Chapter One

Introduction to the study

1. Introduction

The South African democratically elected government has education transformation as one of its major priorities. During the apartheid era, the school science curriculum was dominated by western science. Indigenous Knowledge (IK) and other worldviews were totally excluded from the curriculum. As part of educational transformation, the government introduced a new curriculum, the National Curriculum Statement (Department of Education (DoE), 2002). The new curriculum aims to unite all South Africans, eradicate the injustices of the colonial and apartheid era and bring about equity and equality in education. The National Curriculum Statement (NCS) incorporates Indigenous Knowledge Systems (IKS) and other worldviews into school science at both the General Education and Training (GET) and the Further Education and Training (FET) levels (DoE, 2002, 2003). This is done through Learning Outcome (LO) 3 of the NCS. The GET refers to Grades R to 9 while the FET refers to Grades 10 to 12. In the GET Natural Science Policy Statement, LO 3 is presented as focusing on developing learners' understandings of "the inter-relationships [among] science and technology, society and the environment" (DoE, 2002, p. 10); including an understanding of IKS. Similarly, the NCS Physical Science Policy Statement for FET also describes LO 3 as aimed at developing learners understandings of "the Nature of Science and its relationship to Technology, Society and the Environment" (DoE, 2003, p. 14). The development of learners' understandings of both NOS and IKS is therefore, a major science education curriculum goal in South Africa.

1.1 NOS, IKS and worldview

My study is grounded in the concepts NOS, IKS and worldview. NOS refers to "...an individual's ideas, beliefs, views, perceptions and assumptions about scientific knowledge and the processes by which it is developed and validated" (Vhurumuku & Mokeleche, 2009, p. 97). IK is that knowledge or way of knowing reflecting the dynamic way in which people living within a given geographical locality "...have come to understand themselves in relationship to their environment and how they organize ... folk knowledge of flora and fauna, cultural beliefs, and history to enhance their lives" (Semali & Kincheloe, 1999, p. 3). In this study, I take IK as a knowledge-base of "indigenous" residents of a geographic area which has been developed in science, technology, religion, language, philosophy, politics and other socio-economic systems (Ogunniyi, 2007). Kearney (1984) defines a worldview as:

> ...a culturally organized micro-thought... those dynamically interrelated basic assumptions of a people that determine much of their behaviour and decision making as well as organizing much of their symbolic creations and ethno-philosophy in general…
>
> [Kearney, 1984, p. 1]

Ogunniyi (2003, p. 27) refers to an individual's worldview as "...the product of his/her culture (i.e. knowledge, beliefs, art, morals, laws, customs and practices) in which s/he was reared." In this study, I define worldview as the way individuals perceive and make meaning of their local and global world.

1.2 The South African school curriculum and textbooks

For South Africa, curricula reforms have necessitated changes in the subject matter content, teaching and learning approaches, and instructional materials -including the development and use of new science textbooks. Textbooks are essential resources for transmitting the school curriculum (Chiappetta & Fillman, 2007; Stoffels, 2007). Stoffels (2007) views textbooks as policy instruments that should align with the curriculum. Chiappetta and Fillman (2007) consider textbooks to be resource materials that should reflect education reform recommendations. In South Africa, science textbooks are considered to be the main teaching resources in science classrooms. The introduction of NCS for the Natural Sciences (Grade R to 9) and the Physical Sciences (Grade 10 to 12) has witnessed the emergence of a large number of textbooks, all claiming to be compatible with the new curricula. While this maybe so, no study has been done to assess whether the new textbooks are compatible with the new science curricula. An important issue is whether the new textbooks are compatible with the reform mandate of the new curricula. Chiappetta, Sethna and Fillman (1991, 1993) and Wang (1998) argue that the textbooks are used to determine the content of science lessons and the procedures followed by teachers when delivering lessons. Textbooks influence teachers' instructional decision making and practices.

In line with the new NCS curriculum, Natural Sciences textbooks in South Africa are organized into four main content areas or knowledge strands (DoE, 2002). These content areas are Matter and Material, Energy and Change, Earth and Beyond, and Life and Living.

The content areas encompass four science disciplines namely; Chemistry, Physics, Geography and Life Sciences (Biology).

1.3 Rationale

Several studies have analyzed science textbooks for inclusion of NOS (Chiappetta & Adams, 2004; Chiappetta & Fillman, 2007; Chiappetta & Koballa, 2004). However, all of these studies were done in the United States (US). Some research on representations of IKS in science textbooks has been done in Australia (Ninnes, 2000, 2001). A survey of literature reveals that no study has been done on representations of NOS and IKS in science textbooks in South Africa. Moreover, this survey also shows that no studies have been done in Africa focusing on content analysis of representations of NOS and IKS in Natural Sciences and Physical Sciences textbooks. In content a pre-determined conceptual framework is used as a guide to answering research questions (Chiappetta & Fillman, 2007; Krippendorff, 1980; Wang, 1998). Shulman (1986, p. 9) described representations as "...the use of ideas, illustrations, analogies, examples, explanations and demonstrations...' in ways that enable others to comprehend the subject under consideration. In this study, representations are the depictions, analogies, illustrations, examples, explanations and demonstrations, images or pictures, and texts of NOS and IKS contained in the selected science textbooks. For this study, analysis of textbooks entails using a conceptual framework as a lens to look at representations of NOS and IKS contained in the selected science textbooks.

My study aims to make a contribution to the body of research literature in science education. It focuses on the integration of NOS and IKS into the school science curricula. It was undertaken for the reason that the integration of NOS and IKS into science education is relatively new and open for exploration. It is hoped that this study adds to our knowledge about the nature of representations of NOS and IKS in science textbooks. Additionally, it was envisaged that the study would provide recommendations for the development of curriculum materials; including textbooks.

1.4 Aims of the study

In this study, I analyzed the representations of NOS and IKS in three of the ten Grade 9 Natural Science textbooks used in schools in Gauteng Province of South Africa. My aim was to determine whether the textbooks content reflected the mandate of the curriculum by being compatible with the NCS intention of integrating NOS and IKS into school science curricula. The representations that I investigated in the selected textbooks are used to mediate the concepts of science contained in the textbooks.

The NCS recognizes the challenges and excitement associated with the move towards the integration of other worldviews, specifically NOS and IKS, into the school science curriculum. According to the NCS Natural Science Policy Statement, "... science learning should take into account other worldviews and Indigenous Knowledge Systems" (Department of Education, 2002, p. 12). It invites scholars to participate in research and development in such fields as; curriculum policy, design, materials development, and assessment. This study responds to this call by analysing selected science textbooks content for NOS and IKS representations. The aims of this study are to:

- determine NOS and IKS ideas represented in three selected South African Grade 9 Natural Science textbooks; and
- analyze how NOS and IKS ideas are represented in the selected Natural Science textbooks.

1.5 Research questions

This study was based on the presumption that South Africa Grade 9 Natural Science textbooks have representations of NOS and IKS as stipulated by the curriculum reform mandate. Furthermore, it was assumed that the authors of the textbooks made an effort to integrate NOS and IKS in school science. This is in contrast polarization of the different sciences and/or marginalizing the other. The study was guided by the following questions:

1. What ideas about NOS are included in Grade 9 Natural Science textbooks?
2. How are NOS ideas represented in Grade 9 Natural Science textbooks?
3. What ideas about IKS are included in Grade 9 Natural Science textbooks?
4. How are IKS ideas represented in Grade 9 Natural Science textbooks?

1.6 Conceptual framework

In an effort to respond to the research questions on NOS, an analysis of the selected textbooks was done focusing on seven selected NOS tenets. NOS tenets are the ideas, principles, opinions or doctrines about scientific knowledge and the scientific process that are generally believed or held to be true by members of the science education community (Vhurumuku, 2010). Some of these tenets are described in several science education research articles (e.g. Ryder, Leach & Driver, 1999; Lederman, 1992; Tao, 2003). For this study, the seven tenets chosen as the focus of the analysis are:

- The empirical Nature of Science;
- The difference between observation and inference;
- The functions and relations between scientific laws and theories;
- The role of creativity and imagination in science;
- The tentativeness of scientific knowledge;
- The theory-ladenness and subjectivity of science; and
- The social and cultural embeddedness of the scientific process.

The tenets were selected because of their relevance to the South African science curriculum and because they are emphasized in international science education reform documents (Lederman, 2007). Similarly, four pillars of IKS (Ninnes, 2000) were chosen and used as an analytical framework for the representations of IKS in the selected textbooks. These are:

- Indigenous legends and myths
- Indigenous technology
- Indigenous knowledge of the natural world
- Indigenous social life

Representations of NOS and IKS in the selected textbooks can be categorized in a variety of ways.

On the selected NOS tenets an individual's ideas can be described as either positivist or constructivist or as naïve or informed. The positivist view (Pomeroy, 1993; Tsai 2003) of NOS is largely empiricist and traditional and subscribes to such notions as: scientific knowledge is objective and a true reflection of reality; scientific observations are free from the observer's pre-conceptions; knowledge exists independent of the knower; and observation and experiments are the only infallible sources of scientific knowledge. The positivist view considers scientific knowledge to be out there, waiting to be discovered. The constructivist non-traditional view considers; scientific knowledge is partly subjective and reality as a construction of the knower, and scientific observations as not free from human preconceptions. While recognizing the importance of experiments and observations, constructivists acknowledge that human creativity and imagination play roles in the production of scientific knowledge.

In their reviews; Schwartz, Lederman and Crawford (2004) and Abd-El-Khalick, Waters and Le (2008) have described NOS ideas as naïve or informed. Individuals who hold naïve ideas about scientific knowledge view it as unproblematic, discovered, objective, empirical, and infallible. On the other hand, those who hold informed ideas will view scientific knowledge as problematic, invented, subjective, tentative and revisionary.

This study also describes representations of NOS as either implicit or explicit. An implicit approach to teaching and learning NOS is one in which there is absence of deliberate attention to NOS (Schwartz et al., 2004). In this approach it is assumed that constructed understanding of NOS is a natural consequence of engaging in inquiry. Abd-El-Khalick and Lederman (2000) describe an implicit teaching approach as an approach that deliberately does not provide opportunity for learners to reflect on their science-based activities from within a framework that would enable them to build and internalize desired NOS understandings. Curriculum and instructional approaches are described as explicit when the subject content, teaching methodology and student assessment deliberately aim to develop students' NOS conceptions (Lederman, 2007). That is, students are taught about NOS; and their understanding of NOS is formally assessed. Schwartz et al. (2004) recommend that explicit approaches should aim at drawing learners' attention to targeted NOS aspects through discussions, guided reflection and questioning in the context of activities, investigations and historical examples. In this study, representations of NOS in the selected science textbooks are analyzed through the lenses of naive versus informed and implicit versus explicit.

As is the case with NOS, an individual's views on IKS can be classified as positivist or constructivist (Snively & Corsiglia, 2000; Ninnes, 2000, 2001). An individual holding a positivist view of IKS will, for example, see IKS as static and belonging to history. People who hold positivist views of IKS often dismiss IK as knowledge or practices that were relevant in the past. On the other hand, constructivist views of IKS recognize that IKS is extant and unique to a particular community. They acknowledge that indigenous practices are not homogeneous and that each indigenous community has its own way of knowing. The extent to which IKS might be practiced varies from one community to the other. This might be due to communities adopting western practices.

Equally, the individual's views on IKS can also be described as naïve or informed. A naïve idea about IKS, for example, is to believe that the painting of rocks by *San and Khoi people* are primitive and belong to the past. This idea suggests that the use of this paint is no longer relevant in modern society. It also fails to highlight the possibility that this practice might still be applicable in the *San and Khoi* community or in other communities today. People with informed IKS views will accept the uniqueness of IKS. In this study representations of IKS in the selected textbooks are assessed from the point of view of whether they are naïve or informed.

