature (Liang et al., 2006). Nonetheless, generating scientific knowledge involves scientists' imagination and creativity. Science involves the creative discovery of theoretical entities and explanations. Thus, scientists are required to use their imaginations and creativity at all the times throughout their investigations.

There is no one Scientific Method

Scientists follow different scientific methods in their investigations (Lederman et al., 2002; Liang et al., 2006). There is no single sequence of activities prescribed that will unerringly lead them to functional or valid solutions or answers. Scientific knowledge can be gained through observations, mathematical deductions, experimentation, analysis, speculation and reading (Miller, Montplaisir, Offerdahl, Cheng & Ketterling, 2010).

1.5 Review of the literature

Research done around the world (for example, Bell, Blair, Crawford & Lederman, 2003; Lederman et al., 2002; Crawford, 2000; Chang and Mao, 1999; Lederman, 2007) shows that most secondary school learners hold naive ideas about the NOSI. However, the results of some studies (for example, Liang et al., 2006 and Miller et al., 2010) show that some learners may harbour informed NOSI understandings whilst others have the transitional understandings. A transitional understanding is when learners' understandings of NOSI are showing development from being naive to being informed. Studies done on learners' perceptions of their experiences of nature of scientific inquiry (Rop, 2003; Hofstein, Navon, Kipsnis & Mamlok-Naaman, 2005) suggest that some learners see being actively involved in asking and answering scientifically oriented questions as helpful to their understanding of the nature of scientific inquiry. A study by Bell et al. (2003) found that if learners are involved in apprenticeship experiences could easily be convinced about the tentative nature of scientific knowledge, which is an informed view of the NOSI. However, according to Adyniz, Baksa

and Skinner (2010) a better understanding of NOS and the NOSI does not necessarily result from merely doing science.

Laboratory is considered as a central and distinctive role in science teaching and some science educators believe that learners' NOSI understandings can best be developed using laboratory activities (Hofstein et al., 2005; Hofstein & Lunetta, 2004). In their study, Hofstein et al. (2005) found that learners' who were exposed to inquiry-laboratory approaches asked more and better questions than those exposed to traditional laboratory teaching approaches. They argue that inquiry-laboratory approaches provide learners with opportunities to develop inquiry skills such as hypothesizing and asking questions related to further investigations. Nevertheless, Hofstein and Mamlok-Naaman (2007) argue that although science laboratory work has been given a distinctive role in science education, research has failed to clearly show a relationship between experiences in the laboratory and student learning and their understandings of NOSI.

1.6 Research design

This study used questionnaires and interviews to investigate learners' understandings of the nature of scientific inquiry and their perceptions of the nature of inquiry in their science classrooms. The study sample (n = 120) were Form D high school learners conveniently selected from two schools in an Education District of Lesotho. Learners' NOSI understandings were elicited through a Learners' Understanding of Science and Scientific Inquiry (LUSSI) questionnaire adapted from the instrument of Liang et al. (2006). The LUSSI has Likert type questions, but allows respondents to explain and justify their Likert choices through open-ended answers. Eight learners, 4 from each school were interviewed (semi-structured) to corroborate LUSSI responses as well as get deeper insights into learners' understandings. Learners' perceptions of the nature of inquiry were obtained through a Principles of Scientific Inquiry- Student (PSI-S) questionnaire adapted from Campbell, Abd-Hamid and Chapman (2010). The instrument measures the extent to which learners perceive their classroom experiences to be open ended in terms of inquiry. Eight learners, the same ones used for NOSI understandings, 4 from each school were interviewed (semi-structured) to corroborate PSI-S responses as well as get deeper insights into their perceptions.

All interviews were audio taped and transcribed verbatim. Typological analysis was used for analysing the qualitative data and descriptive statistics was used for analysing the quantitative data.

1.7 Ethical issues

The objective of this study was made clear to Human Research Ethics Committee (Wits School of Education) when applying and asking for their permission to carry on with this study. Some letters were written to the headmasters of two schools in Lesotho asking for permission to give questionnaires and interview Form D students at their schools. The informed consent form and the researcher's information sheet were given to those headmasters. It was clearly indicated on the consent form that the names of their schools, teachers and learners will not be made known. The respondents were also given the informed consent forms and the researcher's information sheet which indicated that they were not forced to participate in this study and that they could withdraw from the study if they want to. It was also indicted in the consent forms that their names and the names of the people they may refer to will remain anonymous. (Refer to Appendix D, F and G for my information sheet and the consent forms respectively).

1.8 Chapters Organisation

Chapter 1: Introduction to the study

This chapter provides the outline of the general background of the study. It outlines the aim of the study including the research questions. The theoretical framework informing and guiding this study was discussed and the literature that is relevant to this study was also briefly reviewed. Methodology and data analysis for this study was also briefly discussed in this chapter.

Chapter 2: Literature review

Chapter 2 gives a detailed review of the literature related to this study. Issues that are discussed include; learner's understandings of the nature of scientific inquiry, their perceptions of their laboratory or classroom experiences on scientific inquiry and the relationship between learners' understandings of scientific inquiry and their experiences on scientific inquiry.

Chapter 3: Research design and methodology

In this chapter, the design and the actual methods used in undertaking the study are discussed. The research instruments that are used, their justification, and administration are discussed. The issues of validity and reliability regarding the research instruments and data collection procedures are also discussed. The methods used when analysing data are fully explained.

Chapter 4: Results and discussion

This chapter presents and discusses the results obtained for this study. The results are discussed under the three research questions; learners' understandings of the nature of scientific inquiry, learners' perceptions of their experiences of scientific inquiry and the relationship between their understandings of NOSI and their experiences of scientific inquiry.

Chapter 5: Conclusions, Implications, and Recommendations.

Chapter 5 describes the conclusions made from the study by responding to the three research questions which were designed to achieve the purpose of the study. Implications and recommendations are raised.

1.9 Conclusion

Chapter 1 has given a brief overview of the purpose of the study, the theoretical framework that informed and guided the study, and the methodology that has been used to conduct the study and to analyse data. Ethical principles and how they were adhered to in this study were described. In the next chapter the literature relevant for the study is discussed.

CHAPTER 2

LITERATURE REVIEW

2. Introduction

In this chapter, the literature related to this study is reviewed under the following headings; learners' understandings of NOSI, learners' perceptions of laboratory or classroom experiences of inquiry and the relationship between learners' experiences of scientific inquiry and their understandings of NOSI.

2.1 Learners' understandings of NOSI

Research done around the world has shown that most secondary school learners hold naive ideas about the NOSI (Bell et al., 2003; Lederman et al., 2002; Crawford, 2000; Chang and Mao, 1999). Such learners' inaccurate understandings of the NOSI are likely the result of inappropriate experiences of scientific inquiry in science classrooms (Ruiz-Primo, Li, Tsai & Schneider, 2010; Vhurumuku, Holtman, Mikalsen & Kolsto, 2006). Research has shown that learners' understandings of NOSI can best be developed if learners are provided with opportunities to practice authentic inquiry (Schwartz et, al., 2004; Bell et al. 2003; Crawford, 2000; Chang and Mao, 1999). Wong and Hodson (2008) suggest a variety of strategies for developing students' NOSI understandings through authentic inquiry. These include providing students with opportunities to ask and investigate their own questions; reflect on their own laboratory work activities and consulting practising scientists (Blonder, Mamlok-Naaman & Hofstein, 2008; Hofstein et al., 2005). Wong and Hodson (2009) indicate that authentic scientific inquiry has a potential in developing, enhancing and enriching learners' understandings of NOSI and can also be used to design effective laboratory work. However, Ruiz-Primo et al. (2010) emphasise that it is important to recognise that scientific inquiry is more than designing experiments, carrying out the procedures outlined, using instruments and recording data properly. But it also involves development of understandings about where scientific theories, principles, and concepts come from within a field of study.

The study done by Liang et al. (2006) when validating LUSSI instrument investigated learners' understandings of scientific inquiry. They used a questionnaire which involves Likert type questions, each followed by an open-ended question. Their results reveal that

some learners hold naive understandings on scientific laws versus scientific theories; some hold transitional understandings on change of scientific theories and on social and cultural influences on science. Others hold less informed understanding on imagination and creativity in scientific investigations and on methodology of scientific investigation. However some learners hold the informed understandings on observations and inferences. These tenets that Liang et al. investigated are the same as the ones investigated in the present study. Their results were similar with those of Miller et al. (2010). Nevertheless, Lederman et al. (2002) found that most learners had an understanding that there is no one scientific method and were able to draw a distinction between observation and inferences and recognize the difference between theories and laws which is different to what Liang et al. (2006) and Miller et al. (2010) found in their studies.

Adyniz et al. (2010) and Lederman (2007) argue that the naive views of NOSI held by learners originate from their lack of experiences in conducting scientific inquiry. They claimed that this happens because high school science laboratories focus only on demonstrations and experimentation aspects of the scientific inquiry, and fail to provide a context for high school learners to understand how the scientific knowledge gets generated and validated. Adyniz et al. wanted to understand how engagement in scientific inquiry experiences in authentic settings influences high school learners' understanding of the nature of scientific inquiry and nature of science. Data was collected through an open-ended questionnaire. Their results were different from that of Liang et al. (2006) as they showed that most of the participating learners have some understanding of NOSI as they were able to differentiate between evidence and data; observation and experimentation. The participating learners also showed an understanding that scientists use multiple methods when solving problems. They also held a sophisticated understanding about the tentative nature of science.

Marchlewicz and Wink (2010) examined how undergraduate learners' views of scientific inquiry shift after introduction of the Activity Model of Inquiry in a general Chemistry course. They used essay prompts, pre- and post questionnaire and interviews to get learners views. The questionnaire that learners completed probe their understandings of the "empirical, tentative, theory-laden, creative and imaginative, and social and cultural embeddedness nature of scientific knowledge, as well as, the myth of a universal scientific method, the difference between scientific laws and theories, and learners' overall view of science" (Marchlewicz & Wink, 2010, p. 309). These were considered to be the tenets of

NOSI in the present study. The results reveal that there are some shifts from a naïve view to a more informed view of nature of scientific inquiry for some learners. It can be argued that such learners whose views shifted from being naive to more informed have a better understandings of the NOSI.

Akerson and Donnelly (2010) examined the kind of understanding that primary learners can attain as a result of being involved and participating in inquiry-based learning. This study was done to reinforce the following NOSI tenets; creativity, tentativeness, observation and inferences. To elicit learners' views they used small group pre-course interview, written assignments, videotaped class discussions and post-interviews. Their results reveal that young learners can be able to develop their understandings of scientific inquiry if they are helped by more experienced learners and teachers and through explicit NOS instruction. Akerson and Donnelly (2010) further point out the importance of allowing learners an opportunity to do their own investigations rather than just listening to their teachers telling them results of investigations as this is very important for their learning through inquiry. The results also show that learners' views of NOSI shifted from being naive to informed. Even though Akerson and Donnelly (2010) did their study with primary school learners, their findings were similar to some researchers who did their studies with high school learners (Marchlewicz & Wink, 2010; Cuevas et al., 2005; Domin, 1999).

As change of scientific theories is one of the tenets of NOSI, Sandoval and Morrison (2003) examined high school learners' ideas about theories and theory change after a Biological inquiry unit. They found that learners' inquiry experiences in their unit focused them on making and justifying claims about particular problems, even though learners did not connect such effort to formal science or science practiced by scientists. Sandoval and Morrison used pre and post-interviews to investigate such ideas and found that learners posses theories as proven hypotheses that have been tested several times. Their results further indicate that learners' inquiry has little influence on their formal understanding of the nature of science and NOSI. They argue that many students seem not to have better understandings of scientific inquiry relative to change of scientific theory. This is supported by Liang et al. (2006) who found that many learners posses transitional understanding in theory changes. However, Miller et al. (2010) found that many learners posses informed view on change of scientific theories.

2.2 Learners' perceptions of their laboratory or classroom experiences of inquiry

Laboratory is considered as playing a central and distinctive role in science teaching and some science educators believe that good benefits in learning arise from using laboratory activities (Hofstein et al., 2005; Hofstein & Lunetta, 2004). They further argue that the laboratory work is an important medium for enhancing attitude, stimulating interest and enjoyment, and finally motivating students to learn science. Hofstein et al. (2005); Hofstein and Lunetta (2004); Domin (1999) claim that inquiry-type laboratories when properly developed have potential to develop learners' abilities and skills such as: posing scientifically oriented questions; forming hypotheses; designing and conducting scientific investigations; formulating and revising scientific explanations; and communicating and defending scientific arguments, which are the tenets of NOSI. They also indicate that this type of laboratory may enhance learners' conceptual understanding and their understanding of NOS and NOSI. Domin (1999) further indicates that if learners are given chance to experience the components on inquiry mentioned above, understand and do them well, inquiry-based laboratory activity will give such learners the opportunity to engage in authentic scientific investigative processes. However, Adyniz et al. (2010) claim that high school laboratories fail to engage learners in inquiry-based learning.

Hofstein et al. (2005) studied the impact of inquiry-type chemistry laboratory experience on learners' development of an ability to ask more and better scientific questions. In their study, 12^{th} grade learners were used to form two groups; experimental (inquiry) and control (traditional) group. In control group, learners were following step-by-step instruction in the laboratory manual. Hofstein et al. (2005) found that learners learning chemistry though an inquiry-laboratory approach asked more and better questions than students in a traditional laboratory setting, because they were given opportunities to develop inquiry skills such as hypothesizing and asking questions related to further investigations. Hofstein et al. argue that this allows learners to learn and experience scientific inquiry with greater understanding. It also provides them with an opportunity to construct their own scientific knowledge by actually doing science as Domin (1999) suggested.

Rop (2003, p.17) explored high school learners' perceptions of motivated and implications of chemistry classroom questioning behaviour, as it is indicated that "posing questions is one of the vital behaviour associated with scientific inquiry". Rop's large ethnographic study is

carried out in one of the high school chemistry class in Unites States of America. The methods for collection of data are; participant observation, informal interviews and journal notes on extended time on site. Rop (2003, p. 21) found that, some learners regularly participate in classroom conversation by asking "Students Inquiry Questions" (SIQs) as a way to "alleviate boredom and engage in intellectual challenges". Learners ask interesting questions about the content as they perceive that a classroom without more scientific inquiry based question is very boring. They also ask SIQs to challenge themselves to think at higher levels. Secondly, they ask SIQs "to fill an intellectual hunger to understand subject matter better" (Rop, 2003, p. 21). According to Rop these learners ask SIQs to enable themselves to understand or learn subject matter in deeper ways. Rop (2003) further maintains that such learners do not want to learn for good grade but for better understandings of NOSI which might help them to go ahead with the scientific knowledge they got hence, perceive that scientific inquiry based question will help them achieve that. It follows that learners in this study claim that social atmosphere in high schools is loaded with scientific inquiry and that actively engaging in scientific inquiry will develop their understandings of NOS and NOSI.

In support to the above literature, Cuevas et al. (2005) suggest that nowadays, the society requires its members to be able to analyse and respond to the complex issues arising daily. They indicate that this can be reached by transforming classroom environment in a way that it persuades learners to take responsible part in their learning and foster scientific inquiry to all elementary learners regardless of grade, achievement, gender, ethnicity, socioeconomic status, home language and English proficiency. To carry out their study, Cuevas et al. (2005) used instructional units, teacher workshops and audio taped and videotaped session for classroom instruction. Pre- and post elicitations were also given to learners to examine their improvement on scientific inquiry. They found that some learners were unable to carry out the inquiry task alone but through probing, such learners performed well. Their statistical results show that learners' ability to conduct inquiry and employ some skills of inquiry has increased, and that those learners who were found to be low achievers have improved. Lastly, all learners participating had developed the inquiry skills for planning and drawing conclusion showing some understandings of NOSI.

Similar results were found by Park Rogers and Abell (2008) who studied undergraduate inquiry-based instruction through the words and actions of learners and instructors. Their results reveal that learners were aware that asking scientific questions, thinking through the

most appropriate method for answering the questions, and making sense of the findings were valuable parts of their learning experience showing that they have a better understanding of NOSI. It can be suggested that this was possible because learners were given chance to engaged in activities similar to that of practising scientists which they indicated as "formal science".

Blanchard, Southerland, Osborne, Sampson, Annetta & Granger (2010) have identified four levels of inquiry that learners' may experience during laboratory practical work. Such levels are verification, structured, guided and open inquiry. This laboratory work was explained by Vhurumuku et al. (2006) as the learning activities whereby experiments are done either by learners or teachers inside or outside a laboratory or a science classroom. Vhurumuku et al. argue that learners' build their understandings of NOSI from their participation in laboratory work. In support Park Rogers and Abell (2008) assert that classroom inquiry can vary along a dimension of teacher directed to student directed for each of the features of principles of scientific inquiry. Like Asay and Orgill (2010), Park Rogers and Abell claim that classroom instruction that includes the five principles of scientific inquiry which are: ask scientifically oriented questions; provide evidence in responding to questions; formulates explanations from evidence; connect explanations to scientific knowledge; and communicate and justifies explanations is considered to be a full (open-ended) inquiry as opposed to partial inquiry whereby learners are not experiencing all of the essential feature of inquiry. Below is the table of different level of inquiry by Blanchard et al. (2010).

