# THE REPRESENTATION OF THE NATURE OF SCIENCE IN SOUTH AFRICAN GRADE 12 LIFE SCIENCES TEXTBOOKS

**by**

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**MINOR DISSERTATION**

**submitted in fulfilment of the full requirements for the degree of**

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## ABSTRACT

This study examined the representation of the nature of science in South African Grade 12 Life Sciences textbooks using a conceptual framework developed by Chiappetta, Fillman and Sethna (1991a). The study investigated the extent to which South African Grade 12 Life Sciences textbooks exhibit the themes associated with the nature of science as an essential tenet in science education. The investigation primarily focused on the identification of the differences and commonalities exhibited by Grade 12 Life Sciences textbooks in terms of the coverage of the themes associated with the nature of science. These textbooks were essentially instructional resources that formed an integral part of the enactment of the National Curriculum Statement and the Curriculum and Assessment Policy Statement promulgated by the Department of Basic Education in South Africa. The investigation revealed a dismal depiction of the nature of science themes across the selected Grade 12 Life Sciences textbooks analysed. In particular, "Science as a body of knowledge" was given substantial coverage as compared to other concomitant themes. While considerable emphasis is placed on the significance of inquiry-based learning as a contemporary pedagogic approach, limited coverage was, however, given to "The investigative nature of science" and "Science as a way of thinking" as relevant themes required for meaningful enactment of inquiry-based learning. Science and technology play a pivotal role towards the fulfilment of societal and economic needs. Yet, the "Interaction among science, technology and society" was afforded limited coverage across the selected textbooks analysed. Implications for meaningful curriculum reform are discussed.

**Keywords:** Nature of science, National Curriculum Statement, Curriculum and Assessment Policy Statement, curriculum reform

**DECLARATION**

I declare that this minor dissertation, titled

***The representation of the nature of science in South African Grade 12 Life Sciences textbooks***

is my own work and that all resources that I have used or quoted have been indicated and acknowledged by means of complete references. It is being submitted for the degree of Master of Education at the University of Johannesburg. It has not been submitted before for any degree or examination at any other university.

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Themba Egnatius Masilela

October 2019

**DEDICATION**

This study is dedicated to current researchers, emerging researchers and indeed those who are aspiring to become members of the research community. I would like to express my deepest gratitude and heartfelt appreciation to my parents Lindiwe Masilela and the late Hendry Kunene who inspired me to be diligent, determined and dedicated to the academic journey undertaken.

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## ACRONYMS

| | |
|---|---|
| NOS | Nature of Science |
| NRC | National Research Council |
| AAAS | American Association for the Advancement of Science |
| OBE | Outcomes-Based Education |
| DOE | Department of Education |
| DBE | Department of Basic Education |
| NCS | National Curriculum Statement |
| CAPS | Curriculum and Assessment Policy Statement |
| PCK | Pedagogical Content Knowledge |

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# CHAPTER 1

## 1.1 Introduction

This Chapter reflects on the purpose of the study, background information and the nature of science (NOS) as a key construct investigated in this study. As accentuated by Abd-El-Khalick, Waters, and Le (2008), science textbooks remain instructional resources used to measure instruction and the outcomes of lessons in classrooms. Teachers heavily rely on science textbooks which may potentially contain erroneous scientific content and this predicament may hamper transference of scientific skills and knowledge to learners. Majority of teachers and learners hold naïve views about the essential features of the nature of science (Lederman, 2007). It is for this reason that this study analysed the representation of the nature of science in South African Grade 12 Life Sciences textbooks with a view to evaluate the extent to which they exhibit themes associated with the nature of science.