Although there is a vast amount of literature on IKS research, I could not access any that discusses IKS from the point of implicit or explicit teaching approaches. In this study, the notions of implicit and explicit teaching as discussed for NOS above were also adapted for analyzing representations of IKS in the selected Grade 9 Natural Science textbooks

1.7 Literature Review

In their review of research on content analysis of Greek school science textbooks, Dimopoulos, Koulaidis and Sklaveniti (2005) found that between 1985 and 2002, only 2% of the 222 studies done on science content analysis were on representations. Dimopoulos et al. (2005) analyzed Physics, Chemistry and Biology textbooks at both primary and lower secondary school levels. Chiappetta, Fillman and Sethna (1991) analyzed seven High School Chemistry textbooks used in the United States (US) for a balance in scientific literacy themes. They used the following scientific literacy themes to classify their data: (a) science as a body of knowledge, (b) science as a way of investigating, (c) science as a way of thinking, and (d) the interaction between science, technology and society (STS). The results of their study showed that the majority of the textbooks analyzed stressed science as a body of knowledge. The textbooks minimally portrayed science as a way of thinking. The results further showed that some textbooks did not give a balanced perspective of NOS, whilst other textbooks placed some emphasis on science as a way of investigating.

In another study Chiappetta, Sethna and Fillman (1993), analyzed five Middle School Life Science textbooks for the balance of scientific literacy themes. They used the same scientific literacy themes used by Chiappetta et al. (1991). They found that most of the textbooks devoted little attention to the interaction of STS and presented the scientific method in a stereotypical way (a series of sequential steps). They concluded that the textbooks analyzed did not provide an authentic view of NOS. Chiappetta and Fillman (2007) analyzed five High School Biology textbooks used in the US for inclusion of four aspects of NOS. They found that the textbooks had a balanced content representation of the four aspects of NOS investigated. They concluded that the textbooks were incorporating National Science Education Standards (NSES) reform guides. Abd-El-Khalick et al. (2008) investigated NOS representations in High School Chemistry textbooks used in the US. They also assessed the extent to which the representations have changed over the past four decades. Their study focused on the textbook sections that had direct relevance to NOS. Fourteen textbooks were analyzed for the empirical, tentative, inferential, creative, theory-driven, and social NOS, as well as the myth of "The Scientific Method". They found that the occurrence of representations of NOS faded with each new edition of a textbook. In other words, the earlier versions or editions of the textbooks had more NOS representations compared to the later ones.

Ninnes (2000) studied the incorporation and representations of IK in selected Junior Secondary Schools science textbooks in Australia and Canada. Four textbooks in the *Dynamic Science Series*[1] used in Australia and three textbooks in the *Science Probe Series*[2]

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[1] *Dynamic Science Series*:

Wilson, D. and Bauer, M. (1991). *Dynamic Science Book 1*. Sydney: McGraw-Hill. (DS1)

Wilson, D and Bauer, M. (1992). *Dynamic Science Book 2*. Sydney: McGraw-Hill. (DS2)

Wilson, D. and Bauer, M. (1994). *Dynamic Science Book 3*. Sydney: McGraw-Hill. (DS3)

Wilson, D. and Bauer, M. (1995). *Dynamic Science Book 4*. Sydney: McGraw-Hill. (DS4)

[2] *Science Probe Series*:

Baumann, F., Bullard, J., Deschner, D., Flood, N., Gore, G., Grace, E., Hirsch, A., Mcgammon, B., Sieben, G., Vliegenthard, W. and Winter, M. (1995). *Science Probe 8 (student edition)*. Toronto: Nelson (SP8) used in Canada were analyzed. Ninnes found that collectively, the two sets of texts provided evidence of the vast amount of IKS that is available in indigenous communities. However, Ninnes' study revealed that the kinds of IKS representations that were incorporated in the textbooks were problematic as they misrepresented the indigenous communities. They represented IKS in ways that were seen to "perpetuate the stereotypic ideas of racism, imperialism and ethnocentrism" (Ninnes, 2000, p. 604). On the contrary, the texts showed that it is possible to incorporate IKS into school science curricula. In another study, Ninnes (2001), investigated representations of ways of knowing in five sets of Junior High School science texts commonly used in Australia. The selected texts had all been published ten years prior to the study. The study revealed that the ways of knowing of minority groups (IKS) are presented as inadequate, inferior, outdated, belonging to the past, and superseded by scientific knowledge. It was also found that the textbooks did not provide learners with opportunities to learn in a variety of ways (from different worldviews).

1.8 Research Methodology

To analyze the content of selected textbooks for representations of NOS and IKS respectively, I adopted Akerson, Abd-El-Khalick and Lederman (2000) analytical framework of seven NOS tenets and Ninnes (2000) analytical framework of IKS pillars. Three commercially available Grade 9 Natural Science textbooks were selected and analyzed for inclusion of both NOS and IKS representations. The selected textbooks are: *Science Today*[3]; *Spot-on*[4]; and *Hands-on Science*[5]. For both NOS and IKS, the content analysis involved reading of each textbook.

Beckett, p., Bullard, J., Czernada, J., Flood, N., Freeman, P., Grace, E., Hirsch, A., Mcgammon, B., Sieben, G., Stokes, T., Winter, M. and Wootton, A. (1995). *Science Probe 9 (student edition)*. Toronto: Nelson. (SP9)

Bullard, J., Cloutier, F., Flood, N., Gore, G., Grace, E., Gurney, B., Hirsch, A., Hugh, D., Madhosingh, C., Millett, G. and Wootton, A. (1996). *Science Probe 10 (student edition)*. Toronto: Nelson. (SP10)

[3] Barker, K., Cohen, S., Doubell, S., Mgoqi, N., Mkhwanazi, V. & Mzolo, P. (2006). *Science Today Learner's Book: Grade 9.* Cape Town: Maskew Miller Longmann (Pty) Ltd.

[4] Soobramoney, B & Vermaak, M. (2006). *Spot On Natural Science Learners' Book: Grade 9*. Sandton: Heinemann Publishers (Pty) Ltd.

[5] Jones, R., Thomas, R. & Johnston, P. (2006). *Hands-on Science Learner's Book: Grade 9*. Cape Town: Juta Gariep.

Data analysis involved coding and recording excerpts identified as carrying relevant NOS tenets or IKS pillars. A rubric used for categories of representations was developed for both NOS and IKS to determine whether the idea under consideration was presented in an implicit or explicit and naïve or informed way. This rubric for categories of representations, was used to allocate a category to each representation of NOS or IKS according to how it was presented. The identified excerpts were arranged in a table. Frequencies of excerpts were counted to determine the tenet of NOS or pillar of IKS that is represented mostly or preferably, and how each tenet or pillar is represented generally.

1.9 Ethics

Although this study was not centered on human subjects, ethical clearance was applied for to the University of the Witwatersrand, School of Education Ethics Committee. It was granted on the basis that the textbooks are available on the public market; and it is in the interest of the public to know if the textbooks are compatible with the requirement of the NCS.

1.10 Chapters outline

Chapter 1: I introduce the study, outlining the theoretical and methodological frameworks.

Chapter 2: I provide a review of the literature, mainly on research on representations of NOS and IKS in school science textbooks.

Chapter 3: I discuss the research design, methodology and data analysis in detail.

Chapter 4: I present and discuss the results for the analysis of representations of NOS.

Chapter 5: I present and discuss the results for the analysis of representations of IKS.

Chapter 6: I conclude the study, discuss the implications of the results and give recommendations for further research.

1.11 Conclusion

In this chapter, I explained the rationale and aims for the study. I introduced and defined the key terms that I used in the study. The concepts NOS, IKS, worldview and content analysis were briefly discussed. The key literature guiding the study was identified. In chapter two, I describe the literature that is relevant to this study in detail. I also discuss how this literature relates to my study.

Chapter Two

Literature Review

2. Introduction

In this chapter, I review the relevant literature on representations and textbook analysis in the areas of NOS and IKS. Although NOS and IKS have been extensively researched, research literature on inclusion of representations of NOS and IKS included in science textbooks is relatively minimal. This leaves a research gap in science education worth exploring.

2.1 Overview of NOS: curriculum reform and research

The inclusion of NOS in science curricula is advocated for by the AAAS (1993, 2008). This is based on the fact that scientific literacy of learners requires an understanding of NOS (Griffiths & Barman, 1995). The AAAS argues that science curriculum must focus primarily on scientific literacy for both intellectual and social upliftment of the society. Globally, many countries that have reformed their science curricula have adopted the position of the AAAS in terms of curriculum development. This idea is supported by Kang, Scharmann and Noh (2004) who argue that science curricular should emphasize developing learners' understandings of NOS. Ryder et al. (1999) have also advocated for inclusion of NOS into the curriculum. These researchers view NOS as dealing with the ways in which scientists develop and use scientific knowledge. NOS focuses on how scientists decide which questions to investigate, how they will collect and interpret data, and how the findings come to be accepted as true. Ryder et al. (1999) affirm that understanding the aspects of NOS is important for scientific literacy.

Substantial research has been done on NOS. Some of this research has covered: 1) students' and teachers' conceptions of NOS (Akerson et al., 2000; Akerson et al., 2006; Lederman, 1992); 2) teachers' understanding of NOS and classroom practice (Lederman, 1999); 3) undergraduate science students' images of science (Ryder et al., 1999); 4) high school students' images of NOS (Vhurumuku, Holtman, Mikalsen & Kolsto, 2006). The studies on NOS have been partly driven by the belief that knowledge of NOS is a prerequisite for scientific literacy (AAAS, 1993, 2008; NCR, 1996). However, despite the huge amount of research, there has been little improvement in learners' and teachers' understandings of NOS

(Akerson et al., 2000; Akerson, Morrison & McDuffie, 2006; Alter, 1997; Kang et al., 2004). Some NOS tenets that seem to be difficult for learners to understand are the differences between observation and inference, and laws and theories; and the subjective nature of science.

2.2 What is NOS?

Akerson et al. (2000) acknowledge the multifaceted discipline of science and its complexity, and suggested that this might lead to disagreements in the definition of NOS. These disagreements on NOS definition are among philosophers, historians and sociologists of science (Khishfe & Lederman, 2006; Schwartz et al., 2004). Crowther, Lederman and Lederman (2005) confirm that the definition of NOS is not readily agreed upon within the science community. They propose that NOS should therefore be defined by its components. Even though there is no agreement on NOS definition, there is shared wisdom among philosophers, historians, sociologists of science and science educators (Akerson et al., 2000) about NOS i.e. individuals from various disciplines of science share some similar views, beliefs and values about NOS. In other words, irrespective of their varied science disciplines, individuals have generally come to accept that scientific knowledge is tentative. However, coming to consensus about what NOS is, is complicated by the fact that individual scientific disciplines tend to be idiosyncratic in terms of their structures and orientations. Lederman (1992) has proposed a definition for NOS, which has been widely cited within the science education community. He states:

> ...NOS refers to the epistemology of science...science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge...NOS is concerned with the epistemological values, assumptions, commitments and beliefs associated with the product of science.. [Lederman, 1992, p. 331]

The products of science are the "laws, theories, principles, models, facts and explanations making up the body of knowledge called science" (Vhurumuku & Mokeleche, 2009, p. 97). In an effort to link the definition of NOS with its characteristics and to clarify the concept, Lederman and Lederman (2005, p. 53) refer to nature of science as "the characteristics of scientific knowledge that result from the scientific investigations that scientists conduct to develop knowledge".

2.3 Some basic NOS tenets relevant to school science

NOS tenets that form the basis of science curricular are stated in curriculum documents such as the NSES (NRC, 1996). These documents are considered to form the basis of science curricular and science education reforms in many countries. NOS tenets have been listed by several authors (Crowther et al., 2005; Khishfe & Lederman, 2006; Lederman, 1992) in their reviews. Akerson et al. (2000, p. 298) asserts that the following tenets are "accessible to the learners and relevant to their daily lives":

- Curiosity is the driving force in science.
- Scientific knowledge is empirically based and derived from observation of natural phenomena.
- Scientific knowledge involves human imagination and creativity. Investigations and procedures needed to carry them out must be designed.
- Scientific knowledge is subjective. Scientists' previous knowledge, training, experience and expectations influence their work.
- Scientific knowledge is never absolute, but subject to change (tentative). Scientific ideas change as new evidence dictates revision of older ideas.

Research has been focusing on exploring an understanding of both the teachers' and learners' conceptions of NOS (Akerson et al., 2000; Akerson et al., 2006; Lederman, 1999; Schwartz et al., 2004). This research has shown that explicit rather than implicit approaches are effective in developing NOS understandings. Consequently, it is imperative for science textbooks to include explicit representations of NOS in their content. In South Africa, the NCS represents an overhaul of the old curriculum in that it mandates the inclusion of the other worldviews in the teaching and learning of Natural Science. The inclusion of other worldviews is encouraged in the science classroom, with NOS and IKS given special attention through LO 3 (DoE, 2002, 2003). DoE (2003, p.11) states that learners should understand:

- The scientific enterprise and, in particular, how scientific knowledge develops;
- That scientific knowledge is in principle tentative and subject to change as new evidence becomes available;
- That knowledge is contested and accepted, and depends on social, religious and political factors;
- That other systems of knowledge, such as indigenous knowledge systems, should also be considered;

- That the explanatory power and limitations of scientific models and theories need to be evaluated;
- How science relates to their everyday lives, to the environment and to a sustainable future; and
- The importance of scientific and technological advancements and to evaluate their impact on human lives.