Table 2.1: Levels of inquiry outlined by Blanchard et al. (2010)

	Source of the Question	**Data Collection Methods**	**Interpretation of Results**
Level 0: Verification	Given by teacher	Given by teacher	Given by teacher
Level 1: Structured	Given by teacher	Given by teacher	Open to learner
Level 2: Guided	Given by teacher	Open to learner	Open to learner
Level 3: Open	Open to learner	Open to learner	Open to learner

Fay, Grove, Towns, Bretz (2007, p.215) came up with a description for each of the levels of inquiry which can be used to identify such levels of inquiry, as shown in Table 2.2 below:

Table 2.2 Rubric to identify level of inquiry from Fay, Grove, Towns, Bretz (2007)

Level of Inquiry	Description
Level 0	The problem, procedure, and methods to solutions are provided to the learner. The learner performs the experiment and verifies the results with the manual.
Level 1	The problem and procedure are provided to the learner. The learner interprets the data in order to propose viable solutions.
Level 2	The problem is provided to the learner. The learner develops a procedure for investigating the problem, decides what data to gather, and interprets the data in order to propose viable solutions.
Level 3	A 'raw' phenomenon is provided to the learner. The learner chooses the problem to explore, develops a procedure for investigating the problem, decides what data to gather, and interprets the data in order to propose viable solutions.

Krajcik, Blumenfeld, Marx, Bass, Fredricks & Soloway (1998) did their study to describe what middle school learners do and where they have difficulties in their first encounters with inquiry learning. In their study, they detail how learners: ask questions; design and plan investigations and procedures; construct apparatus and carry out their work; analyse data and draw conclusions; and present the findings which according to Asay and Orgill, (2010), Park Rogers and Abell (2008) is considered to be full inquiry. The findings point out that, middle school learners are capable of conducting inquiry in their classrooms. That is, they are thoughtful in designing investigations, planning procedures and organizing the collection of data. Krajcik et al. also found that teacher's questioning were crucial in encouraging learners to be thoughtful about the important aspects of inquiry. Even though, Krajcik et al. studied middle school learners, it can be argued that middle school learners may behave in a similar manner with high school learners and with appropriate assistance from their teachers when engaged in scientific inquiry may perform better.

Sadeh and Zion (2009) examined the effects of applying different inquiry methods to high school learners engaged in inquiry. In their study there were two groups involved, that is the group experiencing open inquiry and the group experiencing guided inquiry. Even though, Sadeh and Zion were expecting that learners in open inquiry will outperform the guided inquiry group because they have experienced difficulties and problems that arise during the open inquiry process, their results reveal that there is no difference in learners' performances and on their procedural understanding. This is in line with Furtak (2006) statement which indicates that learners experiencing different levels of inquiry may similarly develop scientific knowledge and understandings of NOSI. On contrary, findings in Fay's et al.

(2007) study clearly show that not all instances of inquiry are equivalent. That is they do not necessarily imply or describe the same learning opportunity for students. Fay et al. further indicate that there are varying degrees of freedom in the students' experiences which result in different learning opportunities.

2.3 Relationship between learners' experiences of scientific inquiry and their understandings of NOSI

A study by Bell et al. (2003) used open-ended questionnaire and semi-structured interviews to explore learners' experiences of science apprenticeship and their NOSI understandings. Science apprenticeship means practising science in ways similar to what professional scientists do in their daily endeavours, which is the same as authentic inquiry. They found that as a result of the apprenticeship experience some learners were convinced that scientific theories can change, which is an informed view of the NOSI. Learners were also seen to develop inquiry skills on specific tasks related to their apprenticeship. According to Wong, Kwan, Hodson and Yung (2009) apprenticeship or internship experiences offer enormous potential for enhancing learners' understandings of NOSI. To the contrary, Grindstaff and Richmond (2008) and Lederman (2007) argue that being involved in a scientific inquiry does not automatically result in NOSI understandings. This is supported by the results of empirical studies (for example, Adyniz et al., 2010; Schwartz et al., 2004; Bell et al., 2003) which show that exposing secondary school learners to authentic research experience and doing science do not necessarily result learners' understandings of NOSI.

In a quasi experimental study, Hofstein et al. (2005) used a practical test and questionnaire to compare the ability to think scientifically and to ask more and better questions when performing experiments in two groups. They found that learners in the experimental group outperform the control group learners by asking high-level questions and by thinking more scientifically when completing the practical test and questionnaire because they had experienced exposure to scientific inquiry. They showed better understandings of NOSI. They argue that providing an opportunity for learners to engage in inquiry-type laboratory may improve their understandings of NOSI (Hofstein and Lunetta, 2004; Hofstein et al.). This is supported by Park Rogers and Abell (2008) who suggest that learners' experiences of full inquiry enabled them to recognize and understand that there is no set of procedural model to follow in scientific inquiry; instead the question you ask and the hypothesis you test

determine the methods used. In a related study, Haefner and Altoona (2004) examined prospective elementary teachers' learning about scientific inquiry in the context of an innovative life science course. Their findings support Hofstein and Lunetta (2004) and Hofstein et al. (2005) who found that engaging learners in authentic scientific inquiry supported the development of more appropriate understandings of science and the NOSI.

2.4 Conclusion

In reviewing the literature, different definitions of scientific inquiry were given as suggested by different authors. Some authors claimed that engaging learners in scientific inquiry help them to improve their performance in science and even develop some skills that will enable them to solve their daily science related problems. This was in line with those who assert that engaging learners in authentic science activities helps them to understand the nature of science and scientific inquiry even better. However, there are those who maintain that learners' experiences of scientific inquiry have nothing to do with their understandings of the nature of science and scientific inquiry. In chapter 3, the research design and methodology is discussed.

CHAPTER 3

RESEARCH METHODOLOGY

3. Introduction

The focus of this study was to investigate learners' understandings of the nature of scientific inquiry in relation to their classroom experiences. In this chapter the research design and methodology are presented and discussed under the following headings: research design; sampling and sample; research instruments; data collection procedure; and data analysis.

3.1 Research design

This exploratory study surveyed learners' understandings of the nature of scientific inquiry and the extent to which learners were experiencing scientific inquiry in their science lessons. As noted in Chapter 1, the study sample (n = 120) were Form D high school learners conveniently selected from two schools in Quthing Education District of Lesotho. Learners' NOSI understandings were elicited through a Learners Understanding of Science and Scientific Inquiry (LUSSI) questionnaire adapted from the instrument of Liang et al. (2006). The LUSSI has Likert type questions, but allows respondents to explain and justify their Likert choices through open-ended answers. Eight learners, 4 from each school were interviewed (semi-structured) to corroborate LUSSI responses as well as get deeper insights into learners' understandings. Learners' perceptions of the nature of inquiry were obtained through a Principles of Scientific Inquiry- Student (PSI-S) questionnaire adopted from Campbell et al. (2010). The instrument measures the extent to which learners perceive their classroom experiences to be open-ended in terms of inquiry. Eight learners, the same ones used for NOSI understandings, 4 from each school were interviewed (semi-structured) to corroborate PSI-S responses as well as get deeper insights into their perceptions.

Questionnaires were chosen for this study because they were considered to be appropriate for collecting data since they are relatively economical in terms of both time and money (Opie, 2004; McMillan & Schumacher, 2006). According to McMillan and Schumacher (2006) questionnaires provide same questions to a larger sample of participants compared to other techniques, and also allow adequate time for the participants to think about responses. Both McMillan and Schumacher (2006) and Neuman (1994) suggest that with questionnaires,

anonymity and confidentiality are best ensured compared with using other methods of data collection. Moreover, the use of questionnaires in studies similar to the current one has been successfully done (see, Liang et al. (2006) and Campbell et al. (2010). Semi-structured interviews were used to corroborate learners' responses to the two questionnaires because they are considered to be a good means of getting relevant information as they allowed the interviewer to have a face to face interaction with the respondents. Moreover, these types of interviews were selected because they provided the researcher with the opportunities for probing in order to clarify answers and to encourage elaborate responses (Fraenkel & Wallen, 1990; McMillan & Schumacher, 2006). The interview questions were adapted from Lederman (1999) and Lederman et al. (2002).

All interviews were audio taped and transcribed verbatim. Typological analysis was used for analysing the qualitative data and descriptive statistics was used for analysing the quantitative data.

3.2 Sampling and sample

Two schools (the first, school 1) is partly a boarding school and the second (school 2) wholly a day school from Quthing district in Lesotho were conveniently chosen to participate in this study. Convenience sampling was chosen because the schools are in the district where the researcher is living. As already noted convenience sampling was used because it was seen as making sense in reducing the expenses for travelling. However, the sample cannot be considered to be the representative of the entire population as it has a high potential for bias (Fraenkel & Wallen, 1990). Consequently, the results of this study cannot be generalised beyond the study sample.

The sample consisted of 120 Form D high school learners (males = 70; females = 50) from two schools in Quthing Education District of Lesotho. The learners' ages ranged from eighteen to twenty years. High school learners were selected for this study because they were considered to be having a better experiences and understandings of scientific inquiry. It was assumed that they would be able to explain themselves better on the issues under investigation compared to learners in the lower forms.

3.3 Research instruments

This section describes and explains the instruments used in this study. These instruments are: the Learners' Understanding of Science and Scientific Inquiry (LUSSI) questionnaire- data from this instrument was used to answer mainly the first research question; the Principles of Scientific Inquiry- Student (PSI-S) questionnaire- data from this instrument was used to answer mainly the second research question; and a Semi-structured interview schedule used for corroborating the responses from the LUSSI and the PSI-S as well as get insights into the responses of the learners. Data from the three instruments was collectively used to answer the third research question.

3.3.1 Learners' Understanding of Science and Scientific Inquiry (LUSSI) questionnaire

The LUSSI questionnaire (see, Appendix A) was adapted from Liang et al. (2006). They developed this instrument and used it to investigate students' understandings of science and scientific inquiry in three different countries; China, Unites States of America and Turkey. The instrument seeks to elicit learners' understandings of six NOSI tenets, namely: (1) the difference between observations and inferences, (2) the difference between scientific laws and scientific theories, (3) how scientific theories change, (4) social and cultural influences on science, (5) the role of imagination and creativity in scientific investigations, and (6) the methodology of scientific investigations. For each of the tenets, the instrument has a Likert part followed by one open-ended question. The Likert part requires learners to indicate their agreement with a statement on a scale ranging from: *Strongly Disagree; Disagree; Uncertain; Agree to Strongly Agree.* Respondents are required to indicate their degree of agreement or disagreement by ticking (√) in the appropriate box. The open-ended part of the LUSSI requires learners to express their opinions on a given tenet through giving reasons for their response to a given statement. An example of an item from the LUSSI with Likert and open ended part is given below:

1. Observations and Inferences

Item		SD	D	U	A	SA
A	Scientists' observations of the same event may be different because what scientists already know may affect their observations.					
B	Scientists' observations of the same event will be the same because scientists are objective.					
C	Scientists' observations of the same event will be the same because observations are facts.					
D	Scientists may make different interpretations based on the same observations.					

Do you think scientists' observations and interpretations are the same or different? Give reasons for your answer.

Other examples of questions in the open ended parts are:

> With examples, explain why you think scientific theories do not change OR how scientific theories may be changed.
>
> With examples, explain whether scientists follow a single, universal scientific method or use different methods.

On the LUSSI, Likert type items were presented in both a positive and a negative way (see, Appendix A). Positive statements are those written in a manner consistent with informed views of the NOSI as depicted in International Science Education Reform documents. Examples of such statements are:

1A. Scientists' observations of the same event may be different because what scientists already know may affect their observations; and

4B. Cultural values and expectations determine what science is conducted and accepted

Statements written in a negative way, to represent a naive view of NOSI include:

5C. Scientists do not use their imagination and creativity because these conflict with their logical reasoning; and

6B. Scientists follow the same step-by-step scientific method to conduct scientific investigations.

Although the LUSSI has been developed and validated by Liang et al. (2006), (the Cronbach's alpha values were found to be 0.67 for both USA and Turkey and 0.61 for China) there was still need to ascertain whether it was appropriate for the African and Lesotho

context. For this reason, the questionnaire was given to a scientist, 3 science educators (in Lesotho) and 5 Form D learners (not those who participated in the main study) to comment on its suitability in terms of the language and the construct validity. The comments obtained appeared to point towards the fact that the LUSSI could be used validly in Lesotho without modification.

3.3.2 Principles of Scientific Inquiry- Student (PSI-S) questionnaire

The PSI-S questionnaire (see, Appendix B) was adopted from Campbell et al. (2006). PSI-S is a Likert questionnaire which Campbell et al. developed and gave to teachers and learners to investigate the extent to which learners were experiencing scientific inquiry in classrooms. The instrument seeks to elicit learners' perceptions of their experiences on five principles of scientific inquiry which are: (A) asking questions/framing research questions, (B) designing investigations, (C) conducting investigations, (D) collecting data, and (E) drawing conclusions. Each principle has four items. In their responses, learners are required to show the extent to which they experience scientific inquiry in science classroom (by ticking (√) in the appropriate box) on a Likert scale ranging from: *Almost never; Seldom; Sometimes; Often to Almost always*. An example of an item from the PSI-S is principle E, drawing conclusions, which is given below:

E. Drawing conclusions

ITEM		Almost never	Seldom	Some-times	Often	Almost always
E1	Students develop their own conclusions for investigations					
E2	Students consider a variety of ways of interpreting evidence when making conclusions					
E3	Students connect conclusions to scientific knowledge					
E4	Students justify their conclusions					

On the PSI-S, items were presented in both a positive and a negative way (see, Appendix B). Positive statements are those written in a manner consistent with reform calls for engaging learners in learner centred activities and open-ended scientific inquiry. Examples of such statements are:

A1. Students formulate questions which can be answered by investigations

B2. Students design their own procedures for investigations

Negative statements are those that encourage teacher centred or closed inquiry. Examples are:

B1. Students are given step-by-step instructions before they conduct investigations

C2. The investigation is conducted by the teacher in front of the class

Although the PSI-S has been developed and validated by Campbell et al. (2010) it was important to ascertain its suitability to the Lesotho context. To find out whether PSI-S was valid and reliable for Lesotho context, the same people (a scientist, 3 science educators and 5 Form D learners) used to comment on the construct validity and reliability of LUSSI were also given the PSI-S. Their comments suggested that the PSI-S could be used without modification in Lesotho.

3.3.3 Interview schedule

A semi-structured interviewing was used to corroborate the LUSSI and PSI-S responses as well as get deeper insights into learners' ideas and perceptions. The interview schedule was divided into two sections (see, Appendix C). The first section was composed of six questions eliciting learners' understandings of NOSI. The second section was composed of five questions aimed at eliciting learners' perceptions of their experiences of scientific inquiry. The questions in the interview schedule were sourced from interview schedules used in previous related studies (Lederman, 1999; Lederman et al., 2002). Below are some examples of questions that were asked in the interview schedule to elicit learners' understandings of the NOSI. Probing and further questioning were done around these questions:

1. After scientists have developed a theory, does the theory ever change? In your opinion, is it important to be taught scientific laws and theories at high school level?
2. Is there any specific method that scientists should use in their investigations or experiments? Explain!
3. Can scientists observation of the same event be different or the same? Why?

Below are some of core questions which guided the interview on learners' perceptions of their experiences of scientific inquiry:

1. Who normally formulates questions for investigations in your classroom?
2. Who designs procedures to be followed when carrying out an investigation?
3. Who conducts investigations in your classroom? How are investigations carried out? During investigations in your classroom, what do you (students) normally do and what are the roles of the teacher?

The interview schedule was considered to be valid and reliable since its questions were developed from valid and reliable instruments by Lederman (1999) and Lederman et al. (2002). The construct validity of the interview schedule was established through discussion with the supervisor and one PhD student at the University of Witwatersrand.

3.4 Data collection procedure

As indicated above, the two questionnaires and semi-structured interviews were used for collection of data in this study.

The researcher went to the two schools in Quthing district to seek for permission from the schools' principals to conduct the study in their schools prior to the data collection. The researcher gave the principals at each of the schools a letter of authorization from the District Education Officer (see, Appendix E) a day before the administration of the questionnaires. The researcher then went on to give learners the parent/guardian consent forms (see, Appendix F) and the information sheet (see, Appendix D) that explains what the study is all about. These letters were distributed at the two schools on the same day. With some follow up, signed consent forms were received from all the learners who participated in the study after a week.

3.4.1 LUSSI questionnaire administration

At each of the schools, the procedure in the questionnaire administration was the same and went as follows:

The researcher handed out the questionnaire to the Form D learners. Learners were reminded that the questionnaire was not a test but an activity meant to find out what they thought about some aspects of the nature of science. As such there was no correct or wrong answer expected, but only their thinking. Before allowing the learners to complete the questionnaire the researcher read through all the items and asked learners to raise concerns or ask questions

if there was anything they did not clearly understand or they felt needed some explanation. Learners were told that they were free to give their answers in English or in Sesotho according to how they felt they could express themselves better. Learners were then given time to complete the questionnaire with the researcher moving around the classroom attending to questions and queries. Learners were given as much time as they wanted to complete the questionnaire. At each school learners took 40 minutes on the average to complete the questionnaire.

Questionnaires were administered at the two schools on the same day, with administration at the first school being done in the morning and the second school being done in the afternoon. At both schools a total of 120 learners completed the questionnaire.

3.4.2 PSI-S questionnaire administration

Questionnaires were administered at the two schools on the same day, with administration at the first school being done in the morning and the second school being done in the afternoon. As done for the LUSSI questionnaire, the researcher explained the statements in English and in Sesotho before allowing learners to respond to the items in PSI-S questionnaire. At both schools a total of 120 learners (same learners who completed LUSSI) completed the PSI-S questionnaire.