## 1.2 Background to the study

The active use of scientific inquiry is a key characteristic of meaningful science teaching. Teachers who incorporate inquiry during instruction inculcate within their learners an understanding that science is both a product and a process (Akben, 2016); Dailey & Robinson, 2016). Not only do learners acquire the fundamental knowledge and skills possessed by scientists, but they also come to understand the nature of science (Abd-El-Khalick, 2013; Akben, 2016). Many South African science teachers have a naïve understanding of scientific inquiry and are therefore unable to effectively teach authentic inquiry (Cavas, Holbrook, Kask, & Ramnikmae, 2013). As a result, these science teachers do not hold a holistic understanding of scientific inquiry and the nature of science (Lebak, 2015; National Research Council, 2000; Osborne, 2014). This reality can be attributed to the nature of traditional teacher professional training that commonly utilises the didactic-teaching approach (Miranda & Damico, 2015). In science teacher education training, inadequate attention has been given to how scientific inquiry processes are taught (Meyer, Meyer, Nabb, Connell, & Avery, 2013). It is often assumed that once teachers graduate from institutions of higher learning, they understand how to conduct scientific inquiry and can successfully transfer knowledge and skills to their learners. Hence, there is a critical need to synthesize a structure providing effective techniques promoting inquiry processes for learning at all levels.

The educational reforms towards inquiry-based science education globally have been entrenched by the National Research Council (1996) and American Association for the Advancement of Science (1989). The two institutions refined science curriculum by disseminating reports such as Benchmarks for Science Literacy (1993), National Science Education Standards (1996) and Science for All Americans (1996). These educational reforms are aimed at incubating inquiry-based approach that enhances the understanding of the nature of science in order to develop inquiry cognitive skills and scientific literacy. Lederman (2003) argues that majority of teachers and learners hold naïve views about the essential features of the nature of science and the mere teaching of the nature of science itself is ineffective to achieve conceptions of nature of science. Lederman (2007) further postulates that misconceptions regarding nature of science are commonly developed in the classrooms by both teachers and learners.

Scientific inquiry and NOS are largely viewed as two different entities and the purpose of current science seeks to amalgamate them. For instance, during instruction learners attain scientific inquiry through the activities provided by the teacher to help learners develop scientific knowledge. These activities involve conducting scientific investigations, constructing models and executing laboratory based practicals similar to scientists' inductions to validate formulated hypothesis and discussions using cognitive skills (National Research Council, 2012). Scientists and learners rely on observations and interpretations to formulate discussions and empirical explanations (American Association for the advancement of Science, 1989). The nature of science informs the conception of science knowledge such as differences between observations and interpretations, informed conceptions of tentativeness, distinction, and subjectivity between scientific theory and law, as well as the role of social and cultural values. According to Schwartz, Lederman & Crawford (2004), engagement in science inquiry alone may not promote learners understanding of the nature of science.

In-service teachers hold naïve conceptions of scientific inquiry and this shortcoming serves as a barrier which adversely affects the development of authentic inquiry (Cavas, Holbrook, Kask & Rannikmae, 2013). In addition, science teachers often lack holistic conceptualisation of scientific inquiry and the nature of science (Lebak, 2015; Osborne, 2014) originating from universities and teacher colleges where teacher professional training primarily relies on traditional didactic-teaching approach (Miranda & Damico, 2015). These teacher professional training programs provide little guidance on meaningful enactment of scientific inquiry and the nature of science (Meyer, Meyer, Nabb, Connell, & Avery, 2013).

The significance of textbooks in enhancing science teaching is well-documented. The prominence of science textbooks as instructional resources is captured by Abd-El-Khalick, Waters and Le (2008) who assert that in large classrooms, textbooks are primary indicators of what is learned and the instructional strategy utilised. Albach and Kelly (1998) stipulate that textbooks transform the curricular intentions into teachable instructional practices by reflecting the goals of science learning. These reflections include understanding the interrelationship of science, the nature of science, environment and society, and developing cognitive, inquiry and technological skills. The quality of textbooks influences the quality of instruction (Lemmer, Edwards, & Rapule, 2008). Swanepoel (2010) further explained that the accessibility of high quality textbooks is a crucial element in the successful implementation curricular improvements. The use of textbooks as instructional resources significantly informed science education reforms in South Africa. A reflection on the evolution of science education reforms in South Africa is provided in the next section.