The GET Natural Science Policy Statement, DoE (2002), encourages integration of IKS and other worldviews into school science through LO 3 Assessment Standard (AS) 1. AS 1 clarifies the competencies that the learners are expected to demonstrate in order for the LO to be achieved. It assumes that at any point in time, there is a possibility that there are different worldviews including IKS in a science classroom.

A survey of the literature reveals previous exclusion of NOS from mainstream science education (Akerson et al., 2000; Akerson et al., 2006; Lederman, 1999; Schwartz et al., 2004). As such, around the world, there are calls for the inclusion of NOS and NOS-related themes in the teaching and learning of science.

2.4 Research on analysis of NOS representations in school science textbooks

There are numerous studies conducted on content analysis of science textbooks (Chiappetta et al., 1991; Chiappetta et al., 1993; Chiappetta and Fillman, 2007). However, as noted in Chapter 1, none of these studies were done in Africa. Related and relevant to this project is the study by Chiappetta and Fillman (2007). In their study, they sampled five High School Biology textbooks adopted by Texas for analysis of inclusion of NOS. Three of the sampled textbooks were widely used in the United States while the other two were used by a few schools. They found that the sampled textbooks appeared to contain an adequate balance of NOS aspects (that they were investigating). They also noted that different strategies for addressing the targeted NOS aspects were used depending on the message that the authors were intending to convey.

Abd-El-Khalick et al. (2008) conducted their study focusing on the analysis of representations of NOS in High School Chemistry textbooks. They found that their sample performed poorly with the representations of the targeted NOS. Firstly, there was little attention given to NOS. Secondly, there were disparate references to some NOS aspects in the textbooks. They also found that NOS was not a central theme or major topic in any of the textbooks. My study analyzes Grade 9 Natural Science (Chemistry, Physics, Biology [Life Sciences] and Geography [Earth Science]) textbooks. It is smaller in terms of the sample size (three textbooks).

2.5 What is IKS?

It is difficult to formulate a definition of IKS without firstly looking at existing definitions and their relevance to this study. It is worth noting that different scholars have defined IKS differently. It is also noteworthy that IKS has been used as an acronym for both Indigenous Knowledge Systems (IKS) and Indigenous Knowledge (IK). In this study, the two are used interchangeably.

The term IKS has been used to refer to Indigenous Science, Traditional Knowledge or Traditional Science (Snively & Corsiglia, 2000), Endogenous Knowledge (Crossmans & Devisch, 2002; Ntsoane, 2002), African Indigenous Knowledge (Ntsoane, 2002). It is interesting to note that Ntsoane preferred to use African Indigenous Knowledge to narrow IKS to the African continent, probably to distinguish it from other non-African knowledges. For my study, the various concepts of IKS were considered and preference was given to using the more generic IKS as opposed to the more specific, for example, "African Indigenous Knowledge".

Ntsoane (2002, p. 1) refers to African Indigenous Knowledge as "...the knowledge base of local people." Snively and Corsiglia (2000, p. 8) refer to Indigenous Science as "...the science knowledge of the long resident, usually oral culture people." Crossman and Devisch (2002) define Indigenous Knowledge Systems as:

> ...a community-, site-, and role-specific epistemology governing the structures and development of the cognitive life, values and practices shared by a particular community (often demarcated by its language) in relation to a specific life-world..." [Crossman and Devisch, 2002, p. 108]

Kibirige and van Rooyen (2006) view IKS as local knowledge that has been developed and is indigenous in a specific location. Ogunniyi (2007) refers to IKS as knowledge systems encompassing science, technology, religion, language, philosophy, politics and other socio-economic systems. He further highlights that IKS is about epistemologies, ontology and metaphysical systems related to human dilemmas. Ogunniyi posits that IKS is

> …a way of knowing and interpreting experiences peculiar or innate to particular cultural groups. IKS refers to a conglomeration of knowledge systems encompassing science, religion, language, philosophy, politics and other socio-economic systems. [IKS is about]…the epistemologies, ontologies and metaphysical systems underpinning …artefacts and the way they are used to create a sense of wholeness, relatedness, complementarity amidst a collocation of human dilemmas. Unlike science whose ethos is reductionism, IKS celebrates plurality, diversity and the holism of human experience… [Ogunniyi, 2007, p. 965]

While my study appreciates and embraces the various definitions advanced by different scholars and researchers; I, adopt the approach to IKS as proposed by Ogunniyi and defines IKS as a knowledge-base of long-term residents of a geographic area which has been developed in science, technology, religion, language, philosophy, politics and other socio-economic systems.

Some scholars argue that IKS is not a science since it has a different approach to knowledge acquisition compared to western science (Good, 1995; Loving, 1995). Snively and Corsiglia (2000) suggest that proponents of western science:

> ...freely acknowledge the existence of indigenous arts, music, literature, drama, political and economic systems in indigenous cultures but somehow fail to apprehend and appreciate the existence of Indigenous Science… [Snively and Corsiglia, 2000, p. 7]

Overall, the proponents of IKS and its integration into school science curriculum have contrasting views to those of proponents of western science. Ogawa (1995, p. 585) argues that “every culture has its own science” which he refers to as “Indigenous Science.” Ogawa indicates that indigenous science is held by a specific cultural group, not a specific individual whilst western science is justified only by the scientific community. Ntsoane (2002) views IKS as a knowledge base for western science. He argues that:

> African Indigenous Knowledge and its related technologies play a pivotal role in the development of scientific knowledge more in the western societies than among the people who own this knowledge. This happens through many forms of international agreements including the Intellectual Property Rights, General Agreement on Trade and Tariffs, etc.” [Ntsoane, 2002, p. 1]

As with NOS, there are also calls for the integration of IKS into mainstream science education (DoE, 2002, 2003; Kibrige & van Rooyen, 2006; Le Grange, 2007; Ninnes, 2000, 2001; Snively & Corsiglia, 2000). Whilst there is abundance of research on IKS, the area of textbook content analysis of IKS representations in textbooks is under-researched, especially in South Africa.

2.6 IKS and school science education

It is important to start by identifying the aspects of IKS that are necessary for school science. Literature on IKS emphasizes the oral character of IKS as its dominating feature (Cruikshank, 1981, 1991; Snively and Corsiglia, 2000). Vansina cited in Snively and Corsiglia (2000, p. 15) defines IKS as oral tradition; "oral testimony transmitted from one generation to the other." Proponents of western science distance themselves from the oral character of Indigenous Knowledge, but science educators and researchers have special interest in some of its strengths that are listed below (Cruikshank, 1981, p. 72):

- Persistence: Stories that were told by a particular cultural group (for example, the Yukon) a century ago are still told in the same detailed structure in this day and age.
- Individual variation and consistency: Individuals sometimes tell different versions of the same story, but they are consistent in their versions even when retelling of stories is separated by years.
- Oral tradition as technology: The conceptual ability to recreate, through language, a situation for someone who has not yet experienced it directly is an adaptive technology carried in the mind, and not in the hand.
- Absence of documentary sources: While researchers may query the absence of documentary source, they do not afford to ignore the oral testimony they get.

Cruikshank (1991) listed limitations of oral narratives that may be confusing to science educators but remain important to indigenous communities. These include literary style and symbolism as well as cultural context; among others. IKS has a different approach compared to western science and it can be valuable for scholars from both western and indigenous communities. In his analysis of textbooks for representations of IKS, Ninnes (2000, p. 606) has identified the four pillars of IKS and lists them as:

- Indigenous legends and myths
- Indigenous technology
- Indigenous knowledge of the natural world

- Indigenous social life

Each of the strengths and limitations of IKS identified by Cruikshank may be classified under one of the categories above, for the purpose of analysing the selected textbooks. Now that I have identified the currently acceptable tenets of NOS and IKS pillars that will be used for analysis in my study, I proceed to explore how they relate to the school science curriculum. From the discussion above, it seems that integrating IKS into western science in South Africa is a challenge. Issues about what aspects of IKS should be integrated arise despite the fact that in South Africa, inclusion of other worldviews in school science is stated in the education policy statement through LO 3.

2.7 Research on analysis of IKS representations in school science textbooks

In South Africa, several studies have been done on integrating IKS into western science at school level (Kibirige & van Rooyen, 2006; Le Grange, 2007), at Adult Basic Education and Training [ABET] level (le Roux, 2004) and at the university level (le Grange, 2004; Kraak, 2000). However, after extensive literature search, I could not find research materials that focus on analysis of representations of IKS in school science textbooks. It seems that research on analysis of IKS representations in school science textbooks is still under-researched by the South African science education community.

Ninnes (2000) investigated the representations of IKS in science textbooks. He sampled science textbooks from Australia and Canada. He argues that the socio-economic, political and educational issues of the two countries are to a large extent similar; hence the choice of his sample. He found that both sets of texts collectively (*Dynamic Science Series* and *Science Probe Series*) had extensive representation of IKS. However, *Dynamic Science Series* had more and consistent representations of Australian IKS than *Science Probe Series* which had Canadian IKS. He attributed the disparities in IKS representations between the two sets of texts to several aspects, including authorship. He proposed that the identified disparities should be a subject for further investigation.

Ninnes (2001) conducted another study on representations of ways of knowing in Australian textbooks. The study highlights various ways of knowing, contrary to universalism of science as claimed by Good (1995) and Loving (1995), i.e. there are different ways of developing and acquiring knowledge. Ninnes argued that his selected sample displayed a variety of ways of responding to diversity. He found that, to a large extent, science continues to be portrayed as superior to other ways of knowing. The texts, he claimed, displayed the representations of "alternative ways of knowing as inferior, outdated and located in the past" (Ninnes, 2000, p. 91).

2.8 Approaches to addressing NOS/IKS in science textbooks

My study investigated whether the selected Grade 9 Natural Science textbooks have representations of NOS and IKS that are implicit or explicit and naïve or informed. These concepts are discussed in detail below.

2.8.1 Implicit and explicit approaches

Several studies have been done on implicit (Abd-El-Khalick & Akerson, 2004; Akerson et al. 2000; Khishfe & Abd-El-Khalick, 2002) and explicit (Akerson et al., 2000; Schwartz et al., 2004) approaches to teaching NOS. However, there is nothing on the use of these two approaches to teach IKS. Schwartz et al. (2004, p. 614) explained an explicit approach to teaching NOS as:

> ...an approach that provides learning opportunities that pay special attention to NOS aspects that are planned for through objectives, instructional attention and assessment. The approach aims to draw learners' attention to targeted NOS aspects through discussions, guided reflection and specific questioning in the context of activities, investigations and historical examples. To be successfully implemented, educator should provide explicit learning opportunities by providing opportunity for practice; assess learners' understanding and provide feedback with re-teaching when necessary... [Schwartz et al., 2004, p. 614]

On the other hand, the implicit approach to teaching NOS refers to "the absence of specific attention to NOS" (Schwartz et al. 2004, p. 614). The implicit teaching approaches assume that understanding of NOS occurs naturally as a result of engaging in inquiry activities. Abd-El-Khalick & Lederman (2000) consider implicit teaching approaches as those approaches that do not help learners achieve the desired NOS understandings. Some research has shown that the explicit approach is more effective than the implicit approach in improving learners' understanding of NOS (Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002). However, other studies show that explicit approaches have limited success (Carey, Evans, Honda, Jay, & Unger, 1989). The success of explicit approaches might be easily influenced by other variables; for example an individual's worldview.

2.8.2 Naïve and informed approaches

Research (see, Lederman, 1992; Lederman, 2007) has consistently shown that learners (and educators) hold naïve views of NOS irrespective of the curricular and research interventions used to enhance their views. Naïve views of NOS have been erroneously associated with positivism. As alluded to in Chapter 1, positivism is a philosophy that holds that the goal of knowledge is simply to describe the phenomena that we experience (Trochim, 2006). Literature attributes this to the erroneous assumption that learning about NOS occurs through "doing science" and enquiry activities (Khishfe & Lederman, 2007). Other studies show that naïve NOS views might be attributed to learners' lack of experience in conducting scientific investigations. To redress the naïve views explicit planning and teaching is required (Abd-El-Khalick & Lederman, 2000).