3.4.3 Semi-structured interviews

Eight of learners who completed the questionnaires (LUSSI and PSI-S) were conveniently selected from the two schools for semi-structured interviewing. The selection of these learners also depended on how far from the school the learners were staying. This was because the researcher had to interview them after school, so their teachers helped by identifying those learners whose homes are near the school or were boarders in the case of the first school (School 1). This unfortunately resulted in only males (n = 4) being interviewed at the second school (School 2). Of the eight learners who were interviewed, 6 were males and only 2 were females. At School 1, two males and two females were interviewed.

Before the researcher started the interviews, she was engaged in a small talk with each of the interviewees in order to create a comfortable environment for them to be relaxed, comfortable and willing to provide honest responses (McMillan & Schumacher, 2006). This talk also

provided a good rapport with her respondents. The researcher allowed her interviewees to use their home language if they felt comfortable so as to ensure that they expressed themselves as fully as possible. Furthermore, she accepted all answers from her interviewees and used probing questions that helped them reason out on what they had said. In addition, she used follow up questions such as "what do you mean by..?" and "how do you manage..?" which were related to what the interviewees had said so as to get more information from the interviewees. Simple language was used when asking the interview questions so that learners could easily understand and answer (Opie, 2004). Each interview was audio-taped. Each interview lasted about 20 minutes. The researcher transcribed all the interviews verbatim.

3.5 Data analysis

As indicated in Chapter 1, this study is composed of quantitative and qualitative data from two questionnaires and semi-structured interviews respectively. Typological analysis was used for analysing the qualitative data and descriptive statistics was used for analysing the quantitative data.

Each interview was audio taped and transcribed before analysis. The eight interview transcripts were analysed as one set of data. Participants were given numbers starting from 1 up to 120 and are named as S1 to S120 (student number 1, to student number 120) to preserve anonymity. All information was entered onto a Microsoft EXCEL 2007 spreadsheet and EXCEL was used in descriptive analysis. Below are the full details of the data analysis.

3.5.1 Analysis of the LUSSI questionnaire data

Hatch (2002) indicates that when the researcher has adapted the instrument, that researcher can also adapt methods of analysing data from the same literature. As a result, part of the method for analysing data was adapted from Liang et al. (2006). As already said, LUSSI questionnaire consists of Likert part and open-ended part.

3.5.1.1 The Likert part of LUSSI questionnaire

As already indicated, for the Likert part, learners were required to indicate their level of disagreement or agreement with statements on the nature of science and scientific inquiry by ticking in the appropriate box from; *Strongly disagree, Disagree, Uncertain, Agree to Strongly agree*. This Likert part was analysed in two ways. In the first way:

Firstly, the number of learners who chose *Strongly disagree, Disagree, Uncertain, Agree or Strongly agree* were counted in all the statements of each tenet of NOSI, the frequencies were converted to percentages and recorded. Secondly, categories of *Strongly disagree, Disagree and Uncertain* were collapsed into one category "Disagree"; and categories of *Agree and Strongly agree* were collapsed into "Agree" category. Frequencies of learners falling into each of the two categories were recorded.

In the second way of analysis:

As already indicated, some Likert items in this questionnaire represent views consistent with International Science Education Reform documents (informed views) while others are not consistent with the standard reform (naive views). As learners were supposed to tick in the appropriate box for whether they Strongly disagree, Disagree, Uncertain, Agree and Strongly agree they were awarded 1,2,3,4,and 5 respectively for all statements which are consistent with the reform documents. Such statements as they appear in the questionnaire are; 1A, 1D, 2D, 3A, 3B, 3C, 4B, 4C, 5A, 5B, 6A and 6D. For statements which are not consistent with the reform documents, the scores were awarded in the reverse order and such statements are; 1B,1C, 2A, 2B, 2C, 3D, 4A, 4D, 5C, 5D, 6B and 6C. Then the total scores were calculated for each tenet on all 120 questionnaires by adding the marks of learners for each item. In each tenet, learners who scored 4–12 were classified as having the naive view and those who scored 13–20 were classified as having the informed view.

3.5.1.2 The open-ended part of LUSSI questionnaire

When analysing the open-ended responses, the scoring rubric developed from Miller et al. (2010) was used. Hatch (2002) has suggested that rubrics can be used when analysing data from open-ended questions. Table 3.1 below shows the rubric that was used to analyse the open-ended responses:

Learners' responses were read and re-read. Learners were categorized according to how they had responded to each open ended item. The frequencies of learners for each were counted. These responses were then classified under four categories which are: Not classifiable; Naive understanding; Transitional understanding; and Informed understanding of NOSI using a scoring guide (see Table 3.1). On further analysis, the Not classifiable and Naive understanding were collapsed into one category "Naive understanding"; and the categories Transitional understanding and Informed understanding were also collapsed into one category

Table 3.1 Scoring guide for scoring LUSSI open-ended responses

Question	Not classifiable	Naive (1)understanding	Transitional(2) understanding	Informed (3)understanding
1. Do you think scientists' observations and interpretation are the same or different? Give reasons for your answer.	Not responding to the question provided, there is no response, a learner said he or she does not know and the responses cannot be classified based on the other three categories.	Learners say scientists' observations and/or interpretations are the same with whatever reason they may give. Responses have alternative conception concerning NOSI or the learner is contradicting him or herself.	Learners indicate that scientists' observations and/or interpretations may be different but fail to provide convincing reasons for justification or did not provide reasons at all.	Learners indicate that scientists' observations and/or interpretations may be different with convincing reasons or examples for justification.
2. With examples explain the difference between scientific law and scientific theory.	Not responding to the question provided, there is no response, a learner said he or she does not know and the responses cannot be classified based on the other three categories.	Scientific laws do not change and are more certain than theories. Proven theories become laws. Responses include alternative conceptions and self contradiction.	Laws and theories are from nature. Give valid examples of theories and laws without elaboration	A scientific theory explains scientific laws. Both scientific theories and laws are subject to change.
3. With examples explain why you think scientific theories do not changes OR how scientific theories may be changed.	Not responding to the question provided, there is no response, a learner said he or she does not know and the responses cannot be classified based on the other three categories.	Scientific theories based on accurate experimentation will not change. Response includes alternative conceptions and self contradiction.	Scientific theories may be changed when experimental techniques improve, or new evidence is produced.	Scientific theories may be changed when existing evidence is reinterpreted.

4. With examples explain how society and culture affect Or do not affect scientific research.	Not responding to the question provided, there is no response, a learner said he or she does not know and the responses cannot be classified based on the other three categories.	Science is a search for universal truth and fact and is not affected by culture and society. Response includes alternative conceptions and self contradiction.	Scientists are informed by their cultures and society. Culture determines what or how science is conducted or accepted. Science is influenced by culture and society with no elaboration.	Scientists are informed by their cultures and society. Culture determines what and how science is conducted or accepted.
5.With examples explain how and when scientists use OR do not use imagination and creativity	Not responding to the question provided, there is no response, a learner said he or she does not know and the responses cannot be classified based on the other three categories.	Scientists do not use imagination and creativity because these conflict with objectivity. Response includes alternative conceptions and self contradiction.	Scientists use their imagination or creativity in some of their work- when designing experiments or solving problems.	Scientists use their imagination or creativity throughout their scientific research.
6. With examples explain whether scientists follow a single, universal scientific method or use different methods.	Not responding to the question provided, there is no response, a learner said he or she does not know and the responses cannot be classified based on the other three categories.	There is a single universal or step-by-step scientific method that should be used. Response includes alternative conceptions and self contradiction.	Scientists may use different methods but their results must be confirmed by the scientific methods or experimentation. The same response with no justification or examples.	Scientists use a variety of valid scientific methods. Give examples of scientific methods.

"Informed understanding." This resulted in two broad categories: Informed and Naive. The numbers of learners under each category were then counted.

3.5.2 Analysis of the PSI-S questionnaire data

As already said, PSI-S is a Likert questionnaire and learners were required to indicate whether they experience each of the statements: *Almost never; Seldom; Sometimes; Often or*

Almost always, by ticking (√) in the appropriate box. The responses from this questionnaire were analysed in two different ways. Firstly, the number of learners who chose Almost never; Seldom; Sometimes; Often or Almost always were counted in all the statements of each principle of scientific inquiry and their percentages were calculated and the results were recorded. Categories of Almost never, Seldom and Sometimes were then collapsed into one category "Never"; and categories of Often and Almost always were collapsed into "Always" category. This resulted in two categories, which are "Never" and "Always".

Secondly, it was also indicated that some statements in this questionnaire like statement B1 and C2 oppose the reform calls for engaging learners in scientific inquiry while other statements are in line with the reform calls for engaging learners in scientific inquiry in their classrooms. As learners were supposed to tick in the appropriate box for whether they had experienced scientific inquiry in their classrooms; Almost never; Seldom; Sometimes; Often or Almost always, they were awarded 1,2,3,4,and 5 respectively for all statements except for B1 and C2. For B1 and C2, the scores were awarded in the reverse order. Then the total scores were calculated for each principle of scientific inquiry on all 120 questionnaires. For each principle, learners who scored 4–12 were classified as never experiencing full scientific inquiry and those who scored 13–20 were classified as always experiencing full scientific inquiry.

3.5.3 Analysis of interview data

In analyzing the interview data, the typological model of analysis was used (Hatch, 2002) and interpretational analysis. Typological analysis predetermined categories are imposed on data set. Learners' responses from the interviews which were corroborating their responses to LUSSI questionnaire were also classified as either naive, transitional or informed views of NOSI in relation to each selected tenet of NOSI for this study. In the interview schedule, question 1 corroborates tenet 2, question 2 corroborates tenet 3, question 3 corroborates tenet 5, question 4 corroborates tenet 4, question 5 corroborates tenet 6 and question 6 corroborates tent 1 (Appendix C). The summary table below was developed to enable the researcher to classify learners' responses:

Table 3.2 Scoring guide for interview responses corroborating LUSSI

Naive view	Transitional view	Informed view
-response include contradictions of basic assumptions	-say correct things but give no reason or give unrelated reason	-based on good knowledge and give relevant examples and reasoning

Learners' responses to the interview which were corroborating PSI-S responses were read several times to find the extent to which learners were experiencing scientific inquiry and also find if learners are experiencing closed or open-ended inquiry in their classrooms. The following summary table below is an example of the rubric which was used to classify learners' responses:

Table 3.3 Scoring guide for interview responses corroborating PSI-S

Type of inquiry	Source of the question	Data collection methods	Interpretation of results and conclusion
Open-ended	Open to learners	Open to learners	Open to learners
Closed-ended	Provided by the teacher	Provided by the teacher	Provided by the teacher

Finally, the total score for each learner in two questionnaires (LUSSI and PSI-S) was calculated and the results were recorded in Excel 2007. The total scores from LUSSI was compared with the total scores from PSI-S to find out if there was any relationship between learners' understandings of the NOSI and their experiences of scientific inquiry.

3.6 Conclusion

In this chapter the design of the research was given, highlighting issues of validity and reliability. The instruments used to collect data were described. The sampling procedure and the sample described. The procedures for collecting data were described and the steps followed in analyzing data were presented and discussed. In the next chapter the results are presented and discussed.

CHAPTER 4

RESULTS AND DISCUSSION

4. Introduction

In this chapter the results are presented and discussed. This is done in the order of the research questions, which are:

1. What are learners' understandings of the nature of scientific inquiry?
2. What are learners' perceptions of their experiences of scientific inquiry?
3. Are learners' understandings of NOSI in any way related to their experiences of scientific inquiry?

4.1 Learners' understandings of the nature of scientific inquiry

The results presented and discussed here are of learners' understandings of the nature of scientific inquiry (NOSI) as determined using the LUSSI (consisting of Likert items and open-ended question for each tenet) and from interviews. For each selected tenet of NOSI, the results from the LUSSI (n=120) are presented and discussed first. This is followed by presentation and discussion of results from the interviews (n = 8).

Results are summarized and discussed for learners' understandings of each of the six NOSI tenets chosen for the study. These tenets are: (1) observations and inferences, (2) scientific laws versus scientific theories, (3) change of scientific theories, (4) social and cultural influences on science, (5) imagination and creativity in scientific investigations, and (6) methodology of scientific investigation.

4.1.1 Observations and inferences

Results from LUSSI: Likert questions

Statements 1A and 1D as appeared in Table 4.1 below are of an informed view while statements 1B and 1C are of naive views. Learners who agree with statements 1A and 1D are considered to be having the informed view of NOSI relative to observation and inferences and those that agree with statements 1B and 1C hold the naive view of NOSI relative to observation and inferences and vice versa.

Table 4.1 Learners' views on observations and inferences

Theme	Disagree %	Agree %
1.Observations and inferences		
A. Scientists' observations of the same event may be different because what scientists already know may affect their observations.	6	94
B. Scientists' observations of the same event will be the same because scientists are objective.	60	40
C. Scientists' observations of the same event will be the same because observations are facts.	55	45
D. Scientists may make different interpretations based on the same observations.	9	91

Most learners seem to have the informed views about observations and inferences. As shown in Table 4.1 above, 94% of learners agree with the statement: scientists' observations of the same event may be different due to the fact that what scientists know already may affect their observations (1A). At the same time, 91% of learners agree with statement 1D indicating an informed view of observation and inferences. It also shows that 60% of learners disagree with the fact that scientists are objective and therefore their observation of the same event will be the same (1B) showing that the majority of the learners hold an informed view about the nature of scientific observations and inferences.

Results from LUSSI: open-ended question

Table 4.2 shows responses of learners to the open-ended part of LUSSI questionnaire. The scoring guide (see, Table 3.1) was used to classify learners' responses. Remember, it was indicated in Chapter 3 that learners' responses were classified under four categories which are: Not classifiable; Naive understanding; Transitional understanding; and Informed understanding of NOSI. These were then collapsed into two categories "Naive and Informed" by collapsing Not classifiable and Naive understanding into Naïve category. Then Transitional understanding and Informed understanding were collapsed into Informed category. Table 4.2 shows that 56 % of the learners seem to have the understanding that; scientists have different knowledge which originates from their different backgrounds, the practices they grew up doing and their daily exposure to scientific information. The different backgrounds that learners suggest in their responses include; the schools that the scientists attended, their different teachers, social and cultural backgrounds.

Table 4.2 Learners' responses to open-ended part of LUSSI questionnaire

Tenets of NOSI	**Naive (open-ended responses)**		**Informed (open-ended responses)**	
	Examples of statements	**Learners (%)**	***Examples of statements***	**Learners (%)**
Observations and inferences	They are the same because scientists are already objective, they have one way of sight because of their knowledge. **(S23)**	44	They are different. This because their observations and interpretations are influenced by scientists' different background in science and their daily exposure to scientific information. **(S109)**	56
Scientific Laws vs. Theories	Scientific theories are facts that scientists come across and they are proven while scientific laws are not proven. **(S15)** Theories talk of truth and laws talk of prove. **(S22)**	83	Scientific theories are the explanations of the given laws. For example, it is stated by Hooke that extension is proportional to the force applied and it is stated by him that beyond elastic limit it is disobeyed. That is to say, the law states that extension is proportional to force and theory that supports that explain that beyond elasticity, the law is disobeyed. **(S119)**	17
Change of Scientific Theories	They cannot change because scientific theories are based on accurate experimentation. **(S23)**	35	Scientific theories may be change because scientists reinterpret existing observations. **(S2)**	65
Social and Cultural Influence on Science	Society and culture do not affect scientific research because the scientists use the universal law of science like here in Lesotho if we use our hands to measure length and other countries use their things the scientists will not accept that they will use universal instruments. **(S13)**	71	They affect scientific research in that there are certain social and cultural beliefs that may discourage any research on certain culture and social issues. In this way, it is likely that scientific research can be minimal or less successful; as such social and cultural beliefs. **(S102)**	29
Imagination and Creativity	They do not use their imaginations and creativity	32	Scientists use their imagination and creativity	68

in Scientific Investigations	when analysing data they have collected because the data need to be analysed with theories or information which already existed. If they use their imagination and creativity, they will analyse the data wrongly. **(S44)**		when they analyse and interpret data and when they collect data. **(S2)** They use them always because they use their minds and these needs more understanding. **(S87)**	
Methodology of Scientific Investigation	They follow a single, universal scientific method for getting things correctly. **(S12)** Scientists follow the same step-by-step scientific method to conduct scientific investigations. **(S28)**	30	They use different methods all over, e.g. other can use some experiments while other can discover and put their discovery on the books to the other. **(S40)**	70

Such learners' believe that scientists interpret their observations basing on their prior knowledge and this leads to different interpretations of the same observation. When responding to the question about whether scientists can come up with the same observation and interpretation of the same event some said:

> S28: Scientific observation of the same event may be different because what scientists know already may affect their observation.
>
> S32: They are different because scientists are not from the same school and their teachers are different and they are not teaching with the same knowledge. They do not think the same way.
>
> S68: They are different because it is also depends on one's own knowledge of science. Over and above, people can observe differently although working on the same experiment.

The above quotations suggest that learners have the understanding that scientists may observe and interpret the same phenomena differently because of their differing knowledge backgrounds. However, the percentage (56%) of learners responding in this way was lower in the open ended responses compared to the Likert questions (73%, see Figure 4.1). Overall, considering the open-ended questions it can be said that 56% of learners demonstrated an informed understanding while 44% demonstrated the naive view. The discrepancy between the Likert and open-ended responses could lie in the fact that learners failed to provide

convincing reasons to justify their responses in the open-ended part. It could also raise questions about the validity of the Likert questions.