### 1.3 Science education reforms in South Africa

The advent of democracy in South Africa resulted in several educational reforms. Curriculum 2005 which was predicated on the aims of Outcomes-Based Education (OBE) was introduced in 1998. The implementation of Curriculum 2005 represented a radical shift from teacher-centred approaches to learner-centred learning (Department of Education, 2002). Curriculum 2005 sought to redress historical injustices and imbalances bequeathed by the previous educational dispensation. The implementation of Curriculum 2005 was essentially a source of frustration to teachers as they lacked the pedagogical content knowledge (PCK) required for meaningful implementation of the curriculum itself (Department of Education, 2005). This fundamental challenge prompted educational curriculum reviews which culminated in the adoption of the National Curriculum Statement (NCS) in 2002 (Department of Education, 2002). The review of the National Curriculum Statement led to the promulgation of the Curriculum and Assessment Policy Statement (CAPS) in 2011 (Department of Basic Education, 2011).

The drive behind science education reforms in South Africa was informed by the need to accomplish scientific literacy among its citizens. Particular emphasis was placed on the development of learners' understanding of scientific knowledge, scientific inquiry and the nature of science (Department of Education, 2002). Furthermore, the introduction of scientific processes such as planning, conducting investigations, collecting data and interpreting variables was included in CAPS (Life Sciences) to foster the development of scientific inquiry. CAPS in its current form still adheres to the principles of NCS. For example, the development of scientific literacy is embedded within the activities learners are required to complete. As stipulated in the Curriculum and Assessment Policy Statement (Department of Basic Education, 2011), the specific aims for Grades 10 to 12 Life Sciences are:

> ***Specific Aim 1:*** *Knowing Life Sciences*
>
> *Involves knowing, understanding, and making meaning of sciences, thereby enabling learners to make many connections between the ideas and concepts. Making such connections makes it possible for learners to apply their knowledge in new and unfamiliar contexts. The process of acquiring a deep understanding of science is about more than just knowing a lot of facts. The scope of knowledge that learners should acquire includes knowledge of the process skills related to carrying out investigations.*
>
> ***Specific Aim 2:*** *Investigating Phenomena in Life Sciences*
>
> *Learners must be able to plan and carry out investigations as well as solve problems that require some practical ability. This ability is underpinned by an attitude of curiosity and an interest in wanting to find out how the natural world and living things in it work.*
>
> ***Specific Aim 3:*** *Appreciating and Understanding the History, Importance and Applications of Life Sciences in Society*
>
> *The third aim of Life Sciences is to enable learners to understand that school science can be relevant to their lives outside of the school and that it enriches their lives.*



A vast majority of South African teachers still rely on the traditional method underpinned by a teacher-centred science teaching approach. This approach is often adopted as an instructional strategy in the learning environment due to factors such as socio-economic, political and educational barriers. In addition, teachers rarely use inquiry-based teaching to meet the requirements of Life Sciences curriculum with the result that science concepts are taught as a means for preparing learners for examinations and not necessarily for application in real-life contexts. The summative assessments prepared by the Department of Basic Education are usually written quarterly. The routine of standardised quarterly testing strengthens the belief that learners should be taught scientific knowledge (knowing science) instead of developing scientific inquiry (doing science) on their own (Hamm, Cullen, & Ciaravino, 2013). In fact, a study by Ramnarain (2016) found that intrinsic and extrinsic barriers prevent South African teachers to develop pedagogical strategies to deliver effective teaching and learning. The intrinsic barriers identified include inadequate professional pedagogical knowledge such as pedagogical content knowledge, content knowledge, and knowledge of learners, education contexts, curricular knowledge and educational expectations. Extrinsic barriers include culture of the school, professional development, sufficiency of resources and time constraints that impede teachers from enacting inquiry-based instruction.

Textbooks remain significant instructional resources which are at the heart of science curriculum reforms in South Africa. The enactment of inquiry-based instruction requires teachers and learners to demonstrate adequate understanding of the NOS tenets. In view of this key practical consideration, this research study primarily focused on the analysis of South African Grade 12 Life Sciences textbooks for inclusion of the NOS. Driver, Leach, Millar and Scott (1996) posit that NOS is an essential component of scientific literacy. While advocacy for NOS has been irresistible in the science education community, there is some disagreement in the literature as to what it specifically entails (Laugksch, 2000). Schwartz, Lederman and Crawford (2004) contend that there is a satisfactory level of agreement on what NOS entails. Lederman (2015) classifies the basic tenets of the nature of scientific knowledge as follows: It is tentative (subject to change), empirically based (based on and/or derived from observations of the natural world), and subjective (involves personal background, biases and/or is theory laden); necessarily involves human inferences, imagination, and creativity (involves the invention of explanations); and is socially and culturally embedded. Two additional important aspects are the distinction between observations and inferences, and the functions of, and relationships between scientific theories and laws.