NOS views or representations which are not naïve are considered to be informed. According to Schwartz et al. (2004) and Abd-El-Khalick et al. (2008), informed views or representations must consistently and in all themes (contexts) demonstrate NOS view or representation of the targeted tenet with no inconsistencies, or else it will be categorized as naïve. An informed representation is a representation that promotes the understanding of the development of scientific knowledge (that is, the epistemology of science). It advances the idea that we each construct our view of the world based on our perceptions of this world. Essentially, informed views can be described as constructivist.

2.9 Conclusion

In this chapter, I discussed the literature on NOS and IKS. I gave an overview of research and the other issues that necessitated the need for curriculum reform. I defined both NOS and IKS and identified the tenets and pillars, respectively, that will be used for the analysis of the selected textbooks. I also gave an overview of research done on the analysis of representation of both NOS and IKS in school science textbooks. I concluded by explaining the approaches and views used in the analysis of textbooks. In the next chapter, I discuss the research methodology used in my study.

Chapter 3

Research methodology

3. Introduction

In this chapter, I discuss the methodology that I used in my study. I describe and explain content analysis as a tool for analyzing textbooks, the textbook selection, details of the analyzed textbooks and textbook content analyses for representations of NOS and IKS.

3.1 Content analysis for analyzing textbooks: the methodological approach

To analyze the selected science textbooks for representations of NOS and IKS, I used content analysis, also called text analysis, as is discussed in Borg and Gall (1979), Freebody (2003) and Krippendorff (1980) and used in the studies of Chiappetta and Fillman (2007) and Wang (1998). Content analysis is chosen for this study because it was used successfully in previous studies focusing on representations of NOS (Akerson et al., 2000; Abd-El-Khalick et al., 2008) and IKS (e.g. Ninnes, 2000, 2001). For analysing representations of NOS, the analytical framework that was used by Akerson et al. (2000) is adapted. The success and credibility of this framework is demonstrated in studies by Akerson et al. (2000) and Abd-El-Khalick et al. (2008) and its continued use in other NOS studies is recommended. However, in my study, NOS analytical framework is chosen for two reasons. Firstly, content analysis requires the use of a conceptual framework. The chosen NOS analytical framework, which is also one of the conceptual frameworks for NOS, comprises of tenets that are considered to be accessible to the secondary school learners. Secondly, NOS framework used for analysis in my study is considered to be useful in promoting the understanding of the development of scientific knowledge (NOS) in learners (Akerson et al., 2000; Abd-El-Khalick et al., 2008).

Similarly, the success of IKS analytical framework adopted for use in this study may be seen in the review by Ninnes (2000). In my study, IKS analytical framework was chosen since it embodies both the strengths and limitations of IKS that were identified by Cruikshank (1981). It is argued that each of the strengths and limitations of IKS can be classified in at least, one of the four pillars of IKS. IKS pillars also show the social fibre that characterises indigenous communities. That is, the identified pillars show that in indigenous communities, knowledge lies in the people and the environment. Jegede (1999) argues that indigenous learners bring what they have learnt from their environments into the science classroom and that indigenous knowledge has resilience. For the learners from the indigenous communities, it may be easier for them to relate to the science concepts that are taught in class (through the textbooks) if examples from their immediate environment are used.

In this study, the use of content analysis involved reading the whole textbook to determine whether words, examples, explanations, demonstrations, pictures, or symbols used in the textbook fit within the chosen analytical frameworks. For NOS, a consensual decision (involving the researcher and an experienced science educator) was made as to whether the representations fit in any of the chosen seven tenets. For example, an activity involving or a statement implying the investigation of a phenomenon was categorized under the empirical tenet of NOS. Furthermore, decisions had to be made about whether NOS idea under consideration was presented implicitly or explicitly and in a naïve or informed manner. Text statements were taken to be explicit if there was a deliberate effort to develop students' NOS conceptions. That is, they were judged by whether they had prompts aiming at teaching and/or assessing learners' understandings of NOS. On the contrary, implicit representations do not have any prompts intended to develop the understanding and the assessment of NOS ideas. For example, a phrase in the textbook that simply conveys the information about the fossils discoveries that were done in the past does not show any deliberate intentions of developing NOS ideas.

Consensual judgments and decisions also had to be made about whether the section of text under consideration represented an informed or a naïve view of NOS. As an example, it had to be determined whether; scientific laws were represented as descriptions and generalizations about phenomena based on observations; and theories as attempts to explain observations. Such representations would be categorized as informed views of NOS. Informed scientific views also include such ideas as: scientific knowledge changes; is invented; subjective; tentative; and revisionary. To the contrary, describing theories as proven facts would be judged to be naïve and so would be suggesting that this knowledge is unproblematic, discovered, objective, empirical and infallible.

IKS representation was also analyzed for its implicit or explicit and naïve or informed character as well as its fit within the four IKS pillars as described by Ninnes (2000). The aim was to determine whether the words, explanations, demonstrations, examples, pictures, or symbols in the textbook fitted within the four pillars of IKS. For example, a statement or phrase explaining how people made art was categorized under the indigenous technology pillar. An example of such a statement is where the textbook referred to the paintings that were done by the *San and Khoi* on rocks and in caves. The phrase is said to be represented implicitly because it does not have any prompts that are intended to develop the learners' understanding of IKS. Such a presentation of an idea is classified as naïve since it locates the indigenous practice to the past. It also fails to consider the possibility that such a practice may still be extant and may also have extended to other communities. Informed views of IKS embrace the existence of indigenous practices, the diversity of indigenous communities and indigenous knowledge.

3.2 The selected textbooks

I identified ten Grade 9 Natural Science textbooks available on the public market for preliminary analysis of the appropriateness of the science content they contained. The identified science textbooks all claimed to be compatible with NCS. A preliminary analysis of the ten textbooks revealed that no textbook contained all the science content knowledge for Grade 9 that is prescribed in the NCS Natural Science Policy Statement. It was found that the depth and breadth of the content covered differs greatly across the textbooks. Out of the ten possible textbooks, three Grade 9 Natural Science textbooks were chosen for analysis of representations of both NOS and IKS. The textbooks are: *Science Today; Hands-on Science; and Spot-On*. Although this study is not about the required Grade 9 content knowledge, the textbooks were chosen because they appeared to have substantial breadth of science content knowledge for Grade 9 compared to their counterparts that were not selected.

At face value, the titles of the three selected textbooks are appealing; promising learners a real scientific venture that shows how scientific knowledge develops. Their description hereunder is based on both their similarities and differences. Their similarities are highlighted first, and then followed by their differences. The identified similarities are:

- The textbooks are organized into either chapters or modules.
- There are well illustrated diagrams, pictures, tables etc.
- They have sufficient activities that support the science concepts and they can be used without being complimented with special resources.

- At the end of each topic there is an assessment task that requires learners to reflect on the content knowledge that they have learned.
- They have a glossary.

The textbooks have differences. The identified differences are as follows:

Science Today**:** The front cover has an NCS emblem. The inside of the front cover has a table summarizing the Learning Outcomes (LOs) and Assessment Standards (ASs) in the entire book. Each chapter and activity shows the LOs and ASs addressed. Most activities were in the form of investigations. Each topic ended with a summary of key concepts.

Spot-On**:** The front cover has an NCS emblem. Modules are introduced by indicating the concepts that are explored. Activities show vertical and horizontal integration of LOs and ASs. Vertical integration refers to integration within the same Learning Area and horizontal integration refers to integration across the different Learning Areas.

Hands-on Science**:** Modules are organized into the four Natural Science themes. Modules are introduced by indicating the concepts that are explored and the skills that might be practiced and/or acquired. The assessment task at the end of each module reflects on and addresses all the four themes. At the end of the textbook, there are resource pages that may be used to enhance learning (for example, there is the periodic table of the elements).

3.3 Content analysis of the textbooks

The content of the selected textbooks was analyzed using NOS and IKS analytical frameworks. A detailed discussion of the two analytical frameworks follows below.

3.3.1 NOS content analysis framework

NOS content analysis framework was used to respond to the first two research questions, which are:

- What ideas about NOS are included in Grade 9 Natural Science textbooks?
- How are NOS ideas represented in Grade 9 Natural Science textbooks?

The analysis was done for ideas and representations of NOS. Table 3.1 shows NOS analysis framework that comprises of NOS tenets with their descriptors. The purpose of the descriptors is to clarify how NOS representations were identified in the sentences, paragraphs, pictures and phrases. It should be noted that NOS tenets are interrelated; they do not exist in isolation and should not be viewed in that way. NOS representations were sought for in texts, pictures, words, phrases, sentences or part of a section that relate to aspects of the scientific process and science knowledge (products of science). In the first instance, analysis focused on determining whether any NOS ideas are represented in the pages, paragraphs, sentences and pictures, words, phrases, and sentences. Secondly, a decision was made about whether NOS idea under consideration was presented implicitly or explicitly and in a naïve or informed manner. Finally, the identified NOS idea was classified under one of the selected NOS tenets.

Table 3.1: NOS content analysis framework

NOS TENETS	DESCRIPTORS OR CHARACTERISTICS
1. The empirical NOS	Scientific claims are derived from, and/or consistent with, observations of natural phenomena. Scientists, however, do not have ‘‘direct’’ access to most natural phenomena: their observations are almost always filtered through the human perceptual apparatus. In their endeavour to uncover evidence pertaining to specific natural phenomena, scientists engage in a messy exercise. There is no recipe-like stepwise procedure (scientific method) that typifies all scientific practice. Scientific method is a ‘myth’. Scientists do observe, compare, measure, test, speculate debate, create ideas and conceptual tools, and construct theories and explanations. However, there is no single sequence of (practical, conceptual, or logical) activities that will unerringly lead them to valid claims, let alone ‘‘certain’’ knowledge.
2. The difference between observation and inference	Observation refers to that which is accessible to the senses. On the contrary, inference refers to that which is not accessible to the senses but manifests itself through its effects; e.g. force.
3. The functions and relations of theories and laws	Scientific theories are well-established, highly substantiated, internally consistent systems of explanations, which (a) account for large sets of seemingly unrelated observations in several fields of investigation, (b) generate research questions and problems, and (c) guide future investigations. Theories are often based on assumptions or axioms and posit (explain) the existence of non-observable entities. In other words, theories are inferred explanations for observable phenomena or regularities in those phenomena. Thus, direct testing is untenable. Only indirect evidence supports and validates theories. On the other hand, laws are descriptive statements of relationships among observable phenomena. Contrary to common belief, theories and laws are not hierarchically related. Theories and laws are different kinds of knowledge and one does not become the other. Theories are as legitimate a product of science as laws
4. The role of creativity and imagination in science.	Generating scientific knowledge involves human creativity in the sense of scientists inventing explanations and theoretical entities. The creative NOS, coupled with its inferential nature, entail that scientific entities (atoms, force fields, species, etc.) are theoretical models rather than faithful copies of ‘‘reality’’.
5. The tentativeness of scientific knowledge	Scientific knowledge is reliable and durable, but never absolute or certain. All categories of knowledge (‘‘facts,’’ theories, laws, etc.) are subject to change. Scientific claims change as new evidence, made possible through conceptual and technological advances, is brought to bear; as extant evidence is reinterpreted in light of new or revised theoretical ideas; or due to changes in the cultural and social spheres or shifts in the directions of established research programs
6. Subjectivity (Theory-Laden) of science.	Scientists interpret things according to what they know. Their cultures and backgrounds influence their interpretation, perceptions and conclusions. Scientists’ theoretical and disciplinary commitments, beliefs, prior knowledge, training, and expectations influence their work. These background factors affect scientists’ choice of problems to investigate and methods of investigations, observations (both in terms of what is and is not observed), and interpretation of these observations.
7. The socially and culturally embedded-ness of the scientific process.	Science is a social enterprise practiced in the context of a larger cultural milieu. Thus, science affects and is affected by various cultural elements and spheres, including social fabric, worldview, power structures, philosophy, religion, and political and economic factors. Such effects are manifested, among other things, through public funding for scientific research and, in some cases, in the very nature of ‘‘acceptable’’ explanations of natural phenomena. Furthermore, scientific knowledge is socially negotiated.