In line with findings of earlier studies (Liang et al., 2006; Miller et al., 2010), most of the learners who participated in this study appear to hold the informed view of NOSI in relation to observation and inferences. This appears to be the conclusion coming out of analysis of both Likert portion and the open-ended part of the questionnaire responses. However, this could be misleading as the percentage of learners whose responses were classified under informed view to the open-ended part were much lower than percentage of learners who demonstrated informed view under the Likert part of the questionnaire. As mentioned, a possible explanation for this might be that most learners failed to justify their responses to the questions. This agrees with the results of Liang et al. (2006) who also found learners struggling to justify their answers. It could be argued that the more reliable understandings of learners are those given to the open-ended questions rather than to the Likert part because in open ended responses they were able to express their views.

Results from interviews

In corroboration with their Likert responses, most of the interviewed learners also demonstrated an informed view about observations and interpretations/inferences. Five of the eight interviewed learners expressed the idea that scientists like any other people are different and hence have different beliefs, ways of thinking and cultures which may influence the way they observe and interpret events. For example one of the learners said:

> S5: that one of observing one thing can hardly happen because people are different in minds and our ways of thinking are different and they will probably have to come up with a different thing, ideas and observations. Yah!

Learners also expressed that each scientist's knowledge contributes to the way he/she interpreted data. The results of this study is in line with that of Akerson and Donnelly (2010) as learners in their study show that they have the informed view as they were able to differentiate between observation and inferences after being involved in a five week course which examined their views on aspects of NOS like observation and inference. The interesting thing about interviews was the fact that learners were able to give as many example as possible to express themselves clearly and what they say can be considered to be

their actual perceptions of issue. This could suggest that interviews are more important and reliable in eliciting learner's views compared to Likert and open-ended questions.

4.1.2 Scientific laws versus scientific theories

Results from LUSSI: Likert questions

Under the second selected tenet of NOSI, statements 2A, 2B and 2C are naive about scientific laws and theories. Statement 2D is the only informed statement of NOSI in relation to scientific laws versus scientific theories. From this it can be said that learners who disagree with 2A, 2B and 2C and those who agree with 2D have the informed understanding of NOSI with respect to scientific theories and laws. Those agreeing with 2A, 2B and 2C and disagreeing with 2D can be said to harbour naive views.

Table 4.3 Learners' views on scientific laws and theories

Theme	**Disagree %**	**Agree %**
2.Scientific Laws vs. Theories		
A. Scientific theories exist in the natural world and are uncovered through scientific investigations.	15	85
B. Unlike theories, scientific laws are not subject to change.	28	72
C. Scientific laws are theories that have been proven.	9	91
D. Scientific theories explain scientific laws	26	74

The results show that most learners seem to have poor understanding of the difference between scientific laws and theories. This is evident in Table 4.3 as most of the learners 85%, 72%, and 91% agree with the naive statements 2A, 2B and 2B respectively. It appears that the majority of the learners who participated in this study have naive ideas about the difference between scientific laws and theories.

Results from LUSSI: open-ended question

Most learners demonstrated a misunderstanding of this tenet as reflected by their responses. They appear to have the understanding that scientific laws are the rules and regulations that scientists should follow when making their investigations, failure of which may lead to inaccurate results. According to them, laws are the conclusions that scientists arrive at after experimentation. These responses arise from the fact that these learners seem to be confusing

scientific laws to scientific methods and the other problem might be of language. That is, learners were unable to express themselves clearly in English. To them once laws have been proven through experimentation, they will never change. About scientific laws some said:

> S26...laws are regulations that show how to deal with something.
>
> S39 ...scientific law are the agreement that is done by scientists that if something is somehow it will stay like that always nothing to change it.
>
> S50..Scientific laws are the rules in scientific studies to be followed when interpreting in science lab.

As these learners indicate, every scientist should follow a certain rule when doing some investigations. Some learners consider theories to be the scientific idea or information that explains scientific laws. In general, participants' responses to the Likert and open ended questions were consistent in this aspect. Most of learners were classified under naive view, that is, 83% for open ended responses (OR) (Table 4.2) and 95% for Likert responses (LR) (Figure 4.1).

On this tenet of NOSI, it was found in this study that most learners have poor understanding of the difference between scientific laws and scientific theories. It seems as if learners have poor knowledge of nature of science even though Lederman (2002) asserts that understanding of nature of science is a prerequisite for scientific knowledge. These may imply that some science teachers do not have understanding of nature of science and therefore do not bother teaching learners about that and if a study can be done on teachers' understandings of NOSI in Lesotho same results may be found. This is not surprising as these findings of the current study are consistent with those of Liang et al. (2006) and that of Miller et al. (2010) who found out that most learners have the naive understanding of scientific theories and scientific laws as they indicate that laws are proven theories and will never change.

Results from interviews

Six of eight learners interviewed demonstrated the naive understanding of scientific laws and theories as they indicate that laws are proven theories which will never change. One student said:

> S6: I don't think, I don't think they will change because e...! For example they have been a e...! The, the, the people who came up with those e...! Lived long time ago and even now they have not changed, we still using their laws.

These learners also believe that theories are discoveries done by scientists when doing some investigations and can put them together to form laws. Only two learners demonstrated the transitional understanding as they indicate that laws are scientific facts which can be explained by scientific theories but failed to justify their responses. Learners' responses to the interview corroborated their answers to the open-ended and Likert part of questionnaire and this suggests that learners hold the naive view on this tenet of NOSI.

4.1.3 Change of scientific theories

Results from LUSSI: Likert questions

Under this tenet of NOSI the first three statements (3A, 3B and 3C) are of informed view of change of scientific theories and 3D is of naive view (see Table 4.4). Learners who agree with the statements 3A, 3B and 3C and disagree with statement 3D have the informed understanding. While those who disagree with statements 3A, 3B and 3C and agree with statement 3D have the naive view.

Table 4.4 Learners' views on change of scientific theories

Theme	Disagree %	Agree %
3.Change of Scientific Theories		
A. Scientific theories are subject to on-going testing and revision	25	75
B. Scientific theories may be completely replaced by new theories in light of new evidence.	43	57
C. Scientific theories may be changed because scientists reinterpret existing observations.	37	63
D. Scientific theories based on accurate experimentation will not be changed.	22	78

In this tenet most learners seem to have an informed view of NOSI in relation to change of scientific theories. This is because most learners agreed with statements 3A, 3B and 3C (75%, 57% and 63% respectively) which are of informed view of NOSI in this tenet. These results clearly indicate that these learners understand what scientific theories are and that they can be changed from time to time. However, this is surprising as these learners denoted in the second tenet that they do not know the difference between scientific law and scientific theory. Most of them even indicated that scientific theories exist in the natural world and are uncovered through scientific investigations. These responses contradict each other.

Results from LUSSI: open-ended question

Results from open-ended question also suggests that most learners harbour informed view on change of scientific theory. This is because most learners seem to believe that scientific theories change from time to time due to scientists reinterpreting the existing observation. As indicated above the reinterpretation brings different observations which in turn bring new evidence to change the existing theory. Moreover, some learners claim that this change of scientific theories can also be brought by the fact that some scientists do not trust each other and therefore keep on making follow ups on what other scientists have done and ended up coming with some new evidence to change the existing theory. For example some learners said:

> S76: Scientific theories may change because sometimes other scientists may not believe other scientists' theories and make follow ups on that theory until they come up with different stories.

> S110: ...It might change because scientists may agree to disagree on something.

Learners' responses to both Likert part (64%) and open-ended part (65%, Table 4.2) of the questionnaire on change of scientific theory seem to highly correspond for learners who demonstrated the informed understanding under this tenet of NOSI.

The current study found that most learners have the informed understanding of scientific theories as they indicate that scientific theories can changed from time to time. Even those who are classified as having the transitional view under this tenet, their responses to the open-ended part do not demonstrate the naive view, it is just that they failed to justify their responses. This finding is in agreement with the findings of Miller et al. (2010) which showed that most learners' posses informed view on change of scientific theories. However, the results from Liang et al. (2006) suggest that many learners hold the transitional view as indicated by their Likert part responses while there are few learners holding the informed view of NOSI in their open-ended responses.

Results from interviews

Five of eight learners interviewed demonstrate the informed understanding of NOSI in relation to change of scientific theories as they clearly indicate that theories can change. They also claim that it is important to be taught such theories because they are the ones that explain to them how scientific laws are developed and help them understand science even better. Some said:

> S6: yes, I think they will change because as time goes on they are new development of new ideas and all the staff so I think they will, they will end up changing.

> S3: even theories, they can change like if us... I would like to make an example with rain. We know that water from the streams evaporates and when it evaporates it will make what? (Asking himself) it will make the clouds out there but as for now ache...too much water has been evaporated but we cannot see rain and do not know why do that happens.

Learners' responses to Likert part, open-ended part of the questionnaire and that from the interviews highly correspond suggesting that these learners have an informed understanding on the change of scientific theory tenet. However, it is surprising that most learners seem to believe that scientific theories change from time to time yet most of them indicated that scientific laws can never ever change in the above tenet on difference between scientific laws and theories.

4.1.4 Social and cultural influences on science

Results from LUSSI: Likert questions

Under social and cultural influences on science, statements 4A and 4D are of naive view and 4B and 4C are of informed view (see Table 4.5). Learners who agree with statement 4A and 4D and those who disagree with 4B and 4C have the informed view of NOSI relative to social and cultural influences on science. On contrary, those who disagree with 4A and 4D and those who agree with 4B and 4C have the naive view on this tenet.

Table 4.5 Learners' views on social and cultural influence on science

Theme	Disagree %	Agree %
4.Social and Cultural Influence on Science		
A. Scientific research is not influenced by society and culture because scientists are trained to conduct "pure", unbiased studies.	38	62
B. Cultural values and expectations determine what science is conducted and accepted.	70	30
C. Cultural values and expectations determine how science is conducted and accepted.	72	28
D. All cultures conduct scientific research the same way because science is universal and independent of society and culture.	35	65

Most learners seem to have the naive view on social and cultural influences on science since 62% and 65% of learners agree to statements 4A and 4D respectively which are of the naive view on social and cultural influences on science (see Table 4.5 above). Moreover, there is a significant portion of learners (70% and 72%) who disagree with the fact that cultural values and expectations determine what and how science is conducted and accepted (statements 4B and 4C respectively) which are also of the naive view of this tenet of NOSI.

Results from LUSSI: open-ended question

Most learners indicate in their open-ended responses that society and culture does not affect scientific research because they belief that science is universal and independent of society and culture. They also believe that scientists are trained to conduct pure and unbiased research. These learners showed an understanding that scientific research has got nothing to do with what people believe but is concerned with what scientists observe in their experiments and what has been proven in front of them. Some of their explanations are as follows:

> S65: Culture does not affect scientific research because it is not what we believe but we observe in an experiment. So what we believe has got nothing to do with what is proven in front of us.

> S82: Culture cannot affect scientific research because here in scientists they are dealing with the facts no matter what does the culture says but the observation might be fair.
> S1: Culture does not affect scientific research because scientists are trained to conduct pure and unbiased studies.

S24: The society and culture do not affect scientific research because they are universal and independent.

The above quotation gives evidence that many learners have the naive view of NOSI in relation to social and cultural influences on science. These learners believe that people's beliefs cannot affect scientific research as it is concerned mostly with what is observable in scientific investigations. Most learners demonstrated this naive view to their responses to both Likert and open-ended part of the questionnaire and the percentage classified as having the naive view is also consistent in both parts of responses which is 71% for OR (Table 4.2) and 83% for LR (Figure 4.1).

The results show that these learners have the naive understanding in this tenet of NOSI. However, the findings of the current study do not support the previous research by Miller et al. (2010) and Liang et al. (2006). This is because Miller et al. found that learners possess transitional view about this NOSI tenet. For the Liang et al. study, the number of learners who showed a transitional view was even smaller for open-ended responses as compared to the Likert response part.

Results from interviews

For this selected tenet of NOSI, three of eight learners interviewed believe that culture has got nothing to do with science, as they indicate that science is science and culture is culture and that these are two different beliefs or practices which are not influencing each other. These learners are identified as having the naive understanding of NOSI relative to social and cultural influences on science. For example, some learners in their explanations said:

S2: I agree with the statement which said science does not agree with that madam. Scientists research exists even if the cultures and those things are not considered when scientists research. Meaning, culture is something that is outside, it cannot influence how researchers think.

S4: individually science cannot be disturbed by the culture and believes that people have but in other way parents can also influence what we know or what we learn about science.

S8: I think the culture cannot influence the, (not clear) culture has got nothing to do with science. Science is science and culture is culture.

Another three learners are considered to be having the transitional understanding as their responses are composed of the naive and informed view of this tenet. Some indicate at the beginning that society and culture cannot influence which science is to be accepted and practiced but through follow up questions their explanations changed and claim that science can be influenced by society and culture.

The results of this study show that most learners have the naive understanding of social and cultural influences on science. It can be inferred that this learners have little knowledge, experiences and understandings of scientific inquiry that is why they seem to believe that society and culture cannot influence scientific research.

4.1.5 Imagination and creativity in scientific investigations

Results from LUSSI: Likert questions

Statements 5A and 5B are of the informed view on imagination and creativity in scientific investigation tenet, while 5C and 5D are of naive view (Table 4.6). Learners who agree with 5A and 5B and disagree with 5C and 5D were classified as having the informed view of this tenet, while those who disagree with the first two statements and agree with the last two were classified under naive view.

Table 4.6 Learners' views on imagination and creativity in scientific investigations

Theme	Disagree %	Agree %
5.Imagination and Creativity in Scientific Investigations		
A. Scientists use their imagination and creativity when they collect data	27	73
B. Scientists use their imagination and creativity when they analyze and interpret data.	27	73
C. Scientists do not use their imagination and creativity because these conflict with their logical reasoning.	77	23
D. Scientists do not use their imagination and creativity because these can interfere with objectivity.	57	43

In this tenet of NOSI, most learners seem to have the informed understanding. This is because most learners agree with statements 5A and 5B (73%, Table 4.6) which are of the informed view of NOSI relative to imagination and creativity in scientific investigation and also disagree with the naive statements in this tenet 5C and 5D (77% and 57% respectively).

This finding suggests that these learners hold a view that imagination and creativity should be used in scientific investigations.

Results from LUSSI: open-ended question

Many learners (68%, Table 4.2) demonstrated an informed understanding as they indicate that imagination and creativity should be used throughout scientific investigations so that scientists can be able to come up with reasonable scientific theories and laws. These learners indicated that since scientists like any other people are different and think differently, that can help in coming up with successful investigations if they use those different imaginations and creativities that each one of them possess. Some learners harbouring the informed views on imagination and creativity in scientific investigations said:

> S84: Scientists use their imagination when they collect data because their imagination will be not the same people do not think in the same way and when they analyse and interpret data.

> S118: Scientists use their imagination and creativity because they think before doing something, example a book comes from a tree even desks so as a scientists who did them he/she thought of them before he can do them, and he imagine before and made a picture or image of it in his/her mind. He/she had the willing from his/her heart.

> S119: Scientists use imaginations when investigating about something, for example one can make investigations on a volcano. And someone can imagine how volcano looks like and can also create a picture of his choice and come across the conclusion that volcano is something that occurs naturally. Scientists can be able to use imaginations and creativity when they want information they do not know.

Learners' responses to both Likert part and open-ended part of the questionnaire seem to be consistent as 68% of learners demonstrated informed understanding in this tenet in open-ended part and 71% in Likert part of the questionnaire.

As mentioned in the literature review, most learners seem to have the informed view on this tenet of NOSI as they claim that imagination and creativity should be used throughout the scientific investigations (Lederman et al., 2002). In previous research, it was found that learners demonstrate less informed understanding as they failed to reach the required standard of the scoring guide (Liang et al., 2006). Learners in Miller's et al. (2010) study also demonstrate less informed understanding of imagination and creativity in scientific investigation tenet. However, in the present study most learners demonstrated that they have

better understanding of NOSI relative to imagination and creativity. It is most probable therefore that these learners have been given the opportunity used their imagination and creativity in their classroom investigations that is why they have a view that scientists should always use their imaginations and creativity when carrying out scientific research.

Results from interviews

From interview responses, five learners demonstrate an informed view of NOSI relative to imagination and creativity in scientific investigation. They indicate that scientists use their imagination and creativity in their experiments and investigations. For example, one said:

> S3: there is no time that they will not use their imaginations because everything which you do, you must think of it before you can perform it. Same as their creativity, they should always use their creativity.

This maintains that these learners believe that imagination and creativity should be used throughout scientific investigations. Two of them assert that scientists use their imagination and creativity but not always, their responses suggest that scientists do not use their imagination and creativity when they are dealing with simpler experiments like finding the density of an irregular object. These learners are considered to be having the transitional understanding in this tenet. The responses from the interview also correspond to Likert and open-ended responses and indicate that most learners have the informed understanding on this tenet of NOSI.

4.1.6 Methodology of scientific investigation

Results from LUSSI: Likert questions

Under methodology of scientific investigation tenet, statements 6A and 6D are of informed view while 6B and 6C are of the naive view of NOSI. Agreeing with 6A and 6D and disagreeing with 6B and 6C demonstrate an informed understanding of NOSI relative to methodology of scientific investigations (see Table 4.7). While disagreeing with 6A and 6D and agreeing with 6B and 6C demonstrate the naive understanding of this tenet.