Adapted from Akerson, Abd-El-Khalick & Lederman (2000), Abd-El-Khalick, Waters & Le (2008)

3.3.2 Procedure followed in the analysis of the textbooks for NOS representations

For each textbook, the procedure below was followed for analysis of NOS representations.

1. Each textbook as a whole was read and re-read.
2. For each of the selected NOS tenets, key terms associated with a chosen tenet were identified, e.g. experiment, evidence, discover and test were associated with the "empirical tenet of NOS" and theory, inference, observation and law were associated with "laws and theories" and/or "observation versus inference".
3. Paragraphs, pictures/diagrams, activities, sentences and phrases that referred to or implied a chosen NOS tenet (e.g. science is empirical, based on experimental evidence) were selected and highlighted. These are referred to as excerpts.
4. Excerpts were read and re-read with the view of making judgments about whether the representation was explicit or implicit. Excerpts that exemplified implicit/explicit representation of NOS tenet under consideration were selected and categorized separately.
5. Highlighted excerpts were read and re-read with the view of making judgments about whether the representation was naïve or informed. Excerpts that exemplified naïve or informed representation of NOS tenet under consideration were selected and categorized separately.
6. The highlighted excerpts were read and re-read to determine the categories of the representation for each of NOS tenets under consideration. They were examined and categorized individually.
7. Categorization was done using a rubric. The rubric below was followed according to how each of the selected NOS tenets was represented. The idea of a rubric was initially used by Abd-El-Khalick et al. (2008) in a similar study. The rubric for this study was developed as follows:
    - 4 = Explicit and informed representations
    - 3 = Implicit and informed representations
    - 2 = Explicit and naïve representations
    - 1 = Implicit and naïve representations
    - 0 = NOS aspects not addressed or no NOS representations

The numbers in the rubric above are in no way intended to put numerical value or judgment to the identified excerpts. They are intended to differentiate the categories of representations of the excerpts. That is, they show how the representations are presented in the sample.

3.3.3 IKS content analysis framework

IKS content analysis framework was used to respond to the last two research questions, which are:

- What ideas about IKS are included in Grade 9 Natural Science textbooks?
- How are IKS ideas represented in Grade 9 Natural Science textbooks?

Table 3.2 shows IKS analysis framework and its descriptors. The descriptors are the basis for the identification of IKS representations. As with NOS, this categorization should not be viewed as rigid because the categories overlap. This categorization is used only to give a broader view of aspects that relate to IKS.

Table 3.2: IKS content analysis framework

IKS PILLARS	EXAMPLES OF DESCRIPTORS
Legends and myths	The origin of phenomena such as the sun, water, wind, fire, phases of the moon, plants and animals; IK legends and myths.
Technology	Use of plant materials to make spears, hunting, housing, clothing and medication; using fire to sharpen tools and weapons; painting as a means of communication; use of rocks and mud in paintings; use of fire to create grasslands.
Knowledge of the natural world	Calendar of the seasons, meaning of natural disasters; communication with the animals; use of astronomical observations to predict phenomena.
Social life	Initiation ceremonies; dance as a means of communication; classification of materials in the physical world, etc.

Adapted from Ninnes (2000)

The three textbooks were analyzed for inclusion and categorization of IKS representations. In the first instance, analysis focused on determining whether any of the selected IKS pillars was represented in the pages, paragraphs and pictures. Secondly, a decision was made about whether IKS pillar under consideration was represented in an implicit or explicit and naïve or informed manner. Finally, the identified IKS idea was classified under one of the selected IKS pillars.

The rationale for adopting Ninnes (2000) IKS analysis framework is that it appears to exhibit a coherent social fibre that characterises indigenous communities. Ninnes shows that issues and concerns related to the integration of IKS in school science maybe similar in the various indigenous communities across the world. The challenges faced by the science learners in other indigenous communities are, to a large extent, also faced by the South African indigenous learners. Furthermore the reasons advanced for integration of IKS in school science in South Africa are similar to those of other indigenous communities around the world, hence the relevance of the framework.

3.3.4 IKS representations

The representations of IKS in the selected Grade 9 Natural Science textbooks relate to aspects of science, technology, religion, language, philosophy, politics and other socio-economic systems. IKS representations are viewed as the language used to mediate the knowledge or concepts of science contained in the textbooks by using indigenous ways. In this analysis, IKS representations are sought for in any text, pictures/diagrams or part of a section in the selected textbooks.

3.3.5 Procedure followed in the analysis of textbooks for IKS representations

Basically, the same procedure followed during the analysis of NOS representations was also followed for the analysis of IKS representations. However, the procedure was adapted for suitability to IKS. For each textbook, the procedure below was followed for analysis of IKS representations.

1. Each textbook as a whole was read and re-read.
2. For each of the selected IKS pillars, key features associated with a chosen pillar was identified, e.g. story telling was associated with “legends and myths”, use of equipments and materials was associated with “indigenous technology” and making predictions based on observation of natural phenomena was associated with indigenous knowledge of the natural world.
3. Excerpts that referred to or implied a chosen IKS tenet (e.g. they use plants to make traditional medicine) were selected and highlighted.
4. Highlighted excerpts were read and re-read with the view of making judgments about whether the representation was explicit or implicit and naïve or informed. Excerpts that exemplified explicit or implicit and naïve or informed representation for each IKS pillar were selected and categorized separately.
5. All excerpts targeting IKS pillar under consideration were examined and categorized individually using the rubric of categories of representations.

6. A similar rubric used for targeting NOS representations was used for targeting IKS representations. This translated to:
    - 4 = Explicit and informed IKS representations
    - 3 = Implicit and informed IKS representations
    - 2 = Explicit and naïve IKS representations
    - 1 = Implicit and naïve IKS representations
    - 0 = IKS aspects not addressed or no IKS representations

Similarly, the numbers are intended to differentiate the categories of representations of IKS for the identified excerpts.

3.4. The rubric for the categories of representations

The rubric for the categories of representations used in this study is adapted from Abd-El-Khalick et al. (2008). The rubric targeted the seven selected tenets of NOS and four pillars of IKS. The selected excerpts from each of the textbooks were grouped together per textbook according to the criteria or aspects of the rubric, i.e. whether the excerpts are implicit/explicit and naïve/informed. If an excerpt fits in more than one of the aspects of the rubric, it is categorized in all those aspects of the rubric. Therefore, the category allocated to a specific tenet of NOS or pillar of IKS for a particular textbook, is based on the selected and recorded excerpts in that textbook. For example, if a tenet of NOS or a pillar of IKS is allocated a category of 1 using the rubric, it translates to the presence of implicit and naïve excerpts about the tenet or the pillar in a textbook.

3.5 Validity and reliability

Prior research on NOS (e.g. Akerson et al., 2000; Schwartz et al., 2004; Abd-El-Khalick et al., 2008) argued and showed that the selected seven tenets of NOS are relevant for and accessible to secondary school (including Grade 9) learners. The use of NOS framework appears to be significant since its purpose focuses on promoting the learners' understanding of NOS. Its purpose seems to be that of ensuring that the learners first understand the different tenets of NOS and their interrelatedness. For example, NOS tenets expose the learners to the idea that the questions or issues that scientists investigate are influenced by their backgrounds and culture. Scientists' current findings are negotiated and validated in their communities (social, professional and academic) before they are accepted; and they may change in future.

Before the analysis was done, I discussed NOS and IKS frameworks with a senior researcher and science educator. The aim was to agree on how the analysis was going to unfold. This approach assisted in ensuring the consistency of the analysis. A concensus was reached on using key terms or descriptors that are associated with NOS tenet or IKS pillars during the analysis. Then, during the analysis for NOS, key terms such as tests, experiment, investigate in the unit of analysis were categorized under the empirical tenet of NOS. Key terms such as observation were categorized either under empirical NOS or the difference between observation and inference tenet of NOS or both depending on how it was phrased in the text, sentence, picture or phrase. For IKS, for example, the use of stories to explain phenomena was categorized under legends and myths. Also, an item that discussed indigenous brewing of beer was classified either under indigenous social life or indigenous technology or both as guided by the excerpts. Categorization of an item of analysis in more than one NOS tenet or IKS pillar showed the interrelatedness of NOS tenets or IKS pillars. Further discussions about the use of the analytical frameworks, initial trials of the analysis of textbooks among the researchers and the science educator, and the consensus reached on the procedure to be used during the analysis ensured that the results are reliable.

3.6. Conclusion

In this chapter, I have outlined the research design used in my study. I gave a brief description of the sampled textbooks. The analytical frameworks used in the analysis of the textbooks were presented in detailed. The approaches and views used in determining the inclusion and categories of representations were explained. The concept of a rubric for the categories of representations that illuminates the categorization of excerpts was discussed. In chapter four, I present and discuss the results of the analysis of the three selected textbooks for the representations of NOS.

Chapter 4

Results and Discussion for NOS Representations

4. Introduction

In this chapter I present and discuss the results obtained from the analysis for NOS representations in the content of the three selected textbooks guided by the tenets of NOS. The presentation of the results follows the order of the research questions as given in Chapter 1. These questions are:

1. What ideas about NOS are included in Grade 9 Natural Science textbooks?
2. How are NOS ideas presented in Grade 9 Natural Science textbooks?

4.1 Ideas about NOS included in the three Grade 9 Natural Science textbooks

As already mentioned, each textbook was analyzed for inclusion and presentation of NOS ideas for each of the seven chosen NOS tenets, which are:

- Science is empirical
- Difference between observation and inference
- The nature of scientific laws and theories
- The role of creativity and imagination in science
- Scientific knowledge is tentativeness
- The role of theory-ladenness or subjectivity in science
- The role of social and cultural embeddedness in science

The frequency counts of the representations for each NOS tenet under each of the four NCS themes of the Natural Science are summarised in Table 4.1 below. The frequency here means the number of times each tenet of NOS was represented across the textbook in line with the definition of representation given in Chapters 1 and 2. For each textbook, relevant exemplary excerpts that represented specific NOS tenet in a Natural Science curriculum theme were first highlighted. The selected excerpts were then grouped according to NOS tenets and NCS themes. The frequencies of the excerpts were counted and recorded for each NOS tenet and NCS theme as shown in the table. The numbers show the counts of the recorded excerpts that presented each NOS tenet in a NCS theme in each of the selected textbooks.

Table 4.1: Frequency counts of representations of each NOS tenet per NCS theme in each textbook

	NCS THEME	NOS TENETS							
Textbook		Empirical	Observation vs. Inference	Creative	Tentative	Theory-driven	Social / Cultural	Laws & Theories	Total
Science Today	EC	16	14	1	0	0	0	4	35
	MM	23	15	0	0	5	0	0	43
	LL	18	10	3	1	3	3	4	42
	EB	5	12	3	3	2	7	4	36
	Total	62	51	7	4	10	10	12	156
Hands-on Science	EC	6	4	0	0	0	0	4	14
	MM	14	1	3	0	2	0	2	22
	LL	9	4	4	1	2	2	1	23
	EB	8	4	0	1	2	0	5	20
	Total	37	13	7	2	6	2	12	79
Spot-On	EC	9	2	0	0	0	0	1	12
	MM	5	0	0	0	0	0	0	5
	LL	9	2	0	0	1	0	3	15
	EB	6	4	0	0	2	1	1	14
	Total	29	8	0	0	3	1	5	46

Theme codes: Energy and Change (EC); Matter and Material (MM); Life and Living (LL); Earth and Beyond (EB)

Table 4.1 shows that only two of the seven targeted NOS tenets are represented to some considerable degree. These are: 1) science is empirical; and 2) the difference between observation and inference. The remaining tenets of NOS are minimally represented or not represented at all. I identified a total of 156 excerpts in *Science Today*. 40% of the identified excerpts categorized in the empirical tenet of NOS and 33% belong in the observation and inference tenet of NOS. Laws and theories tenet of NOS account for 8% of the identified representations and the others contributed less that 8% each and share the remaining 19%. For *Hands-on Science*, a total of 79 excerpts were identified and recorded. 47% of the representations are classified in the empirical tenet of NOS and 16% are classified in observation and inference tenet of NOS. Laws and theories follow with 15% of the representations. A similar trend is observed for *Spot-On*. Of the 46 recorded excerpts, the empirical tenet of NOS has 63%, observation and inference tenet of NOS has 17 % and laws and theories tenet of NOS has 11%. In all the three textbooks analysed, the empirical tenet of NOS is most represented followed by observation and inference tenet of NOS. Laws and theories tenet of NOS is the third most presented tenet of NOS but the percentage contribution of the representation is 15% at most in *Hands-on Science*.

In the sections below, the ideas about NOS included in the representations are discussed under the sub-headings: science is empirical; the difference between observation and inference; and other tenets.

4.1.1. Science is empirical

Table 4.1 shows that the three textbooks analysed include numerous excerpts that relate to the empirical NOS across all the four NCS themes. However, scrutinising the excerpts reveals that different ideas about the empirical tenet of NOS are presented in all the three textbooks. A typical example of a representation of the empirical tenet of NOS is found in Activity 8 of *Science Today* (pages 10-11). Part of this activity reads: "Repeat the experiment a few more times. Each time set up the incoming beam at a different angle." Through such activities, the three textbooks appear to advance the idea that scientists perform experiments and/or investigations in an endeavour to collect evidence needed to develop or validate scientific knowledge. The idea that scientists carry out tests, experiments and investigations appears to be dominant in all the three textbooks.

Another idea related to the empirical tenet of NOS presented in all the three textbooks is that scientists make observations, first, in order to investigate the natural world. That is, scientists make observations which lead them to make certain claims. The claims made about the observed phenomena are then investigated to establish evidence that supports or disprove the claims; thereby alluding to the empirical tenet of NOS. Representations of the empirical tenet of NOS are illustrated in the selected textbooks through activities and/or statements that show scientists to be conducting investigations, experiments and tests; and making discoveries in the process. Below is an excerpt from *Science Today*, exemplifying the empirical tenet of NOS:

> ..Later in the 19th century and in the early 20th century scientists investigating fossils in the different parts of the world made some interesting discoveries. They noticed that there were the remains of the same kind of animals and plants on continents that are now separated by huge oceans... [Science Today, p. 144]

Whilst the selected textbooks make an effort to include the empirical tenet of NOS in their content, they do not proceed to explain how the required evidence is gathered. In most cases, the empirical tenet of NOS is illustrated in the form of reported statements or activities. From the Tables 4.1 and 4.2, it may be noted that *Hands-on Science* and *Spot-On* presented limited excerpts under the empirical tenet of NOS as compared to *Science Today*. However, collectively the three textbooks may be said to generally present a variety of ideas related to the empirical tenet of NOS.

Another striking feature in two of the three textbooks (*Science Today and Spot-On*) relates to the existence of the "Scientific Method." The idea that a "Scientific Method" exists is clearly noticeable in these two textbooks. For example, some activities in, *Spot-On*, suggest the use of the "Scientific Method" with the extract on page 157 that says: "Plan an investigation of how smoking affects lung capacity. Refer to Module 1, the Scientific Method." However, *Hands-on Science* is silent about the "Scientific Method." In all the three textbooks, there is no attempt to illustrate that the scientific process is complex and subjective, that the "Scientific Method" is a myth, and that scientists do their work in a variety of ways as dictated by their respective fields of interest, training and background. This is a desirable NOS understanding for learners.

4.1.2 The difference between observation and inference

The three textbooks included a variety of ideas about the difference between observation and inference tenet of NOS. However, excerpts that illustrate that there is the difference between observation and inference are minimal. *Spot-On* and *Science Today* contained the excerpts that show different ways in which observation and inference tenet of NOS are presented. In *Spot-On*, there is an inference on "force". It is stated: "What is a force? We cannot see forces, but we can see the result of their action" (p. 51). *Science Today* made inference about colour change by saying: "The colour change that you saw at the end of the reaction in Activity 4 tells you that the products are neutral" (p. 67).

It is noticeable that, collectively, the textbooks appear to be consistent in forwarding the idea that scientists make observations and inferences in gathering scientific knowledge.

4.1.3 Other tenets

There is also an attempt in all the three textbooks to illustrate the use of laws and theories in science. As with the difference between observation and inference tenet of NOS, the distinction between scientific laws and theories is not adequately illustrated in the textbooks. The presentation of the scientific laws and theories in the selected textbooks imply that they are developed and used for the advancement of science. Table 4.1, shows that the frequency counts of the exemplary excerpts in all the remaining tenets across the three textbooks are low or non-existent. That is, the majority of NOS tenets that Lederman (1999) identified as being central to the learners' understanding of NOS are not presented in the three analyzed textbooks. This may suggest that the learners are disadvantaged in terms of getting exposure to NOS.

4.2 How are NOS ideas presented in Grade 9 Natural Science textbooks?

The frequency counts for the categories of representations for each of NOS tenet in each textbook are summarized in Table 4.2 below. To produce Table 4.2, a decision was made as to whether the selected excerpts fit in any of the following categories of representations:

- 4 = Explicit and informed representations
- 3 = Implicit and informed representations
- 2 = Explicit and naïve representations
- 1 = Implicit and naïve representations
- 0 = NOS aspects not addressed or no NOS representations

The numbers differentiate the categories of representations for the identified and recorded excerpts for each of the three textbooks analyzed.

Table 4.2 shows the frequency counts of the categories of representations on the targeted NOS tenets for each of the selected textbooks. The frequencies represent the counts of the categories of representation of the target NOS tenet as adjudged using the rubric discussed in

Chapter 3. Analysis of Table 4.2 shows that the selected textbooks presented excerpts mainly implicitly and in a naïve manner. *Science Today* and *Spot-On* presented a scatter of implicit and informed representations while *Hands-on Science* seems not to have excerpts that are informed.

Table 4.2: Frequency counts of the category of representations of each of NOS tenets in each textbook

	Categories of representations	**NOS tenets**							
Textbook		**Empirical**	**Observation vs. Inference**	**Creative**	**Tentative**	**Theory-driven**	**Social / Cultural**	**Laws & Theories**	**Total**
Science Today	EI	0	0	0	0	0	0	0	0
	II	0	1	1	1	1	0	1	5
	EN	0	0	0	0	0	0	0	0
	IN	62	50	6	3	9	10	11	151
	Total	62	51	7	4	10	10	12	156
Hands-on Science	EI	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	EN	0	0	0	0	0	0	0	0
	IN	37	13	7	2	2	6	12	79
	Total	37	13	7	2	2	6	12	79
Spot-On	EI	0	0	0	0	0	0	0	0
	II	10	0	1	0	0	0	4	15
	EN	0	0	0	0	0	0	0	0
	IN	19	8	0	0	3	1	1	32
	Total	29	8	1	0	3	1	5	47

Codes for categories of representations rubric: Explicit and informed (EI), Implicit and informed (II), Explicit and naïve (EN), Implicit and naïve (IN).

A brief overview of the presentation of the category of excerpts of NOS in each of the analyzed textbooks is discussed hereafter. *Science Today* contains the implicit/naïve excerpts in all the selected seven tenets of the NOS and that translates to 97% of all the recorded excerpts from the textbook. It also contains one implicit/informed excerpt in each of the five tenets of NOS, which is the other 3% of the representations, and it excludes the empirical and the social and cultural embeddedness tenets of NOS (see Table 4.2). Similar to the frequency counts of the excerpts, 40% of the implicit/naïve excerpts belong in the empirical tenet of the NOS. These are followed by 33% and 8% of observation and inference tenet of NOS and laws and theories tenet of NOS, respectively. The theory-driven and social and cultural tenets of NOS are equal at 1% and the creative and tentative tenets of NOS are below 1%. However, there are no explicit informed or naïve representations in the textbook.

All of the excerpts in *Hands-on Science* are represented in an implicit and naïve manner. The percentages of excerpts are 47, 16 and 15 for the empirical, observation and inference, and laws and theories tenets of NOS respectively. The creative tenet of NOS follows at 8% and the rest are below 8%. *Spot-On* does not have excerpts in the tentative tenet of NOS, but it has 62% of the empirical tenets of NOS and 17% of the observation and inference tenet of NOS. It has some excerpts which are implicit and informed in the empirical, creative, and laws and theories tenets of NOS. Whilst there are scattered instances of informed excerpts in *Science Today* and *Spot-On* as shown in Table 4.1 and 4.2, generally the representations are largely implicit and naïve. The selected textbooks appear to refer to the selected tenets of NOS implicitly rather than explicitly. It also seems that the selected textbooks contain more naïve as compared to informed representations of NOS.

Table 4.2 also shows that there are no explicit representations of NOS in all the three textbooks. It seems that, NOS representations in the selected textbooks do not deliberately focus on developing learners' NOS ideas. Lack of explicit representations of NOS in the textbooks may imply lack of opportunities that initiate the guided discussions that target the tenets of NOS in the science classrooms. This might also mean a limited possibility for educators' engagement with NOS tenets during science teaching. In turn, it may result in the learners' inability to achieve the desired NOS understandings. Abd-El-Khalick and Lederman (2000) and Khishfe and Abd-El-Khalick (2002) argue that an explicit teaching approach is more effective than an implicit teaching approach in improving learners' understanding of NOS.

The predominantly implicit and naive categorization of the representations of NOS in the three textbooks is illustrated in excerpts from the textbooks given in Table 4.3. An example is a statement from *Hands-on Science,* which reads: "We can't see gravity, yet we know it is there. We can see the effects of gravity – a glass falling off a table or a raindrop falling to the ground" (p. 24).

Table 4.3: Examples of exemplary excerpts in textbooks corresponding to the categories assigned to the target NOS

NOS aspect	Category	Example of representation
1. Empirical	3	Later in the 19th century and in the early 20th century scientists investigating fossils … made some interesting discoveries. They noticed that there were the remains of the same kind of animals and plants on continents that are now separated by huge oceans. … these fossil finds supported the idea that the continents had once been joined. (ST, p. 144)
	1	Activity 2: Investigate whether we need light to see things. (ST, p. 2). See Appendix B
2. Observation vs. Inference	3	Activity 3: Investigate weathering in your environment. (ST, p. 154). See Appendix B
	1	We can't see gravity, yet we know it is there. We can see the effects of gravity – a glass falling off a table or a raindrop falling to the ground. (HOS, p. 24)
	1	The first scientific description of this volcano (Oldoinyo Lengai) was by G. A. Fischer in 1883. He observed smoke rising from the summit. (SO, p. 22)
3. Creative	3	Dinosaurs present during the Mesozoic era became extinct possibly because of a change in climate … approximately 65 million years ago. The change in climate was probably caused by a huge amount of dust that … blanketed the earth for many years, cutting off sunlight and causing a severe drop in temperature. (ST, p. 111)
	1	Atoms have a nucleus, which is made of protons and neutrons. (HOS, p. 45)
4. Tentative	3	Then, in the 1960's, new information was discovered about the sea floor. Scientists used this to develop a convincing theory about how the continents change their position. This theory is called theory of plate tectonics. (ST, p. 144).
	1	Before it was generally accepted that the earth moves around the sun, most people believed that the earth stood still while the sun moved. (HOS, p. 129)
5. Theory-driven	3	Dinosaurs present during the Mesozoic era became extinct possibly because of a change in climate caused by a collision between the earth and a large meteorite approximately 65 million years ago. This change in climate might have had an effect on the vegetation on which the dinosaurs fed. (ST, p. 111).
	3	Why does the climate change? Scientists are not completely sure, but several theories have been accepted. One theory is that the sun's radiation has not been constant … during the last 5 million years. . . The second theory suggests that the earth's orbit changes. (HOS, p. 143)
6. Social and cultural embedded-ness	3	His (Darwin) book (*The Origin of Species)* has been important in helping scientists understand biodiversity and how species evolve. Some groups of people do not accept the theory of evolution for religious reasons. (ST, p. 106).
	3	Most scientists in Wegener's day disagreed with his idea because they were so different from the existing and accepted theories. The theory of continental drift was accepted long after Alfred Wegener's death in 1930. (SO, p. 16)
	1	Darwin and Wallace's ideas were made public at the same time at the Linnean Society of London. Darwin is usually given the credit for the theory of natural selection because he

		provided a huge amount of evidence to back up the theory. (HOS, p. 21)
7. Laws and theories	3	One of the great ideas in science is the theory of natural selection. This theory helps us to explain how species have come to be adapted to the environment in which they live… The theory of evolution and natural selection is not a belief system, like a religion, but is simply a framework of ideas that help us to explain things that have been found and observed in nature. (HOS, p. 20)
	3	Scientists have proposed theories in an attempt to explain how biodiversity came about. Natural selection or survival of the fittest is one of these theories. (SO, p. 104)
	1	Scientists used these findings to develop the theory of plate tectonics. This theory states that the earth's crust is made up of huge plates that move (ST, p. 145).