Table 4.7 Learners' views on methodology of scientific investigation

Theme	Disagree %	Agree %
6.Methodology of Scientific Investigation		
A. Scientists use different types of methods to conduct scientific investigations.	9	91
B. Scientists follow the same step-by-step scientific method to conduct scientific investigations	55	45
C. When scientists use the scientific method correctly, their results are true and accurate.	8	92
D. Experiments are not the only means used by scientists to get scientific knowledge.	45	55

The results of this study suggest that most learners harbour the naive understanding on methodology of scientific investigation. This is because learners' responses seem to indicate that learners do not know what a scientific method is. To explain this, Table 4.7 shows that 55% of learners indicate that scientists follow the same step-by-step method to conduct their scientific investigation and 92% believe that if they follow such method correctly, their results will be true and accurate. Yet 91% indicate that different methods should be used when conducting scientific investigations.

Results from LUSSI: open-ended question

Most learners indicate in their constructed responses that scientists use different scientific methods for their investigations. They further indicate that scientist investigates on different things which require them to use a variety of methods. Moreover, some different methods should be used to examine the existing observation, that is, to check if they will get similar results to what they got when they were using a particular method. These learners also assert that scientists have different levels of education and access to technology; as a result they have to use methods which will be relevant to a particular context. Below are some of learners' explanations:

> S102: They do not use a universal scientific method because the nature of things that are studied is different and the conditions that might surround the issues under study differ.

> S106: Scientists use different methods when doing scientific investigation because sometimes they may use computers or experiments to deal with different method to conduct scientific investigations.

> S39: Scientists use different methods because all of them did not think about the same thing. Their imaginations are different because everybody got its creativity for everything he/she want to do.

These learners (70% for OR, Table 4.2) were classified as having the informed understanding of NOSI in relation to methodology of scientific investigation.

The findings of this study under methodology of scientific investigation tenet demonstrate that most learners have the informed understanding of methodology on scientific investigation. This is because most learners in their open-ended responses demonstrated that they understand that there should be different methods to be used for scientific investigations. However, the number of learners (70%) in open-ended part does not correspond to their responses in the Likert part as in the Likert part most learners (55% Figure 4.1) seem to posses the naive view in this tenet. The responses to the open-ended questions can be considered to be more important than those from the Likert part. That is why it can be concluded that most learners hold the informed view in this tenet. The results of this study differ from that of Miller et al. (2010) and that of Liang et al. (2006) who found that learners possess less informed understanding on methodology of scientific investigation.

Results from interviews

From the interview responses, all learners indicate that there are different scientific methods to be used in scientific investigations. Even though, most learners were classified as having the informed view of NOSI relative to the scientific methods for investigations, they indicate that they do not know other scientific methods except experimentation. This is still consistent to their responses in the open-ended part of LUSSI since learners failed to give examples of scientific methods other than experimentation. This was in line with the results of Liang et al. (2006) which suggested that learners do not know types of scientific methods other than experimentation. Some learners when asked to give other example of scientific method, they said:

> S8: I really cannot think of another method that they use, but I think they do not rely on one method.

> S3: rather than experiments? I, I, I don't think they are there.

One observation that was made was that some learners confuse different methods with different steps within the scientific experiments, and that was made evident in their open-

ended and interview responses. One learner (S3) said "there are other ways of which you can perform e...experiment". According to this learner, different steps followed in an experiment are different scientific methods. This finding further support the idea of Liang et al. (2006) as they indicate that learners do not know what a scientific method is.

Figure 4.1 below shows the summarized responses of learners for Likert part of the questionnaire per tenet of NOSI and the number of learners in percentage. As indicated in chapter 3, in responding to the items, learners were required to indicate whether they strongly disagree, disagree, uncertain, agree and strongly agree and were given a score of 1, 2,3,4,5 respectively for positive items. For negative items, the scores were in the reverse order. The lowest score per theme (tenet) is 4 and the highest score is 20. In every theme all learners who score 4-12 were classified as having the naïve view under that particular tenet and those who scored 13-20 were classified as having the informed view.

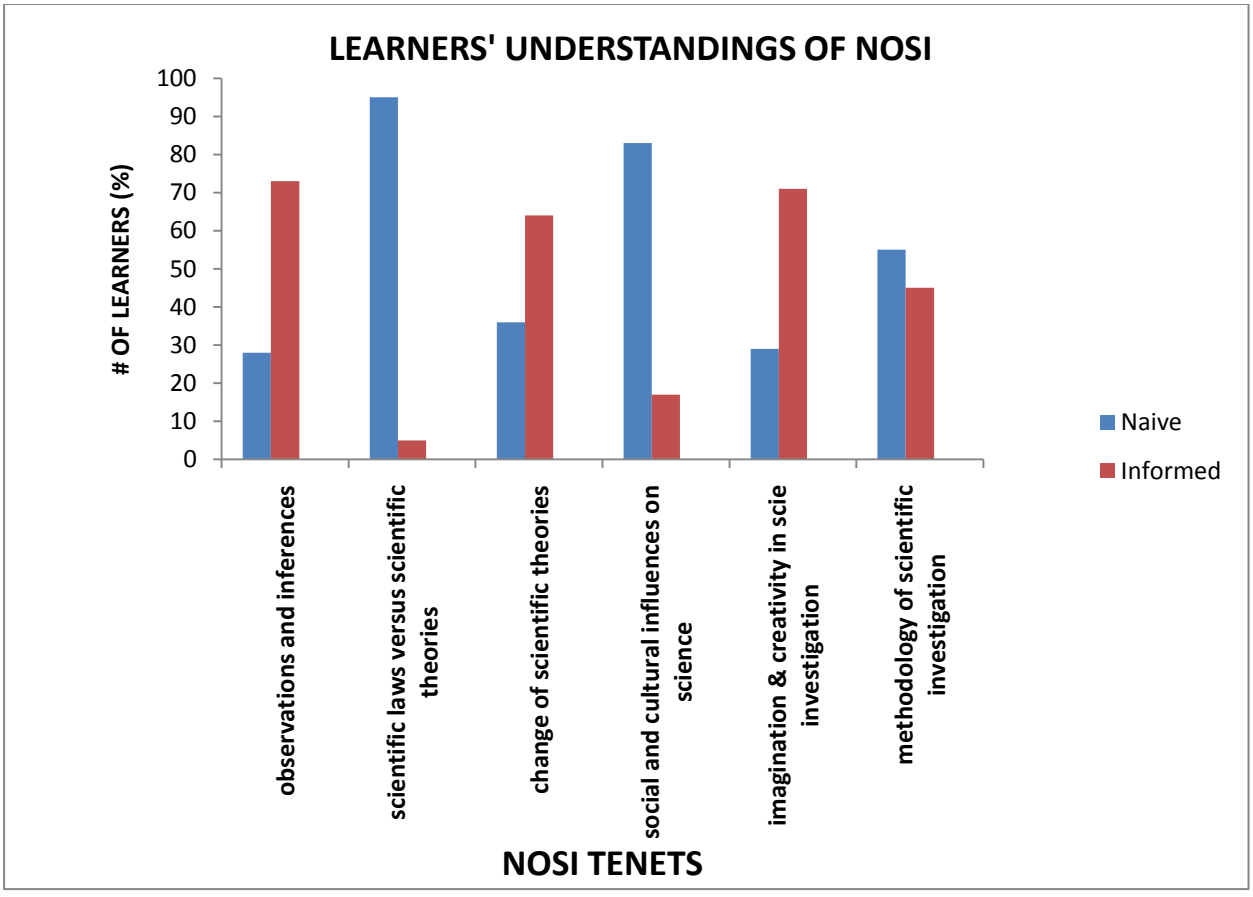


Figure 4.1 Learners' understandings of NOSI

The present study is the first to investigate learners' understandings of NOSI in Lesotho. On the question of what are learners' understandings of the nature of scientific inquiry? It was found that the results of this study on Likert part of the questionnaire suggest that most learners posses informed understanding on (1) observations and inferences; (3) change of scientific theories; (5) imagination and creativity, and possess the naive understanding of NOSI on (2) scientific laws versus theories; (4) social and cultural influence on science (6) methodology of scientific investigation. However, this result is not convincing because in learners' responses to the open-ended part of the questionnaire and from the interview responses they seem to have the naive view only in tenets (2) scientific laws versus theories and (4) social and cultural influence on science. These findings suggest that learners' understanding of nature of science and scientific inquiry needs further investigation and this is an important issue for future research in Lesotho.

4.2 Learners' perceptions of their experiences of scientific inquiry in classroom

The results presented and discussed here are of the extent to which learners are experiencing scientific inquiry in science classrooms as determined using the PSI-S questionnaire and interviews. The results from the PSI-S (n = 120) are presented and discussed first, followed by those from the interviews (n = 8).

Results are summarized and discussed for learners' perceptions of their experiences of each of the five principles of scientific inquiry chosen for the study. These principles are: (A) asking or framing research questions, (B) designing investigations, (C) conducting investigations, (D) collecting data, and (E) drawing conclusions. There are four statements under each principle which are aligned to reform calls for engaging learners in scientific inquiry except statements under principle B (B1) and C (C2) which support teacher directed approach.

4.2.1 Asking/framing research questions

Results from PSI-S: Likert questions

This principle focuses on extent to which learners are given the opportunity to ask their own research questions for investigations. Percentage of learners under never column are for learners who are given less chance to ask their own questions and those under always column are always responsible for framing their own questions for investigations.

Table 4.8 Learners' experiences on asking/framing research questions

Principles of scientific inquiry	Never %	Always %
A. Asking/framing research questions; in the science classroom		
A1. Students formulate questions which can be answered by investigations	79	21
A2. Student research questions are used to determine the direction and focus of the lab	64	36
A3. Students framing their own research questions is important	25	75
A4. Time is devoted to refining student questions so that they can be answered by investigations	71	29

The results of this study suggest that learners are rarely given the opportunity to experience scientific inquiry by asking scientific questions for investigations, even though Krajcik et al. (1998) assert that asking good questions comes from having experience of asking questions and learning how questions influence the design and conduct of an investigation. This is because 64% of learners indicate that their research questions are never used to determine the direction and focus of the lab in their classrooms. Most learners (75%) in this study have the same view as that of learners' in Rop (2003) who seem to believe that actively engaging in scientific inquiry by asking students inquiry questions will develop their understandings of NOS and NOSI. However, in this study learners are not given that opportunity to ask their own questions in their classrooms (79%). It can be argued that these learners are not experiencing open-ended inquiry in their classroom as their teachers are always doing part of the work on their behalf. The results of this study opposes that of Rop (2003) whereby learners were given opportunity to ask students inquiry questions

Results from interview

The results from the interview are consistent with that from the Likert questionnaire as five of the eight learners interviewed claim that they are never given chance to formulate their own questions for investigations but their teachers always do. When learners were asked about who formulates questions for investigations in their classroom, some said:

S6: ok, it's always the teacher.

S5: Yah, actually our teacher.

S8: I think most of the time is the teacher.

Three of the interviewed learners also indicate that their teachers formulate the questions for investigations in most of the time except in rare cases where they have asked the teacher to give them chance to formulate their own questions. They indicate that they are only given chance when they are dealing with simpler things like finding the density of objects. This still suggests that learners are rarely experiencing scientific inquiry in their classroom in relation to asking their own research questions for investigations.

The results of this study show that the scientific inquiry that learners are experiencing in their classroom relative to asking scientific questions for investigation is teacher directed (Asay & Orgill, 2010) as learners claim to be given questions by their teachers in most of the time. This suggests that these learners are always experiencing partial or less scientific inquiry in their classrooms in relation to this principle of scientific inquiry. As Hofstein et al. (2005) found in their study that involving learners in inquiry-laboratory activities enable them to be able to ask better research questions, it can be argued that learners in this study are rarely given that opportunity to be involved in inquiry-laboratory activities, that is why their teachers are always helping in providing them with questions for investigations knowing that they would not be able to do that be themselves.

4.2.2 Designing investigations

Results from PSI-S: Likert questions

The second principle of scientific inquiry focuses on the extent to which learners are given opportunity to design their own procedures to be followed when conducting their investigations. Percentage of learners under “Never column” (Table 4.8) are for learners who are not given chance to design their own procedures and those under “Always column” are always responsible for designing their own procedures to be followed when conducting investigations. However, statement B1 is the opposite as it is supporting teacher directed approach.

Table 4.9 Learners' experiences on designing investigations

Principles of scientific inquiry	Never %	Always %
B. Designing investigations; in the science classroom		
B1. Students are given step-by-step instructions before they conduct investigations	17	83
B2. Students design their own procedures for investigations	88	12
B3. Students engage in the critical assessment of the procedures that are employed when they conduct investigations	59	41
B4. Students justify the appropriateness of the procedures that are employed when conducting investigations	73	27

In reference to Table 4.8 above, it can be argued that learners in the present study are never given the opportunity to design their own procedures to be followed when conducting their investigations as suggested by the reform calls. This is because most learners for all the statements fall under Never column B2 (88%), B3 (59%), B4 (73%) and for B1 (83%) which is the opposite under Always column. These results suggest that most learners are never given chance to experience more scientific inquiry under this principle and the inquiry that learners are experiencing is teacher directed.

Results from interview

The corroborating responses from the interview also suggest that learners are not given the opportunity to engage in scientific inquiry by designing their own procedures for investigations as most of them claim to be given the step-by-step instructions before they conduct investigations. Only two students indicate that they are sometimes guided by their teachers to design their own procedures for investigations, but they never did that on their own. For example, some learners said:

> S1: e... normally our teachers always design the procedure to be followed.
>
> S6: e...., the procedure, the procedures are always given by the teachers. Yes our teachers. We are always told what to do.
>
> S8: I think we take the procedure from the textbook that we are using.... Yah. I don't think we will be given chance to design our own procedures because, like it is said that we are not... we should not add water to acid but add acid to water. So I think if we are to design our own procedure then we might cause some problems.

According to the learners quoted above, they have never given chance to design their own procedure and they seem to believe that it is because they might cause some problem during the investigations if they can be given such an opportunity.

Relative to this principle of scientific inquiry, this study found that inquiry that learners are experiencing in their classroom is also teacher directed (Asay & Orgill, 2010) as they claim to be given methods to follow by their teachers or ordered to use the procedure in their textbooks. These findings suggest that these learners are always experiencing closed-ended inquiry in their classrooms.

4.2.3 Conducting investigations

Results from PSI-S: Likert questions

Conducting investigations is another principle of scientific inquiry selected in this study. This principle focuses on the extent to which learners are responsible to carrying out procedure for investigations. Percentage of learners under "Never column" (Table 4.10) are for learners who are not given chance to conduct the procedures and those under "Always column" are always responsible for conducting the procedures during investigations. However, statement C2 is the opposite as it is supporting teacher directed approach.

Table 4.10 Learners' experiences on conducting investigations

Principles of scientific inquiry	**Never %**	**Always %**
C. Conducting investigations; in the science classroom		
C1. Students conduct their own procedures of an investigation	76	24
C2. The investigation is conducted by the teacher in front of the class	42	58
C3. Students actively participate in investigations as they are conducted	51	49
C4. Each student has a role as investigations are Conducted	52	48

The results as appeared in Table 4.10 above indicates that learners are given less opportunity to participate by conducting their own procedures of an investigations. This is because most learners (76%) claim not to be conduction their own procedures for investigations but their teachers (58%). It can be argued that these learners were mostly experiencing closed-ended inquiry (Asay & Orgill, 2010) for conducting investigation as their percentages in "Never"

column is higher than in "Always" column. The results under this principle suggests that learners are experiencing scientific inquiry by participating in investigations that are conducted by their teachers but they are seldom given chance to conduct their own procedures.

From the literature, Cuevas et al. (2005) found that learners' ability to conduct inquiry and to employ some skills of inquiry is increased when learners are being helped by their teachers using probing questions. The results of this study suggest that inquiry that learners are experiencing is teacher directed (Blanchard et al., 2010) as learners in this study seem not to be having such opportunity as being helped by their teacher with probing questions for them to be able to decide for themselves on how and when to conduct the investigations in their classrooms.

Results from interview

As a follow up question to the questionnaire on conduction of investigations, learners are asked about who conducts the investigations and what the roles of learners and their teachers are during the conduction of the investigations. In their responses, learners indicate that in most of the time their teachers are the ones who conducts investigations and they are given chance to observe and give their own opinions on what they are observing. They also indicate that in rare cases when they are given chance to conduct the experiments, they normally work in small groups and each member of a group is assigned a role to do during investigations. One conversation went as follows:

> **Researcher:** Ok, let's say now you are doing the experiment, who normally conducts it? Is it the students or the teacher?
>
> **S6:** Ok, the problem in our school is because we don't have enough equipment but some teachers are willing to give us the equipment and we conduct the experiment and they tell us what to do. But most of the time is our teacher who conducts the experiments.
>
> **Researcher:** Ok, that means you as students carry out your own procedure in rare cases due to lack of equipment?
>
> **S6:** Yes madam.

This suggests that learners are not experiencing full inquiry under this principle of conducting investigations because they are always directed by their teachers on what to do and when to do what they have to do.

In the same way learners are not experiencing full scientific inquiry relative to conducting the investigation in their classrooms. It can be argued that learners are experience partial scientific inquiry as they indicated that in most of the time it is their teachers who perform the investigations in front of the class. Asay and Orgill (2010) also found the same results in their study. There are several possible explanations for this result. One can be that there are no enough scientific materials and equipment that will enable them to conduct the investigations for themselves as most learners claimed. Another possible explanation for this is that, time allocated for their investigations is very limited, and if they are the ones conducting investigations they will never complete them. As a result teachers resort to classroom demonstrations.