Codes: *Science Today* (ST), *Spot-On* (SO), *Hands-on Science* (HOS)

Such a statement seems to allude to a naïve view of NOS. To suggest that gravity is actually there but cannot be seen is to hold a realist but rather naïve view of NOS. It is opposed to the constructivist and more acceptable idea that gravity is a construct created by the scientist to explain what is observed. At the same time a few statements in the textbooks can be described as informed, for example:

> Why does the climate change? Scientists are not completely sure, but several theories have been accepted. One theory is that the sun's radiation has not been constant … during the last 5 million years... The second theory suggests that the earth's orbit changes [Hands-on Science, p.143].

The excerpt above alludes to the idea that scientific theories are suggestive and tentative explanations and that known scientific knowledge is never absolutely certain. This quotation can be described as implicit but demonstrating an informed view (rubric: category 3). Literature on NOS views (Crumb, 1965; Jungwirth, 1972; Meichtry, 1992; Lederman, 1992) has consistently shown that learners (and educators) have naïve views of NOS even when there are both curricula and research interventions intended to improve their views. Abd-El-Khalick and Lederman (2000) are of the view that NOS needs to be explicitly addressed in order to redress the naïve views held by both learners and educators. The data in Tables 4.1 and 4.2 appear to show that the three selected textbooks do not have excerpts that are targeted to explicitly teach learners about NOS. Most of the representations are both implicit and naïve.

4.3 Conclusion

In this chapter, I presented and discussed the results of the analysis of the representations of NOS in the selected science textbooks. The results showed the tenets of NOS that seem to be preferred or easier to present. For each of the targeted NOS tenet that was presented, the ideas presented about the tenets of NOS were highlighted. Overall, the three textbooks presented NOS in an implicit and naive manner. However there are scattered instances of explicit and informed representations of NOS. In Chapter 5, I present and discuss the results of the analysis of representations of IKS.

Chapter 5

Results and Discussion for IKS Representations

5. Introduction

In this chapter, I present and discuss the results of analysis of IKS representations in the selected textbooks. Presentation of the results followed the order of the research questions for IKS given in Chapter 1. These research questions are:

3. What ideas about IKS are included in Grade 9 Natural Science textbooks?
4. How are IKS ideas presented in Grade 9 Natural Science textbooks?

5.1 Ideas about IKS included in the three Grade 9 Natural Science textbooks

Each textbook was analyzed for inclusion and presentation of IKS for each of the chosen IKS pillars, which are:

- Legends and myths
- Indigenous technology
- Indigenous social life
- Indigenous knowledge of the natural world.

The discussion of the results of the analysis of the textbooks is done focusing on the selected textbooks collectively. Analysis of the three textbooks for the presentation of IKS ideas revealed that generally, inclusion of IKS ideas in science textbooks was minimal. Table 5.1 shows some excerpts of IKS representations from the three selected textbooks.

Science Today presented a total of six excerpts on IKS, five of which could be categorized under indigenous social life and only one on indigenous technology. The textbook seems not to have included excerpts that presented other two pillars of IKS. *Hands-on Science* presented only one excerpt in the entire book and it was categorized under IKS pillar of indigenous technology. According to the analysis, other IKS pillars were not presented at all. *Spot-on* also had only 3 excerpts in the three IKS pillars. The analyzed textbooks seemed not to have any representation on IKS pillar, “indigenous knowledge of the natural world.” Collectively, the three analyzed textbooks presented a total of 9 IKS representations.

Table 5.1: Examples of IKS excerpts in the analyzed textbooks with their corresponding categories of representations

Textbook	IKS facet	Categories of representations	Excerpt(s) presented
Science Today	Indigenous social life	1; 3	Most cultures have various rituals and practices to be followed during pregnancy and birth (p. 104)
	Indigenous social life	1; 3	Case Study: Pregnancy and birth in Tibetan culture (p. 125)
	Indigenous technology	1	Traditional homes in our country use thatch and thick mud walls (p. 179)
Hands-on Science	Indigenous technology	1; 3	In rural India, a traditional bio-fuel that is still used today is dried cow dung (p. 117)
Spot-On	Legends and myths	3	The *Maori* legend of volcanoes [caption of a legend on volcanoes] (p. 23)
	Indigenous technology	1; 3	The paints were used to make drawings on the wall of dwellings and in rock shelters and caves, such as those made by the *San and Khoi* people (p. 35)
	Indigenous technology, indigenous social life	3	Traditional medicine [used by the Zulus] and biodiversity [caption of a case study] (p. 109).

It seems that the analyzed textbooks put forth contradictory ideas about IKS directly or indirectly. Firstly, some excerpts related to IKS presented the idea that indigenous people are homogeneous. In *Science Today* (p. 179) part of a statement that reads, "Traditional homes in our country use thatch and thick mud walls." This statement does not specify the communities that prefer such homes. This kind of idea about IKS is referred to as "essentialism." Gandhi (1998) cited in Ninnes (2000) describes essentialism as a way of considering indigenous people as homogeneous. This approach ignores the diversity within the indigenous communities and it is stereotypic. This perception limits the ways in which the indigenous identities can be constructed. Such stereotypes may perpetuate the idea that there is no diversity among indigenous people but that there is only one culture or common cultural practices in indigenous communities. On the contrary, *Science Today* (p. 125) used a case study to explain pregnancy and birth in Tibetan culture. The case study specifies the cultural practice of the specific community.

At the same time, the selected textbooks referred to knowledge of specific indigenous communities or selectively used modifiers (some, most) to avoid the essentializing approach. The following excerpts show how each of the analyzed textbooks acknowledge the diversity in indigenous communities. *Spot-On* presented: "The Maori legend of volcanoes" (p. 23). *Science Today* has a sentence that says, "Most cultures have various rituals and practices to be followed during pregnancy and birth" (p. 104). *Hands-on Science* has a phrase on page 117: "In rural India, a traditional bio-fuel that is still used today is dried cow dung."

Another idea that is prominently presented across the three selected textbooks is that indigenous people or indigenous practices are 'traditional'. Ninnes (2000, p. 612) argue that "the use of 'traditional' is intended to prescribe elements of authenticity to particular indigenous identities." Literature (McConaghy, 1998) has shown that prescriptions of identities may sometimes be used as a means of controlling indigenous people, and as such might be viewed as a form of cultural imperialism. While *Spot-On* makes use of the word(s) 'traditional' and/or 'tradition', it sometimes locates the traditional communities by using or including descriptions such as "*traditional medicines used mainly by the Zulu*." Such use of descriptions embraces the reality that indigenous practices are diverse. The following passage is an extract from *Spot-On* and sheds light on some of the practices of the indigenous *Zulus*:

> More than 1 020 plant and 150 animal species are used for traditional medicine in Kwa-Zulu Natal, of which 45 plant species are sold in large volumes in the markets. …. Traditional medicine is deep rooted in *Zulu* culture and is unlikely to be replaced by western medicine [Spot-On, p. 109]

It also appears that the selected textbooks use present tense in the excerpts that relate to indigenous practices or knowledge. An example from *Hands-on Science* is stated: "In rural India, a traditional bio-fuel that is still used today is dried cow dung" (p. 117). In this instance, the use of present tense may be indicating that the indigenous practice is still extant in the relevant communities. Ninnes (2000, p. 613), affirms that "the use of present tense indicates that practices and beliefs are extant; and implies that multiple knowledge and interpretations of reality are possible in contemporary society." Such affirmations may indicate that there are various worldviews that may offer varying interpretations and explanations of ways of knowing in general.

In an attempt to include the variety of IKS ideas in the science textbooks, the excerpts or examples present contradicting locations of indigenous practices. For example, an extract from *Spot-On* states:

1. The paints were used to make drawings on the wall of dwellings and in rock shelters and caves, such as those made by the *San and Khoi* people (p. 35)

2. More than 1 020 plant and 150 animal species are used for traditional medicine in Kwa-Zulu Natal, of which 45 plant species are sold in large volumes in the markets. …. Traditional medicine is deep rooted in *Zulu* culture and is unlikely to be replaced by western medicine (p. 109)

Another extract in *Hands-on Science* is phrased:

3. In rural India, a traditional bio-fuel that is still used today is dried cow dung (p. 117)

The first statement locates the indigenous practice in the past whilst the last two statements locate it in the present. As alluded to in the preceding paragraph, Ninnes (2000) argues that the use of present tense indicates that indigenous beliefs and practises are extant. However, Ninnes views the use of past tense in describing indigenous beliefs and practises and locating them to the past. Contradicting locations of IKS may induce cognitive conflict for science textbook users (learners and educators). That is, it may cause confusion as to whether IKS is extant or not.

5.2 How are IKS ideas presented in selected Grade 9 Natural Science textbooks?

Table 5.1 shows the identified categories of representation for each of the targeted IKS pillars for each textbook. The categories were allocated using the categories of representations discussed in Chapter 3. Each category differentiates the representations for each of the target IKS pillars. The rubric is:

- 4 = Explicit and informed representations
- 3 = Implicit and informed representations
- 2 = Explicit and naïve representations
- 1 = Implicit and naïve representations

- 0 = IKS aspects not addressed or no IKS representations

It was indicated earlier in this chapter that there seems to be generally few IKS excerpts in the three analyzed textbooks collectively. Examples of the identified excerpts are also shown in Table 5.1.

As indicated in the table, the excerpts in each of the analyzed textbooks are categorized in 1 and/or 3 for the category of the representations. These categories imply that some excerpts convey implicit messages which are both naïve and informed. It appears that IKS representations in the analyzed textbooks do not necessarily target IKS pillars. The categories obtained may imply that the representations in the selected textbooks may not provide learners with opportunities for discussions of the targeted IKS pillars. As with NOS, lack of explicit IKS excerpts in science textbooks might pose a challenge for educators willing to engage with IKS aspects during science teaching. This, in turn, may directly result in the learners' inability to achieve the desired IKS understandings. It need not be over-emphasized that an explicit teaching approach is more effective and preferred than an implicit teaching approach in improving learners' understanding of concepts (Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002)

The implicit/naïve or implicit/informed category of representations of IKS in the three textbooks is illustrated with excerpts from the textbooks given in Table 5.1 above. For example, consider this statement in *Science Today* (p. 179): "Traditional homes in our country use thatch and thick mud walls, which are good insulators." This statement presents an implicit and naïve representation of IKS. It does not seem to identify the indigenous communities that prefer the use of thatch roofed and mud homes. Another statement from the same textbook, *Science Today* (p. 104) says; "Most cultures have various rituals and practices to be followed during pregnancy and birth." This statement may also be described as naïve. It seems naïve to suggest that diverse practices occur only during pregnancy and birth. It would be interesting and preferable if the textbooks suggested other rituals that are practiced in indigenous communities. It may be possible that rituals are performed for other social occasions also. However, the statement acknowledges the differences in indigenous practices by using the modifiers.

An excerpt in *Spot-On* reads: "The paints were used to make drawings on the walls of dwellings and in rock shelters and caves, such as those made by the *San and Khoi* people (p. 35). The excerpt locates the practice of drawing on walls and rocks in the past and assigns it to a particular indigenous community. There seems to be no attempt to show that the practice is still extant and which other communities practice it. The same can be said for the case study on "Traditional medicine and biodiversity" (*Spot-On*, p. 109). It appears that there is no evidence to establish whether there are other indigenous communities that prefer the use of traditional medicine like the *Zulus*. However, the latter excerpt identifies the indigenous community and its preference and therefore avoids essentialism. This approach embraces the uniqueness of IKS in the indigenous community.

5.3 Conclusion

In this chapter, I have presented and discussed the representation of IKS in the three analyzed textbooks. The results reveal that each textbook presented limited excerpts and ideas through its representations of IKS. Collectively, the textbooks presented a variety of ideas. Analysis of the excerpts for determining the nature of the approach used revealed that IKS excerpts seem to be presented mostly in an implicit and naïve manner and to a lesser extent in an implicit and informed manner. There appeared to be no indication of an attempt to include excerpts that are explicit and informed. The low frequency counts of the excerpts may imply that it is still a challenge to include or integrate the representations from other worldviews (IKS in this instance) in science textbooks. In chapter six, I conclude my study. I also discuss the implications of the findings and make recommendations for future research.

Chapter 6

Conclusions, Implications and Recommendations

6. Introduction

In this chapter, I conclude the study and summarize the main findings. I also discuss the implications of the results. Finally, I give recommendations for stakeholders in science education and research.

6.1 Conclusions

6.1.1 NOS and IKS ideas included in Grade 9 science textbooks

Firstly, my study reveals that there is limited inclusion of NOS ideas in the three selected science textbooks. It was found that each science textbook that was analyzed included a variety of ideas on the empirical tenet of NOS and the difference between observation and inference tenet of NOS. The other remaining tenets of NOS that were targeted were presented minimally or not presented at all. Expressions of the empirical tenet of NOS dominant in the selected textbooks include: 1) scientists do experiments and investigations to collect data needed to develop scientific knowledge; and 2) scientists make observations as part of their investigations.

While the selected textbooks included the empirical tenet of NOS in their content, they fail to explain how scientists gather evidence. *Science Today* and *Spot-On* portrayed the "Scientific Method" as a guiding principle when doing experiments and investigations. Presenting the "Scientific Method" as a characteristic method that is followed by all scientists masks the complex and subjective nature of the scientific process and misrepresents the scientific enterprise. Interestingly, *Hands-on Science* was silent about the existence of the "Scientific Method".

Also, included in the analyzed textbooks was a variety of ideas about the difference between observation and inference tenet of NOS. For example, the excerpts show that scientists make observations of natural phenomena and they conduct experiments. The scientists also observe patterns and shapes and make inference where possible. However, the excerpts in the selected textbooks are not presented in ways that would lead learners to understand that there are differences between observation and inference.

In general, my study revealed that inclusion and presentation of NOS in selected science textbooks is aligned to a large extent with the findings of Chiapetta et al. (1991); Lumpe and Beck (1996) and Abd-El-Khalick et al. (2008), who found that for their textbook samples, NOS was not used as an organizing theme for science education. The need to use NOS as an organizing theme during science teaching and learning is emphasized by science curriculum documents (e.g. AAAS, 1990; NRC, 1996; NCS, 2003). Prior research showed that using NOS as an organizing theme in teaching and learning can develop learners' scientific literacy. The failure to include representations that are related to NOS in science textbooks is evidence that the tenets of NOS are given less attention in science textbooks than is advocated by science reform documents. There are, however, activities in the selected textbooks that focus on scientific investigations; but they do not give a coherent or logical treatment of tenets of NOS. The activities do not show the relationship between the various NOS tenets and appear mostly to be treating each in isolation. This may be indicating that there is a challenge associated with inclusion of the tenets of NOS in South African school science textbooks.

My study also analyzed IKS ideas included in the selected Grade 9 science textbooks. The ideas were categorized into the four (4) IKS pillars listed in Chapter 3. I found that IKS ideas included in the selected science textbooks were minimal. Some of IKS ideas that were included in the textbooks were contradictory. For example, some of the ideas presented indigenous communities as homogeneous whilst other ideas seemed to indicate that indigenous communities are diverse. There are also ideas that tend to acknowledge the existence of IKS in the present while others locate IKS in the past. The textbooks tend to present some of the practices in communities as indigenous without justification. For example, the use of mud walled and thatch roofed houses as shelter and cow-dung as fuel is presented as a preference of the indigenous communities.

6. 1.2 The category of representations of NOS and IKS presented in Grade 9 textbooks

NOS ideas in the three selected textbooks are presented mostly in an implicit and naïve manner. I also noticed that most of the ideas are related to the empirical tenet of NOS and the difference between observation and inference tenet of NOS. Representations of other remaining five tenets of NOS were few and mainly in an implicit and naïve manner. There is, however, a scatter of implicit and informed presentations of NOS ideas in the selected science textbooks.

For IKS, the identified excerpts were presented in an implicit/naïve and implicit/informed manner as opposed to the preferred explicit and informed manner. Implicit and naive representations in science textbooks may imply that the learners are likely to continue to be challenged with respect to achieving the desirable understanding of IKS.

6.2 Implications

In the first instance, I need to indicate that the results of my study may not be generalised due to the size of the sample. However, my study seems to indicate that the authors of the selected science textbooks failed to respond to the goals of the Natural Science Policy Statement (NCS) on inclusion of NOS and IKS. Deliberate attention needs to be given to the integration of NOS and IKS in science textbooks that are used in the science classrooms of South Africa. There is a need to include more representations of both NOS and IKS in an explicit and informed manner. This is important given the centrality of textbooks in science learning in South Africa. Globally, textbooks are the main learning resource materials in the majority of classrooms (Chiappetta et al., 1991, 1993; Chiappetta & Fillman, 2007; Stoffel, 2007; Wang, 1998), including in South Africa. There is a need for government of South Africa to assess and evaluate textbooks for their compatibility with the NCS.

It also appears that both NOS and IKS were not planned for or assessed in the analyzed textbooks, which contributed to a lack of explicit representations for both NOS and IKS. Most of the representations of NOS and IKS in the selected textbooks did not have prompts that would give the learners the chance to engage in discussions or guided reflections about NOS or IKS. It is important for authors to provide activities in the textbooks that give learners opportunities to reflect on NOS and IKS. The findings of this study imply that there is still a lot of work to be done in order to bring NOS and IKS into South African science classroom. As noted, the analyzed textbooks presented a variety of NOS ideas in two of the seven targeted NOS tenets mainly in an implicit and naive manner. Loading the learners with messages without providing opportunities for engagement may delay learning about NOS and/or IKS. This might explain why research continues to show that learners have misconceptions about NOS. Lack of IKS ideas in science textbooks may suggest that IKS has no explanation for naturally occurring phenomena. There must be advocacy, therefore, for inclusion of both NOS and IKS in science textbooks.

6.3 Recommendations

It may not be easy to recommend ways of improving the integration of NOS and IKS in Grade 9 science textbooks. Abd-El-Khalick et al. (2008) found that there is a consistent decrease of NOS representations in new editions of science textbooks that they analyzed. That is, the older the science textbook the more occurrences of NOS representations (ideas) it has. I acknowledge that their finding may not be representing the South African situation. However, I recommend that the science textbook writers should learn from research so as to improve the quality of textbooks. It might be necessary that the science textbook writers take up courses on NOS that will enhance and broaden their understanding of NOS. Research (e.g. Akerson et al., 2000) has shown that people who have never been exposed to NOS lack the knowledge of how it may be presented in a way that can be understood.

Ninnes (2000) showed that it is possible to include representations of IKS in a variety of ways in the science textbooks. My study adopted Ogunniyi (2007) definition of IKS which acknowledges the diversity of experiences of the varying indigenous groups. Snively and Corsiglia (2000) alerted of the oral nature of indigenous knowledge. It is recommended that the authors form partnerships with indigenous communities and gather indigenous knowledge from them since IKS is primarily not documented. Through such partnerships the authors may be exposed to the reality that IKS is unique to each community. They may also understand the dynamics in indigenous cultures. Research articles and written records of IKS may also be consulted (if they are accessible). Some indigenous communities have cultural villages which they use as tourist attractions. This is where their rich heritage is preserved. Such places may be visited to get an idea of the practices of a particular indigenous community. There are also institutions which have been established during this democratic dispensation solely for the preservation of and/or research about IKS in general.

I also recommend that educators and learners should use a wide variety of textbooks [and other resources] during the science lessons. This study has shown that each science textbook may contain a limited amount of NOS and IKS ideas, as well as limited science content. However, a variety of science textbooks may expose a collection of NOS and IKS ideas much better.

I further recommend that research in the field of NOS and IKS representations in textbooks be intensified. This will be an added effort and contribution to the envisaged integration of other worldviews in the school sciences. As indicated in earlier sections, the size of the sample of my study does not allow for generalization of the findings. This study may be modified in a variety of ways for further research, some of which are listed below:

- The sample may be increased at the same or different grade.
- Another study may focus on Natural Science textbooks of any grade at GET level or Physical and Life Sciences textbooks at FET level.

6.4 Conclusion

This study analyzed the representations of NOS and IKS in selected South African Grade 9 Natural Science textbooks. The analysis was prompted by the transformational issues in South African education of including IKS and other worldviews in the teaching of the sciences. Specifically for this project, analysis was made for inclusion and the categories of representations of NOS and IKS in the selected Grade 9 Natural Science textbooks. Local and international literature related to the study was reviewed. NOS and IKS analytical frameworks were used for the analysis of the three selected textbooks. NOS analytical framework adopted Lederman’s (1999) seven tenets of NOS and IKS analytical framework adopted Ninnes’ (2000) four pillars of IKS. The results of the analysis were presented and discussed. My findings in this study are that the empirical tenet of NOS and the difference between observation and inference tenet of NOS were fairly represented in the selected textbooks, but mainly in an implicit and naïve manner. The other five remaining targeted tenets of NOS were a few scatter of implicit and naïve representations. For IKS, the selected textbooks had a few excerpts which were a combination of implicit/naïve and implicit/informed representations, but they presented a variety of IKS ideas. The frequencies of the category of representations for NOS were mainly in the form of implicit/naïve presentation of NOS tenets. For IKS, collectively the analyzed textbooks had few representations. Generally, the analyzed textbooks had mainly implicit and naïve representations of NOS and IKS.

The findings of my study imply that a lot of effort must be put into finding alternative ways of integrating NOS and IKS in school science. For now, it appears that some of the science textbooks have not responded to the curricular mandate. However, in the meantime, the science education community must explore ways of encouraging the science textbook authors to bring NOS and IKS in the science classroom. Unfortunately, the supposedly alternative ways of integrating NOS and IKS in school science, do not form part of my study. I made recommendations to science textbook authors on how they may improve the inclusion of the representations of NOS and IKS in the science textbooks. Finally, I recommended to science education community the direction for further research on textbook analysis for representations of NOS and IKS.

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APPENDIX A

Grade 9 Natural Science textbooks used in the analysis

Barker, K., Cohen, S., Doubell, S., Mgoqi, N., Mkhwanazi, V. & Mzolo, P. (2006). Science Today Learner's Book: Grade 9. Cape Town: Maskew Miller Longman (Pty) Ltd.

Jones, R., Thomas, R. & Johnston, P. (2006). Hands-on Science Learner's Book: Grade 9. Cape Town: Juta Gariep.

Soobramoney, B. & Vermaak, M. (2006). Spot On Natural Science Learners' Book: Grade 9. Sandton: Heinemann Publishers (Pty) Ltd.

APPENDIX B

Examples of textbook activities

Activity 6: Revise forces exerted by magnets (Science Today, page 22)

You will need: two bar magnets:

1. Read the (above) information about magnetic forces.
2. Take two bar magnets and first hold them so that the two north poles are pointing towards each other. What do you notice?
3. Now hold the magnets so that the North Pole on one magnet points towards the south pole of the other magnet. What do you notice?
4. From your observations, describe the forces magnets exert on each other.

Activity 2: Investigate whether we need light to see things (Science Today, page 2)

1. Read the 'How to' box on how to identify variables.
2. Plan and design an investigation to prove that we need light to see things. Use the questions below to help you:

(a) What are your variables?

(b) What is your independent variable? How will you change this variable?

(c) What is your dependent variable? How will you measure this variable?

3. Conduct your investigation.
4. What can you conclude from this investigation?

Activity 3: Investigate weathering in your environment (Science Today, page 154)

1. Read information on pages 152 and 153 on physical and chemical weathering.
2. Look around your neighbourhood for different examples of rock. It could be rock from the ground or rock used in buildings.
3. What kind of weathering do you think is taking place in these rocks?
4. Choose one type of rock to look at more closely.
5. Examine the rock for clues of physical or chemical weathering (or both).
6. Decide what kind of weathering is affecting the rock.
7. Draw a sketch of the rock showing how weathering is happening.
8. Share your findings with your group. If possible, show them the rock.

Activity 13: Think about how scientific theories change (Science Today, page 146)

1. Read section 5 on changing ideas about continental drift
2. Each person in your group should choose one of the time periods over which the theories were developed, mentioned in section 5.
3. Take it in turns to explain the ideas of how the continents moved during your chosen time period. In your explanation, give the broad idea, the evidence for it and any explanation for how the movement took place.
4. Once each person has explained their ideas, the other members of the group can ask questions and give their views about whether the ideas are accepted or not.
5. When you have all had a turn, you should each write one statement about what you have learnt about how scientific theories develop over time. Share your ideas with your group, and together write a paragraph using the ideas you all agree with.
6. Share these ideas with your class.