4.2.4 Collecting data

Results from PSI-S: Likert questions

This principle of scientific inquiry focuses on the extent to which students are engaged in making decision on the collection of data during investigations. Percentage of learners under "Never column" (Table 4.11) are for learners who are not given chance to decide when and which data to collect during investigations and those under "Always column" are always responsible for deciding when and which data should be collected.

Table 4.11 Learners' experiences on collecting data

Principles of scientific inquiry	**Never %**	**Always %**
D. Collecting data; in the science classroom		
D1. Students determine which data to collect	69	31
D2. Students take detailed notes during each investigations along with other data they collect	29	71
D3. Students understand why the data they are collecting is important	34	66
D4. Students decide when data should be collected in an investigation	84	16

The results as appear in Table 4.11 indicate that learners are not given chance to decide when and which data should be collected during the investigations. This is because 69% of learners claim that they never determine which data to collect. Moreover, 84% of learners claim that they never decide when data should be collected. Even though, they are not the ones

determining when and which data to collect, they seem to understand the importance of data they are collecting (66%) as they even participate by taking some detailed notes of what is happening during the investigations (71%). These suggest that learners are experiencing partial inquiry (Asay & Orgill, 2010) relative to the collection of data, as part of the work is done by their teachers.

Results from interview

As indicated under conduction of investigation above, learners claim that they always take detailed notes during each investigation as they are recording the results from the experiments. They indicate that they normally record their data in their notebooks. These learners said their teachers tell them what to observe and what to record during the investigation and this suggests that they are not experiencing full scientific inquiry under collection of data. For example one learner explains by saying:

> **S5**: Sometimes you may find that the experiment is being done by me, and then I get it over. Then the next person comes. But we always give each of us a task to do but concentrating on the whole thing.
>
> **Researcher:** OK! So who normally record the data?
>
> **S5**: Just one of the students in his notebook.

These results suggest that learners understand the importance of collecting data as they indicate that they always take detailed notes of what is happening during the investigations. However, it can be argued that they are experiencing partial scientific inquiry relative to collection of data (Asay & Orgill, 2010) as in most the cases their teachers are the ones to determine which data they have to collected and when is to be collected.

4.2.5 Drawing conclusions

Results from PSI-S: Likert questions

This is the last principle of scientific inquiry selected for this study. It focuses on the extent to which learners are responsible for drawing conclusions during investigation. Percentage of learners under "Never column" (Table 4.12) are for learners who are not given chance to conclude on what has happed during the investigation and those under "Always column" are always responsible for drawing conclusions after every investigation

Table 4.12 Learners' experiences on drawing conclusions

Principles of scientific inquiry	Never %	Always %
E. Drawing conclusions; in the science classroom		
D1. Students develop their own conclusions for investigations	68	32
D2. Students consider a variety of ways of interpreting evidence when making conclusions	61	39
D3. Students connect conclusions to scientific knowledge	34	66
D4. Students justify their conclusions	53	47

According to learners' responses, it seems like they are given less chance to engage in scientific inquiry by considering a variety of ways of interpreting evidence when making conclusions (61%, see Table 4.12 above). Moreover, 68% of learners claim that they never develop their own conclusions for investigations and 53% were never given chance to justify their own conclusion for the investigation done.

In this principle of scientific inquiry, learners are experiencing closed-ended inquiry in most of the time. This is because they are not involved in making decision for conclusion even though they are the ones to connect their conclusions to scientific knowledge. However, the teacher is the only one to indicate which conclusion they are to go with and which one to ignore. This indicates that the scientific inquiry that these learners are experiencing is teacher directed (Asay & Orgill, 2010).

Results from interview

Learners maintain that after they have collected the data there will be some discussion on what happened, they indicate that they are given chance to voice out their opinions and interpretation concerning the investigation up until they come up with the conclusion. They indicate that their conclusions are always in line with what the textbooks are saying as their teachers are always dependent on such textbooks. Nevertheless, they indicate that the last word is always from their teachers and they have to go with what their teachers are saying. In relation to this issue, some learners said:

> S3: madam I want to say (laughing) it is because..., you know s/he did it before and he has already expecting something. And if we fail to do something she /he will come with

the conclusion that. A... no you were not supposed to do this, you were supposed to do that.

S6: ok, we write the conclusion, that we have come up, we have with this... with this solution, so and actually and e..., at the end the teacher will be the one who says the last word maybe.

This result suggests that learners are not experience full scientific inquiry under this principle as they are always guided in coming up with the conclusion for the investigation.

In general, the results indicate that in this principle, learners are less engaged in scientific inquiry in their classroom. The results of this study are consistent with that of Cuevas's et al. (2005) who found that learners' development in inquiry skills for planning and drawing conclusion can be enhanced by guided-inquiry. Since these learners are guided by their teachers in their discussions after the collection of data, they are able to come up with the conclusion for their investigations even though their teachers are the ones to say the last word on which conclusion to go with.

Very little was found in the literature on the question of what are learners' perceptions of their experiences of scientific inquiry? However, the current study found that learners are experiencing closed or less scientific inquiry as they are never given full control on the investigations done in their classrooms (Blanchard et al., 2010; Asay & Orgill, 2010), it seems like their teachers are always available to guide and direct them. These learners can be considered to be experiencing closed scientific inquiry as they are not always experiencing all the selected principles of scientific inquiry for this study (Asay & Orgill 2010). However, the results from figure 4.2 suggests that learners were experiencing this closed scientific inquiry most often relative to principle (B) designing investigations; (C) conducting investigations and (D) collecting data. They seem to be experiencing open inquiry always relative to principle (A) asking questions/framing research questions and (E) drawing conclusion.

Figure 4.2 below shows the summarized responses and percentage of learners per principle of scientific inquiry. As indicated in chapter 3, when responding to the items, learners were required to indicate whether they are experiencing scientific inquiry almost never, seldom, sometimes, often or always and were given a score of 1, 2,3,4,5 respectively for positive items. For negative items, the scores were in the reverse order. The lowest score per theme (tenet) is 4 and the highest score is 20. In every theme all learners who score 4-12 were

classified as never experiencing open scientific inquiry under that particular principle and those who scored 13-20 were classified as experiencing the open scientific inquiry always.

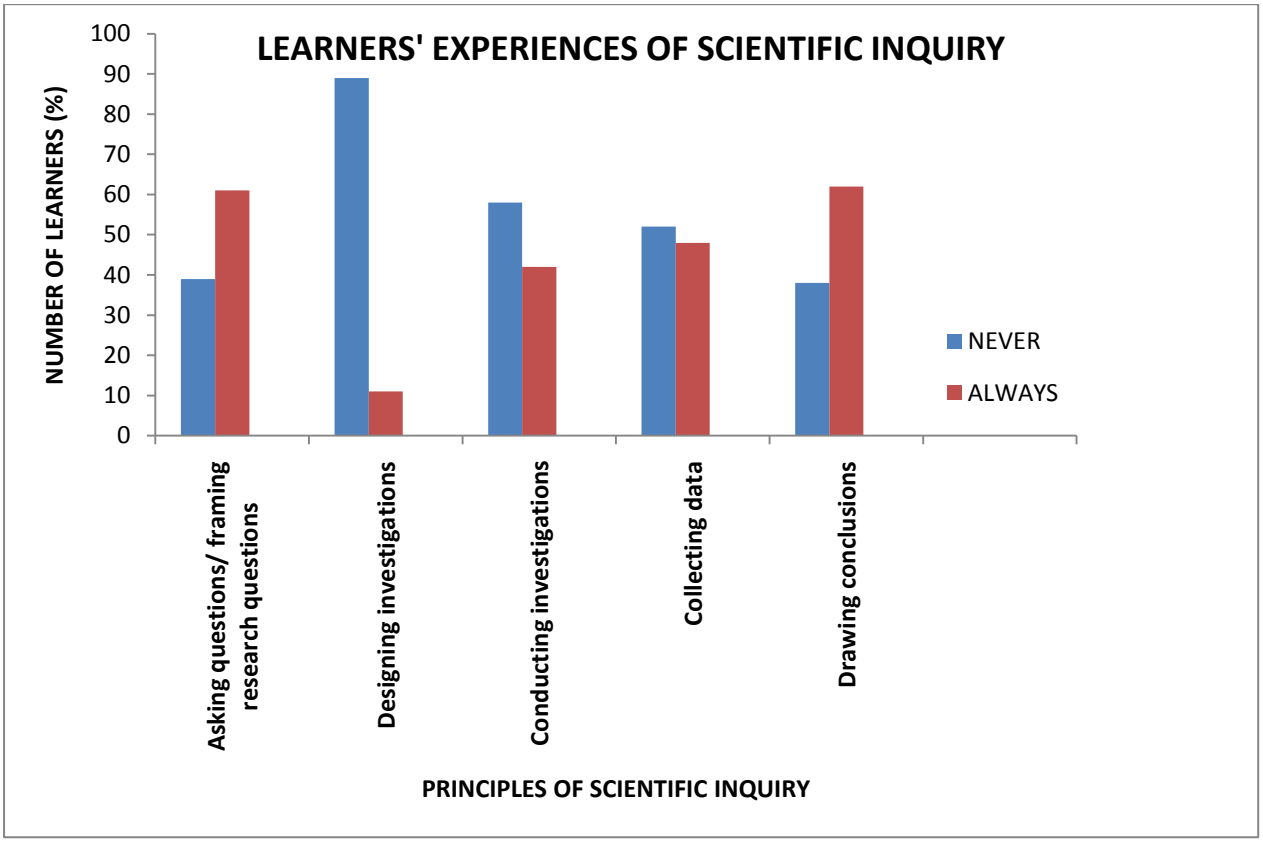


Figure 4.2 Learners' experiences of scientific inquiry in classroom

In general, according to figure 4.2, it seems as if learners were never given chance to design their procedures for investigations and by determining for themselves on how and when to conduct such investigations. Another important finding was that learners were sometimes given chance to collect their own data as the chart above indicate almost equal number of learners who claim that they never collect data and those who say that they always participate in the collection of data. It is somewhat surprising that learners claim to be always given chance to ask their own questions for investigations and draw conclusion on their findings yet they are never given opportunity to design and conduct their own investigations. Thus, a further investigation in Lesotho is needed on this issue.

4.3 Relationship between learners' understandings of NOSI and their perceptions of their experiences of scientific inquiry

The results presented and discussed here are of the relationship between learners' understandings of NOSI and their perception of their experiences of scientific inquiry as determined using all three instruments LUSSI, PSI-S (n = 120) and from interviews (n = 8). The results from the two questionnaires will be presented and discussed first followed by the results from the interviews.

4.3.1 Scatter diagrams to analyse the relationship between learners' understandings of NOSI and their perceptions of their experiences of scientific inquiry

The chart in which learners' total scores from two questionnaires (LUSSI and PSI-S) were used to explore the possibility of any relationship between learners' experiences of scientific inquiry in their classroom and their understandings of NOSI is shown in Figure 4.3 below.

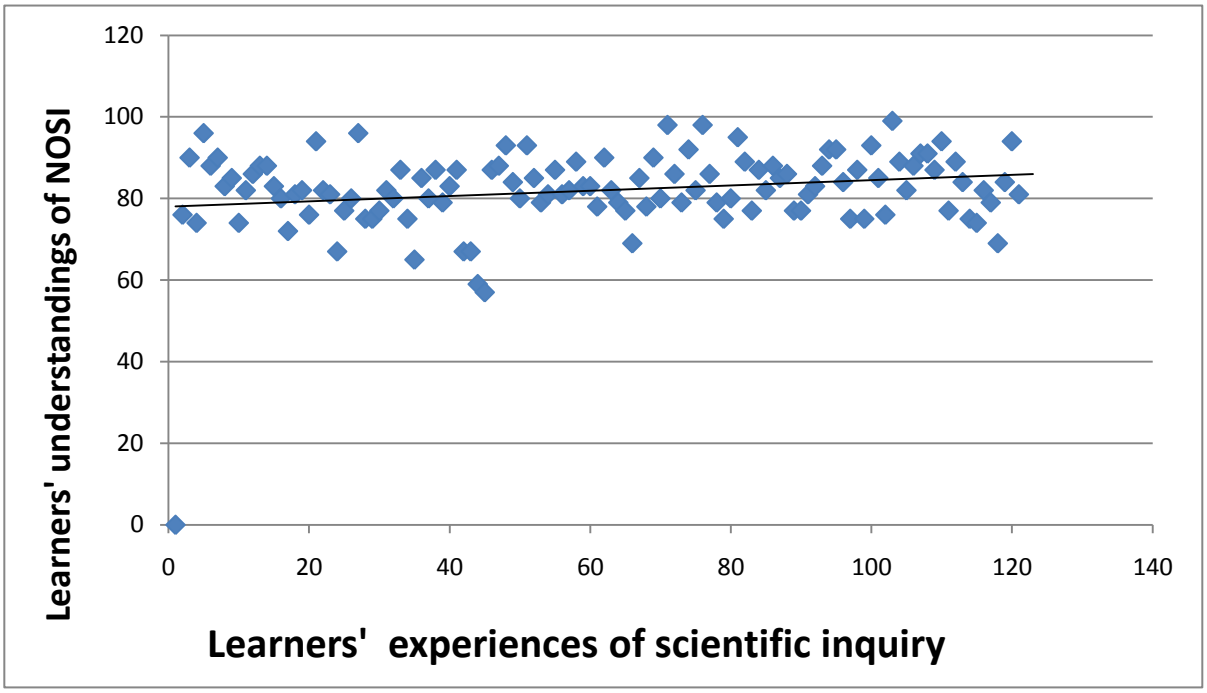


Figure 4.3 Scatter plot showing the relationship between learners' understandings of NOSI and perceptions of their experiences of scientific inquiry (n = 120).

The chart suggests that there is a very weak positive correlation between learners' understandings of NOSI and the perception of their experiences of scientific inquiry. This might suggests that engaging learners in inquiry in their classrooms does not necessarily

mean learners will have better understandings of NOSI. The converse is also true in this instance. This is in line with Grindstaff and Richmond (2008); Lederman (2007) who indicate that being involved in a scientific inquiry does not automatically produce NOSI understandings. However, there is no enough evidence that could maintain that little experiences of scientific inquiry that learners had might be the source of their poor understandings of NOSI. The findings in this case contradicts Haefner and Altoona (2004) who found that engaging in scientific inquiry supported the development of more appropriate understandings of science and scientific inquiry.

4.3.2 Results from the interviews

Learners seem to lack more knowledge on the nature of science and scientific inquiry. The reason for this is not clear but it may have something to do with the fact that most learners indicated that they were not experiencing scientific inquiry more often in their science classrooms. To clarify this, most learners were not able to give different methods for scientific investigations, they belief that experimentation and different steps that are followed in different scientific investigations are the scientific methods. This suggests that these learners had never been allowed an opportunity to engage in other methods of scientific inquiry other than experimentation. Therefore, it can be argued that if learners have never experience other methods of scientific investigations in their classrooms, then they may not know them. One learner when asked whether there is a specific method to be used by scientists in their investigations, he said:

> S3: Ya! There are many methods which are supposed to be used. Yes madam, you are not supposed to follow one step of doing things

This learner was confusing scientific methods with steps that can be followed when using a certain method. This finding is not surprising as Liang et al. (2006); Miller et al. (2010) find the same thing. The other learner when asked to give other scientific methods other than experimentation, she indicated that she does not know them but she beliefs that there are other methods that scientists use. Learners claimed that in most of the cases their teachers were the ones performing some experiments in front of the class. This might mean that even if the teacher might use different method of investigations other than experimentation, learners may not know because they were not the ones experiencing that.

The other thing that most learners indicated which shows that they are not experiencing scientific inquiry in their classroom is that, they are never given chance to ask their own questions for investigations, they are denied chance to decide when and how they can collect data for investigations and that the conclusion after every investigation is given by their teachers. Perhaps all these happens because their teachers know that their learners lack the understandings of NOS and NOSI and if they can try to engage them in open-ended inquiry, that might take more of their time. It can also be inferred that teachers themselves lack pedagogical knowledge to involve their learners in scientific inquiry.

4.4 Conclusion

The analysis and discussion of results done in this Chapter shows that generally, learners hold less informed understandings of NOSI. The results also show that these learners were not experiencing open-ended scientific inquiry more often in their science classrooms. Scientific inquiry that they were experiencing is mostly teachers directed as their teachers are always guiding and directing them on what to do and what not to do. The scatter plot results suggest that there is a weak correlation between learners' understandings of NOSI and their experiences of scientific inquiry. In the next Chapter the conclusions from the study, implications and recommendations are discussed.

CHAPTER 5

CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

5. Introduction

The purpose of the study was to investigate learners' understandings of the nature of scientific inquiry in relation to their classroom experiences. The study particularly focuses on learners' understandings of the NOSI, perception of their classroom experiences and exploring whether there was a relationship between learners' understandings of NOSI and their experiences of scientific inquiry. From the results and discussion presented in Chapter 4, three main conclusions emerged from this study:

1. Learners showed that they hold less informed understandings of the NOSI
2. Learners are experiencing closed inquiry (teacher-oriented) as achieved from their perceptions of their classroom experiences
3. There is a weak positive correlation between learners' understandings of the NOSI and their perceptions of their experiences of scientific inquiry.

The listed conclusions are elaborated separately in the next section. These will be followed by: implications and recommendations for science teaching and learning; recommendations for policy makers and curriculum developers; recommendation for further research; and strengths and limitations of the study.

5.1 Learners' understandings of the nature of scientific inquiry

The analysis and discussion of the results of LUSSI questionnaire (Appendix A), which elicited learners' understandings of the nature of science and scientific inquiry showed that, generally, the sampled learners posses less informed understandings on the NOSI. However, most of the sampled learners can be said to hold an informed view on observations and inferences. On this issue they seem to believe that scientists have different knowledge which resulted from their different background and such knowledge compels them to come up with different observations and interpretations even if they were dealing with same event. They also hold the informed understanding on the change of scientific theories. On this issue the dominant view appears to be that scientific theories are subject to on-going testing which resulted in the change of the existing theories due to new evidence found. The learners also

show an informed understanding on imagination and creativity. Here learners harbour the belief that scientists use their imaginations and creativity throughout their scientific investigations for them to come up with new scientific theories and laws. This was evident from all of the responses learners gave (that is from LUSSI- open-ended and Likert responses and from the interview responses).

The sampled learners hold a naive understanding on scientific laws versus scientific theories. This is evidenced by the fact that they were not able to differentiate between a theory and a law. They believe that laws are proven theories which never change. They also hold the naive understanding on social and cultural influences on science as they believe that culture has nothing to do with science and scientific investigations. Looking at methodology of scientific investigations, learners' responses from the interviews and LUSSI open-ended part, it was evident that learners hold the informed view as they indicated that there are different scientific methods that can be used in scientific investigations. This contradicts their responses to Likert part of LUSSI which reveal that they have the naive view under this tenet. Since learners possess informed understandings on more tenets of NOSI and naive view on few tenets of NOSI, it was therefore generally concluded that they hold less informed understandings of the NOSI.

5.2 Learners' perceptions of their experiences of inquiry in laboratory or classroom

A Likert questionnaire PSI-S (Appendix B) was used to provide information on how the sampled learners perceive their experiences of inquiry in their classroom. The results from PSI-S questionnaire reveal that learners are experiencing closed-ended inquiry (teacher-oriented) in their science classrooms. This was evident as learners indicate that they were never given chance to design their own procedure to be followed during investigations. The learners' responses to both PSI-S and interviews also reveal that they are always told to use the procedure from their textbooks or the ones provided by their teachers. In the same way PSI-S and interview results suggested that learners are not the ones responsible for conducting procedure for investigations. The inquiry that learners were experiencing in this case was only by looking at their teachers conducting the experiments in front of the class-*teacher demonstrations*. The results from both Likert questionnaire and interviews also suggest that while the learners were aware of the importance of collecting data during investigations, they were not allowed to participating fully investigations as their teachers

always order what kind of data was to be collected and when. It appears that learners always experience closed inquiry.

However, learners' responses to the Likert questionnaire suggest that they do experience some form of open inquiry in terms of asking/framing research questions and drawing conclusion. Interestingly and puzzling are their responses to the interviews which reveal that their teachers are the ones who always give them questions for investigations. The final word of the teacher appears to be the one which carries the day. Overall, one might conclude that the learners sampled for this study were experiencing partial inquiry (Asay and Orgill, 2010; Park Rogers and Abell, 2008).

5.3 Relationship between learners' perceptions of their experiences of scientific inquiry and their understandings of the NOSI

A scatter plot was done to explore whether there was any relationship between the sampled learners' understandings of the NOSI and their perceptions of their experiences of scientific inquiry in their classrooms. This plot was based on the total scores for each of the investigated variables. Learners' scores on the LUSSI were correlated against their scores on the PSI-S. It was found that there was a weak positive link between learners' understandings of NOSI and their perceptions of their experiences of scientific inquiry. Interview results and responses from the open-ended part of LUSSI also suggest a weak relationship as learners emphasised that there are different scientific methods but they do not know them, and that they never experienced such methods in their classrooms. This might somehow suggest that lack of learners' experiences of scientific inquiry leads to naive understandings of the NOSI.

5.4 Implications and recommendations for science teaching and learning

The results of this study suggest that teaching and learning of science in Lesotho is inconsistent with the recommended standards suggested by science curriculum reform documents. The teachers use closed-ended scientific inquiry, instead of open-ended inquiry instruction in classrooms. This closed-ended scientific inquiry deprives learners of the opportunity to develop essential scientific skills in solving authentic science-related problems. It is therefore recommended that teachers should engage learners in inquiry activities rather than always carrying out demonstrations in front of the class. Another issue coming out is that there is not enough science equipment in their laboratories which might be

what also persuades teachers not to involve learners in doing the experiments in their laboratories. The improvement of availability of related science materials is recommended. The government should provide funds to help schools. Moreover, having clear goals and taking learners' experiences into consideration is critical for determining ways to make inquiry-based teaching and learning most effective. Therefore, high school teachers are encouraged to share their successes and examine their constraints in designing and implementing inquiry teaching.

5.5 Recommendations for policy makers and curriculum developers

The results of this study suggest that the Lesotho science curriculum needs to be reviewed. The study has shown that learners are not engaged in full scientific inquiry in their classrooms. This suggests that the curriculum should be structured in such a way that it persuades science teachers to use open-ended inquiry only in their classrooms and inquiry-type experiments in their laboratories. This might help science teachers develop their inquiry-teaching skills. It is recommended that some workshops be done for teachers aimed at developing their pedagogical knowledge and skills regarding the use of inquiry oriented instruction in their classrooms. There are some potential barriers to enactment of open-ended scientific inquiry in science classrooms such barriers are limited resources, lack of time and high curriculum demands. These might require addressing by curriculum developers and policy makers so as to support teachers' implementation of full scientific inquiry.

5.6 Recommendation for further research

Previous studies focused on learners' understandings of the nature of science (Liang et al., 2006; Miller et al., 2010). It was found that most learners posses the informed understandings on the NOSI. Other studies were done on whether engagement in scientific inquiry can result in better understandings of NOSI (Bell et al., 2003; Adyniz et al., 2010). Results show that better understandings of NOS and the NOSI do not necessarily result from being involved or experiencing scientific inquiry. However, there is a contradiction as Haefner and Altoona (2004) found that engaging in scientific inquiry supported the development of more appropriate understandings of science and scientific inquiry. The current study found that there is a weak relationship between learners' understandings of NOSI and their experiences of scientific inquiry. It is therefore recommended that further studies should investigate if involving learners in scientific inquiry can have any influence on their understandings of

NOS and NOSI. Again, the sample that was used for this study was too small to be considered representative of the entire population of learners in Lesotho. Therefore, the conclusions made in this study cannot be generalised to the whole of Lesotho. This limited number of participants calls for further investigations with larger sample sizes.

5.7 Strengths and limitations of the study

One of the strengths of this study is the use different methods. Interviews were used to corroborate the responses to the Likert questionnaires (PSI-S and LUSSI) and the open-ended questions in another questionnaire (LUSSI). This enabled the researcher to recognise whether learners' responses to both the questionnaires and the interviews are the same or different. Moreover, interviews enabled learners to express their perceptions and their views on the NOSI and the probing questions from the research helped them to further elaborate on their responses. These helped in getting more data to answer all the research questions in this study. Secondly the use of a mechanical device to collect interview data has reduced bias and loss of other relevant and important data.

The sample used for this study was too small to be considered representative of the entire population of learners in Lesotho. As a result, the conclusions made in this study cannot be generalised to Lesotho learners as a whole. Nevertheless, these conclusions will be useful in the teaching and learning of science in other districts of Lesotho.

The researcher was a novice in conducting interviews, and this might have influenced the collection of data negatively. The reason being, the interviewer might not have use probing questions where necessary. This was evident when the researcher was reading the interview transcripts and found that there are some explanations missing, perhaps she could have asked more questions for learners to provide such information. Nevertheless, the collected data was still useful in answering all the research questions.

The period for collection of data in this study was limited especially that this study opted for borrows aspects of qualitative research. This short period of time for collection of data deprived the researcher to get to know the interviewees better, establish rapport, and build trust and create an environment for free disclosure of information. The researcher could have visited the schools and talked with the interviewees before the interviews but it was not possible, she was only known by the interviewees on the day of collection of data. However,

the short conversation that the researcher had with individual interviewees has contributed towards reducing threats to the validity of collected data.

5.8 Conclusion

In this chapter the following conclusions were made based on findings from the study: Learners showed that they hold less informed understandings of the NOSI; learners are experiencing closed inquiry (teacher-oriented) as achieved from their perceptions of their classroom experiences; there is a weak negative correlation between learners' understandings of the NOSI and their perceptions of their experiences of scientific inquiry. It was recommended that teachers should engage learners in inquiry activities rather than always carrying out demonstrations in front of the class. It was also recommended that curriculum developers and policy makers should address barriers which hinder the implementation of open-ended scientific inquiry in science classrooms. The strengths and weaknesses of the study were discussed. It has been recommended that further research should investigate how learners' perceptions of their experiences on scientific inquiry are related to their understandings of the NOSI.

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APPENDIX A

Learners' Understanding of Science and Scientific Inquiry (LUSSI) Questionnaire

This questionnaire seeks to find out what your views of science and scientific inquiry are. There is no right or wrong answer. Just indicate what you believe in or think.

Please read each statement carefully, and then indicate the degree to which you AGREE or DISAGREE with the statement by ticking (√) in the appropriate box choosing from the following: (**SD**= Strongly Disagree; **D**= Disagree; **U**= Uncertain or Not sure; **A**= Agree; **SA**= Strongly Agree).

1. **Observations and Inferences**

Item		SD	D	U	A	SA
A	Scientists' observations of the same event may be different because what scientists already know may affect their observations.					
B	Scientists' observations of the same event will be the same because scientists are objective.					
C	Scientists' observations of the same event will be the same because observations are facts.					
D	Scientists may make different interpretations based on the same observations.					

Do you think scientists' observations and interpretations are the same or different? Give reasons for your answer.

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2. Scientific Laws vs. Theories

Item		SD	D	U	A	SA
A	Scientific theories exist in the natural world and are uncovered through scientific investigations.					
B	Unlike theories, scientific laws are not subject to change.					
C	Scientific laws are theories that have been proven.					
D	Scientific theories explain scientific laws					

With examples, explain the difference between scientific theories and scientific laws.

---

3. Change of Scientific Theories

Item		SD	D	U	A	SA
A	Scientific theories are subject to on-going testing and revision					
B	Scientific theories may be completely replaced by new theories in light of new evidence.					
C	Scientific theories may be changed because scientists reinterpret existing observations.					
D	Scientific theories based on accurate experimentation will not be changed.					

With examples, explain why you think scientific theories do not change OR how scientific theories may be changed.

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4. Social and Cultural Influence on Science

Item		SD	D	U	A	SA
A	Scientific research is not influenced by society and culture because scientists are trained to conduct “pure”, unbiased studies.					
B	Cultural values and expectations determine what science is conducted and accepted.					
C	Cultural values and expectations determine how science is conducted and accepted.					
D	All cultures conduct scientific research the same way because science is universal and independent of society and culture.					

With examples, explain how society and culture affect OR do not affect scientific research.

---

5. Imagination and Creativity in Scientific Investigations

Item		SD	D	U	A	SA
A	Scientists use their imagination and creativity when they collect data					
B	Scientists use their imagination and creativity when they analyze and interpret data.					
C	Scientists do not use their imagination and creativity because these conflict with their logical reasoning.					
D	Scientists do not use their imagination and creativity because these can interfere with objectivity.					

With examples, explain how and when scientists use or do not use imagination and creativity

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6. Methodology of Scientific Investigation

Item		SD	D	U	A	SA
A	Scientists use different types of methods to conduct scientific investigations.					
B	Scientists follow the same step-by-step scientific method to conduct scientific investigations					
C	When scientists use the scientific method correctly, their results are true and accurate.					
D	Experiments are not the only means used by scientists to get scientific knowledge.					

With examples, explain whether scientists follow a single, universal scientific method or use different methods.

THE END

THANK YOU

APPENDIX B

Principles of Scientific Inquiry – Student

This questionnaire seeks to find out the extent to which you are experiencing scientific inquiry in your classrooms.

Please read EACH statement carefully, and then select the response that best describes your answer to each question by ticking (√) in the appropriate box choosing from the following; Almost never, Seldom, Sometimes, Often and Almost always

A. Asking questions/ framing research questions: *in the science classroom*

ITEM		Almost never	Seldom	Some-times	Often	Almost always
A1	Students formulate questions which can be answered by investigations					
A2	Student research questions are used to determine the direction and focus of the lab					
A3	Students framing their own research questions is important					
A4	Time is devoted to refining student questions so that they can be answered by investigations					

B. Designing investigations: ***in the science classroom***

ITEM		Almost never	Seldom	Some-times	Often	Almost always
B1	Students are given step-by-step instructions before they conduct investigations					
B2	Students design their own procedures for investigations					
B3	Students engage in the critical assessment of the procedures that are employed when they conduct investigations					
B4	Students justify the appropriateness of the procedures that are employed when conducting investigations					

C. Conducting investigations: ***in the classroom***

ITEM		Almost never	Seldom	Some-times	Often	Almost always
C1	Students conduct their own procedures of an investigation					
C2	The investigation is conducted by the teacher in front of the class					
C3	Students actively participate in investigations as they are conducted					
C4	Each student has a role as investigations are Conducted					

D. Collecting data: ***in the classroom***

ITEM		Almost never	Seldom	Some-times	Often	Almost always
D1	Students determine which data to collect					
D2	Students take detailed notes during each investigations along with other data they collect					
D3	Students understand why the data they are collecting is important					
D4	Students decide when data should be collected in an investigation					

E. Drawing conclusions: ***in the science classroom***

ITEM		Almost never	Seldom	Some-times	Often	Almost always
E1	Students develop their own conclusions for investigations					
E2	Students consider a variety of ways of interpreting evidence when making conclusions					
E3	Students connect conclusions to scientific knowledge					
E4	Students justify their conclusions					

THE END

THANK YOU

APPENDIX C

Learner interview schedule

For SUSSI

1. What is a scientific theory and what is a scientific law? What is the difference between a law and a theory?
2. After scientists have developed a theory, does the theory ever change? In your opinion, is it important to be taught scientific laws and theories at high school level?
3. Scientists perform scientific experiments and investigations when trying to solve problems. Do you think scientists use their imaginations and creativity when doing these experiments and investigations? Explain!
4. Some people claim that science is infused in 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 practised. Others claim that science is universal. That is, science is not affected by social, political, philosophical values and intellectual norms of the culture in which it is practiced. Which statement do you agree with? Why?
5. Is there any specific method that scientists should use in their investigations or experiments? Explain!
6. Can scientists observation of the same event be different or the same? Why?

For PSI-S

7. Who normally formulate questions for investigations in your classroom?
8. Who design procedures to be followed when carrying out an investigation?
9. Who conduct investigations in your classroom? How are investigations carried out? During investigations in your classroom, what do you (students) normally do and what are the roles of the teacher?
10. Who is responsible for recording data during investigations? How is data recorded?
11. How do you come up with the conclusion for conducted investigation or experiment?

Introduction

1. Thank you for being willing to be interviewed. …
2. Details of info letter:
   - You may withdraw at any time.
   - Your name will be kept confidential, but I may anonymously quote the things you say.
3. I am using a voice recorder to capture the interview.
4. Do you have any questions?
5. Please sign the consent form.

Follow-up questions

For breadth:	**For depth:**
• What else? • Tell me more.	*Interrogate jargon:* • That's interesting, can you tell me more about that. • What do you mean by …? • Why? • Please give me an example of …. • What makes you say that? • Can you expand on your answer for me..? • Can you give me the view that you think is wrong..?

APPENDIX D

Information Sheet

Research Study on "Lesotho High School Learners' understandings of the Nature of scientific inquiry in relation to classroom experiences"

My name is LIEKETSENG LEMATLA. I am a researcher studying Master of Science Education in the School of Education at the University of the Witwatersrand. I am carrying out a study on Lesotho high school learners' understanding of nature of scientific inquiry in relation to classroom experience, looking at Form D learners. My research should not only benefit the institutions where it is conducted, but also the Lesotho educational system in improving the teaching and learning of Science.

I am asking for permission to use questionnaire and interviews some of your learners/your child. The interviews will take 20 – 30 minutes which I will audio record. I would like to make it clear that giving permission in this study is entirely voluntary, no harm is envisaged, and all information will be treated as confidential and names not known. Participants can choose to accept or decline to answer any questions, and can withdraw from the study at any given time.

My research results will be presented in my research report. Part or all the results of this study may be presented at a conference and/or published in an academic journal. In order to maintain anonymity and confidentiality, all names I use will be pseudonyms.

I will provide you with a summary of my research results on completion if you would like to have them.

Thank you for your anticipated cooperation.

Lieketseng Justinah Lematla (Mrs).

APPENDIX E

University of the Witwatersrand
Private Bag 3
Johannesburg 2050

5 August, 2010.

The Education Inspector
Ministry of Education and Training
P.0. Box 47
MASERU 100,
Lesotho

Dear Sir/Madam;

RE: Application for conducting a research study in Lesotho schools

My name is LIEKETSENG LEMATLA. I am a researcher studying Master of Science Education in the School of Education at the University of the Witwatersrand. I am carrying out a study on Lesotho high school learners' understanding of nature of scientific inquiry in relation to classroom experience, looking at Form D learners. My research should not only benefit the institutions where it is conducted, but also the Lesotho educational system in improving the teaching and learning of Science.

I am asking for permission to carry out my study in any two schools in Quthing. I will use questionnaire and interviews on participating learners. The interviews will take 20 – 30 min which I will audio record. I would like to make it clear that giving permission in this study is entirely voluntary, no harm is envisaged, and all information will be treated as confidential and names not known. Participants can choose to accept or decline to answer any questions, and can withdraw from the study at any given time.

My research results will be presented in my research report. Part or all the results of this study may be presented at a conference and/or published in an academic journal. In order to maintain anonymity and confidentiality, all names I use will be pseudonyms. I will provide you with a summary of my research results on completion if you would like me to.

Thank you for attending to my request

Yours sincerely

LIEKETSENG LEMATLA. (386288)

APPENDIX F

University of the Witwatersrand

Wits School of Education

Informed Consent Form for Conducting Research in Science Classrooms

Research Topic: Lesotho high school learners' understandings of nature of scientific inquiry in relation to classroom experience

I, _____the parent or guardian of _____ give permission to Lieketseng Lematla of the University of Witwatersrand to interview and give questionnaire to my child at school for the research on Lesotho high school learners' understandings of nature of scientific inquiry in relation to classroom experience. I realize that no harm will result from my child's participation in this study, and that the study is being conducted for purposes of improving the learning of Science in our schools. I give permission for the material to be used for research or teaching only.

I am not forced to give permission for my child to participate and understand that he/she may withdraw from the study at any time. I understand that the results of the study may be published, but the name of my child and of people he/she will refer to will remain unknown.

Name: _____

Signature:_____

Date: _____

APPENDIX G

University of the Witwatersrand

Wits School of Education

Informed Consent Form for Conducting Research in Science Classrooms

Research Topic: Lesotho high school learners' understandings of nature of scientific inquiry in relation to classroom experience

I, _____the principal of _____ give permission to Lieketseng Lematla of the University of Witwatersrand to interview and give questionnaire to learners at my school for the research on Lesotho high school learners' understandings of nature of scientific inquiry in relation to classroom experience. I realize that no harm will result from my learners' participation in this study, and that the study is being conducted for purposes of improving the learning of Science in our schools. I give permission for the material to be used for research or teaching only.

I am not forced to give permission for learners' participation and understand that they may withdraw from the study at any time.

Interviews

I understand that the real name of my school will not be used in the transcripts. In addition, the names of the participating learners and those of the people they will refer to in the interview will be kept confidential.

I understand that the results of the study may be published, but the name of my school and the names of the learners will remain unknown.

Name: _____

Signature:_____

Date: _____

APPENDIX H

Interview transcript for student number one (S1)

I: you can feel free to speak in Sotho, if you think you will be able to express yourself more clearly, no problem I will translate that. As I have indicated my study is on learners' understanding of scientific inquiry. According to how you understand, what can you say are the scientific theories?

S1: Theory... e... theories are the things that e.... we as people e.... they can be changed from time to time.

I: What about the laws?

S1: The laws e.. the laws are the things that cannot change.

I: They cannot change?

S1: Yes madam

I: Let me just see what you have written here,(looking on questionnaire). Hmmm! so what are the difference between the two, the scientific theories and the scientific laws?

S1: Scientific theories and the scientific laws, e.... we can say that the difference is that, they can e.... theories they can e..... are the things that a person can do them, then after some time he can change them.

I: Hmm!

S1: We have shown that e... laws?

I: Yes laws

S1: Eeer! laws will never change, they will always be the same. There is no way to change them

I: Can you give me one example that shows that laws cannot change?

S1: Eeer... Newton's laws

I: Why do you think it can't change?

S1: I have learnt it in lower levels of education and up to now there are still the same, it does not change madam.

I: Ok! So that is why you are saying laws cannot change?

S1: Yes madam

I: Ok, I have another question here, it says scientists have developed a theory, ok, this one you have already answered because you said theories can change but laws cannot change

S1: Yes madam

I: So do you think it is important, ...if a law is something that cannot change at all, do you think it is important that you are being taught those same laws always at school level?

S1: Ya, they are important, if we can know as to how comes that those laws are there.

I: Hmm!

S1: Yes madam those are the things we can know. ...

Interview transcript for student number two (S2)

I: The interview will just be based on this questionnaire that you have just filled here; I just need some explanations on what you have already indicated. So according to your own thinking, what is a scientific theory? And what is the scientific law? And how are they different or the same?

S2: Scientific theory is the explaining of things which are being discovered by the scientists

I: Oh, they are explaining the things that are discovered by the scientists?

S2: Yes madam

I: What about the laws?

S2: Law are the scientific facts

I: Oh laws are the scientific facts?

S2: Ya!

I: Oh that means they are what scientists call, like this is the fact and there is nothing else

S2: Yes madam

I: So after scientists have developed a theory, do they change?

S2: No madam they don't change but they give more details on what others, other scientific, have found

I: Or they just add on what is already there

S2: Yes madam

I: Ok! So, do you think it is important to be taught the scientific theories and laws at school?

S2: Yes madam, it is important because we increase our knowledge concerning those things

I: How.... How is your knowledge increased?

S2: Eeer! We know things which we are not.. We know things which are not.... (Straggling to talk)

I: You can speak in Sotho no problem (laughing)

S2: Yes madam. Which we are... *(So that we can be able to learn about things which not easy to lean)*. Ke hore re khone ho ithuta ka lintho tseo eleng hore haho bo bebe hore re tsebe ka tsona.

I: Hmmm, if you know laws then they will enlighten you to know that oh! This thing is like this

S2: Yes madam.

I: Ok! Like we have said scientists perform scientific experiments and investigations to try to solve some problems like the problem of AIDS, we know that scientists are busy looking on how to solve that problem, how they find the cure all those things. Do you think they use their imaginations and creativity when doing all those things?

S2: Yes madam, I think so that they use their imagination and creativities

I: How, how? Do they ...?...

Interview transcript for student number three (S3)

I: We are simply going to follow up on the questionnaire that you have already answered, just for you to explain more on what you have said. There was one question which was talking about the difference between the scientific theory and laws. Would you explain that to me, what are they and how are they different?

S3: Ok, madam, the scientific theories are what the scientists have discovered and after discovering it, they just e... they continue with it Madam, and.... when we talk of the scientific laws we talk of things that scientists have to follow in science.

I: That is only they should follow?

S3: Yes madam.

I: Does it mean... if they are some things they have to follow, will they change with time? That is the laws?

S3: Yes madam, some do change, but some do not change.

I: Can you give me the examples of those which change and those which do not change.

S3: As we have indicated earlier that HIV/AIDS were not allowed to have children but as for now they are allowed to have children that means that law has changed. But as for... as we talk on elements like chlorine and sodium how they reacts, they cannot change because we will make an experiment right now and next time it want to change it, a... it cannot change because we saw it and we did observe it how reacted.

I: Ok. After scientists have developed the theories like you have said the theories are... what have you said about the theories? You said they are realities which are discovered by the scientists, can they change?

S3: Even theories, they can change like if we... I would like to make an example with rain. We know that water from the streams evaporates and when it evaporates it will make what? (Asking himself) it will make the clouds out there but as for now ache...too much water has been evaporated but we cannot see rain and do not know why do that happens.

I: Ok! (Laughing). Ok, scientists perform scientific experiments and investigations when drying to solve different problems, we can consider that problem of AIDS or some other things. Do they use their imaginations and creativity when trying to do such experiments?

S3: Ya. Sometimes they use their imaginations on how they will come up with a certain experiment.

I: That is they will first have to imagine what kind of experiment can we do?

S3: Yes madam.

I: Is there any time when they do not use their imaginations?

S3: There is no time that they will not use their imaginations because everything which you do, you must think of it before you can perform it. Same as their creativity, they should always use their creativity

I: Regardless of what experiment they are doing?

S3: Yes madam.

I: Ok, I have these two statement here, the first one indicate that science is infused within the culture of different people, that is science can be influenced by culture, it can be influence by political, economical life of people in which that science is practised. The other one say cannot be influenced by that. Which statement do you go with?

S3: That is cannot e....?...

Interview transcript for student number four (S4)

I: Ok my first question here is for you to tell me the difference between scientific laws and scientific theories

S4: I think the scientific laws are the...the laws that scientists have made that do not change while the theories are the studies of science that change from time to time.

I: Ok! Meaning theories can change but laws does not change

S4: Yes madam.

I: Can you give an example for a law?

S4: I know Hooke's law

I: Hmm! so think Hooke's law can never ever change?

S4: I think it would never change madam.

I: Ok. Any example of a theory that you know?

S4: I think a... it will the theory of particles

I: So think the theory of particles can change due to some investigations?

S4: Yes madam

I: Ok! do you think it is important to be taught those theories and laws,... let's start with theories, if you are saying theories can change, is it important to be taught those theories if we know that maybe tomorrow they will change or after some time they will change?

S4: I think madam; the theories give a little glue of what the law consists of. So I think it is better if we keep learning even though they change.

I: Hmm! so what about the laws?

S4: The laws, I think it is important because they never change, so you have learned stays the same.

I: OK. Do you think the scientists when they perform the experiments or the investigations to solve the problem, like maybe the problem of AIDS, do they use their imaginations and creativity?

S4: I think creativity would work, even though what you imagine is never always true.

I: Hmm.

S4: Yes madam

I: But creativity is important. So you mean they are using their imaginations and their creativity at all the times?

S4: Yes madam.

I: Ok. I have two statements here indicating different views from different people. Some people believe that the culture.... the culture including the economical life and political life are influencing the science that we know, science that we accept. Other people believe that no! No! No! Science cannot be influenced by those kinds of things. Which statement do you go with?

S4: Individually science cannot be disturbed by the culture and believes that people have but in other way parents can also influence what we know or what we learn about science. ...

Interview transcript for student number five (S5)

I: This interview will simply be based on what you have already indicated in the questionnaires, it will enable you to explain more on what you have said. The first question goes like; what can you say a scientific law is and a scientific theory is?

S5: Ok! Like a said last time, a scientific law is a proven theory which can never be changed any more but a theory is, a theory can still be changed e... if more investigations which convinces are done

I: Hmm! you are saying a theory is the one that can change

S5: Ya. Ya. A theory can change but a law cannot.

I: As the scientists are developing theories which keep on changing from time to time, do you think it is important to be taught such changing theories at school level?

S5: Ya, it is important even though they are changing for our general knowledge. Just like if there was a certain theory, a few past years and I was able to go through it, then right now there is another new theory, just for my personal.... I got that past knowledge, a broad knowledge. ya!

I: Hmm! what about this laws which are not changing then? Is it important to learn something which is stagnant, which is not changing, which is not improving?

S5: Yes, I think it also has its importance that, it doesn't confuse; we know that we are talking about one thing for maybe the rest of the period.

I: Can you give me an example of any scientific law that you know?

S5: Ok! I remember Hooke's law, a... even though I tend to forget what it talks about right now.

I: So like you have said, it doesn't change?

S5: Ya. Ya!

I: What about an example of a theory?

S5: (clearing his throat). Em! A theory maybe I can say it's a group eight elements are un-reactive or they are the least reactive elements in the periodic table. I think that is a theory.

I: Ok! em! As you know that the scientists are the ones that are doing these investigations to come up with new evidence so that the theories can be changed, or to come up with a solution for different problems, do you think they are using their imaginations and creativity when doing those experiments?

S5: Ok, I think.... I don't think that e... ya, they can use their imagination and creativity. But imagination do not apply it doesn't apply to (unclear) because what you imagine is not what I can imagine, so people are different, so they can come up with different imaginations. Ya.

I: Ok.

S5: But I think they are using them, their common sense.

I: Oh! They are using them?

S5: Ya.

I: Their creativity, do they use their creativity?

Interview transcript for student number six (S6)

I: This interview is based on the questions that appear in the questionnaires and it's for you to elaborate here and there. Our first question, what is a scientific theory and what is a scientific law? Or what is the difference between the two?

S6: The scientific theory.... the scientific theory is the, is not actually, I think is not actually the facts but it's what proofs what we think are the facts.

I: Oh! It proofs what we think are the facts?

S6: Yes madam.

I: So that means it might proofs it right or it might proofs it wrong?

S6: Yes madam.

I: What about the laws?

S6: The laws are....are the facts, those are the facts.

I: Hmm!

S6: Yes madam

I: So do you think this scientific theories after they have developed by the scientist, do they change?

S6: The theories?

I: The theories, yes.

S6: Yes, I think they will change because as time goes on they are new development of new ideas and all the staff so I think they will, they will end up changing.

I: What about the laws?

S6: I don't think, I don't think they will change because e...! For example they have been a e...! The, the, the people who came up with those e...! Lived long time ago and even now they have not changed.

I: (laughing) they have not changed? And we are still using their laws?

S6: Yes madam.

I: Ok! We know that the scientists are the one which are performing the scientific investigations and experiments maybe to solve some problems or to come up with new proofs, do you think they are using their imaginations and creativity when doing their experiments?

S6: I don't think all of them but some I believe they use their imaginations and creativity because em..., some proofs that e...., human being, e...., human being is not created by, by God. Some say it is created, they, although they are not,..They are not mentioning that they are created by God but they proofs that there is someone behind.

I: Like when we talk about the origin of Earth of cause. Some scientists believe that earth originated from the big bang as you listen to them where was that big bang from?

S6: They do not know. ...

Interview transcript for student number seven (S7)

I: Our first question is on the difference between scientific law and scientific theory. What is the difference between,... or what is the scientific law and what is the scientific theory?

S7: I think a scientific theory is what are scientists think are there and what is actually there.

I: Ok!

S7: While scientific laws are what they have investigated I mean theory, they put together theories and then they prove that they are there and then they call them laws.

I: You said scientists are the ones that are developing theories; do you think that they do change after some time? Theories?

S7: I think theories do not change since they are facts and they do not change.

I: Hmmm! So what about laws?

S7: I think laws can change because sometimes people are not accurate when testing for some things and sometimes other scientists who come e.....who are more accurate that the first ones and since technology is now there people investigate better things and laws can change.

I: Ok! You have said the scientists perform the experiments and investigations when trying to solve some problems around them. So do you think in these investigations and experiments, do they use their imaginations and creativity?

S7: I think they use their knowledge

I: Hmmm!

S7: I think they use their knowledge because they... they don't just put theories together they have to choose which ones to use. They have to know other things so that they have clue of what they are doing.

I: Meaning their imaginations are involved?

S7: Ya! I think so. They imagine things and then prove them.

I: Ok, there are some statements here which says that....the...the....science is infused in cultural practices, in political, social and economical lives of different people. So they are saying this culture, political life of people determines which science is to be accepted or which science is to be practiced. So other scientists are saying culture has nothing to do with science, political life has nothing to do with science and economical life has nothing to do with science. So which statement do you agree with?

S7: I think culture has nothing to do with science, it does not affect science. But it may happen that some people may not do some investigations because of their culture.

I: Ok! Can you give me an example?

S7: I think..... Like...there are experiments that Basotho people can't do because they believe are not good.

I: Yes, like which one? (Followed by complete silence)..... (Laughing)

S7: I'm trying to think of an example....

I: Hmmm! There was one example I got from one student when talking about cultural influences (giving different example that were given by other learners)...

Interview transcript for student number eight (S8)

I: Ok this interview is based on what you have already said in the questionnaire, it's just that you will need to elaborate here and there. E...! There was a question which was talking about the scientific theories and the scientific laws, what do you think a scientific theory is? And a scientific law is according to your own understanding?

S8: According to my own understanding and the knowledge I got from my fellow colleague in class, he explain the scientific theory as something that explains a fact. And I think I can say a scientific law is a law that guides science in some way, ya.

I: Ok. So what is the difference between the two? Can either one of them change or not change?

S8: Ya, I think a law can change because if a scientist who was investigating a certain law was not accurate enough and it would be, it won't it would have to change, that scientific law that was not accurate enough.

I: What if he was accurate? Will it not change at all?

S8: Yes I think it will not change at all.

I: Ok, (laughing), what about a theory?

S8: A theory cannot change because it explains a fact and the fact will always remain that way.

I: Ok. we know that the scientists are the ones who are using the investigations maybe to come up with e.... some different proofs that will result in changing the laws, do you think it important to be taught laws and theories at school?

S8: Definitely, because learning those laws when still at school will help us realise some things, that is some things are happening in our lives but they don't come to our recognition but having those scientists investigating them, they come to our recognition and we understand them very well. For instance, em! While I was in form B, I didn't know why an iron sometimes has a red light on and sometimes there was no light until I discovered in a science book that there is a bar metal that connects to the spring and sometimes does not connect to the spring. That's why the light goes on and off.

I: Wow! Wonderful. So that means you need to be taught laws and theories in school, even if they can change it does not matter?

S8: Ya.

I: Ok! Scientists as they are performing their experiments and their investigations, do you think they are using their imaginations and their creativity to do that?

S8: No. They don't, if they use their imaginations then, they are going to tell us a bunch of lies.

I: (laughing).

S8: I think if they are not using their imaginations, then they will definitely be telling us the truth.

I: Ok.

S8: Because I can just imagine that I could count the stars.

I: Yes?

S8: And that's my imagination but the truth is I cannot count the stars. ...

APPENDIX I

University of the Witwatersrand

Wits School of Education

Informed Consent Form for audio recording of the interviews

I, _____agree that the interview on learners' understandings of nature of scientific inquiry in relation to classroom experience conducted by Lieketseng Lematla of the University of Witwatersrand can be audio taped.

I give permission for the material to be used for research or teaching only.

I am not forced to participate and understand that I may withdraw from the study at any time. I understand that the tape will be stored safely for about four years and that the results of the study may be published, but my name and the name of people I will refer to will remain unknown.

Name: _____

Signature:_____

Date: _____