## 1.4 Problem statement and rationale

Majority of teachers and learners hold naïve views about the essential features of the nature of science and mere teaching of NOS is ineffective to achieve conceptions of NOS itself (Lederman, 2007). Lederman (2007) postulates that misconceptions associated with the NOS are commonly developed in the classroom by both teachers and learners. The National Research Council (2000) posits that teachers rely on traditional didactics approach that is aimed at learners' understanding of disconnected science content knowledge that does not develop cognitive skills such as critical thinking, reasoning, analysing and problem solving. Moreover, teachers need to emphasise fundamental features of NOS and learners will subsequently recognise and understand the scientific process themselves. However, this cannot occur since teachers have inadequate experience with scientific inquiry exacerbated by their naïve conceptions of NOS when developing scientific knowledge (Anderson, 2007).

The learner-centred approach should make provision for meaningful understanding of the nature of science as a key curriculum goal for science teaching (Department of Basic Education, 2011). However, NOS is an abstract and difficult construct for science teachers to enact in their classrooms. Majority of science teachers confuse NOS and scientific method (Ryan & Aikenhead, 1992). The use of quality textbooks as instructional resources is central to effective teaching and learning. The Curriculum and Assessment Policy Statement (Department of Basic Education, 2011) advocates that learners should acquire a conceptualisation of NOS as a key strategic imperative. It is envisaged that textbooks would provide meaningful guidance to teachers to adequately address this emphasis.

Research conducted on science textbooks used in other countries revealed that certain features of NOS are unsatisfactorily addressed (Abd-El-Khalick, Waters and Le, 2008); Chiappetta & Fillman, 2007). Abd-El-Khalick, Waters and Le (2008) analysed high school Chemistry textbooks used in the United States of America and ranked them poorly in their representations of NOS. McComas (2003) analysed Biology textbooks used in the United States of America and found that a clear distinction between laws and theories (aspects of NOS) was not apparent to enhance learners understanding of NOS. Provision of accurate and well-documented definitions with suitable examples to enable learners to understand NOS was recommended by McComas (2003). There is a prevailing paucity of research studies on the analysis of science textbooks for their inclusion of NOS within the broader South Africa context. Moreover, research on the depiction of NOS in South African science textbooks primarily focused on the analysis of Grade 10 Life Sciences textbooks and Grade 9 Natural Sciences textbooks (e.g., Ramnarain & Padayachee, 2015; Ramnarain & Chanetsa, 2016). Hence, there is a need for research to be carried out on the depiction of NOS in South African Grade 12 Life Sciences textbooks in order to fill this void.

The role of science textbooks as instructional resources required for improving the understanding of NOS tenets is especially crucial within the broader South African context. Studies on teacher conceptualisation of NOS in South Africa revealed that teachers have an insufficient conceptualisation of the NOS. A pilot study conducted by Dekkers and Mnisi (2003) in the Limpopo Province of South Africa found that most teachers surveyed hold common myths about NOS. A study conducted by Linneman, Lynch, Kurup and Bantwini (2003) in the Eastern Cape Province of South Africa attained similar findings.

According to Yager (1996), textbooks are intended to accommodate grade-level content and resources needed for the academic year. The school-based science textbooks have been utilised by most teachers to support their instruction (Schwartz, Lederman & Crawford, 2008). The major structural deficiency of current science textbooks is the predominant emphasis on knowing about science than investigating, assessing questions and natural phenomena and critical analytical skills. This grim reality is exacerbated by the adoption of instructional strategies that limit the development of learners' intellectual capabilities. Overall, science textbooks have routinely focused on low-order cognitive skills such as the acquisition of facts at the expense of critical problem solving skills such as assessing and application of the scientific concepts. Thus, teachers who exclusively depend on science textbooks for instruction often fail to sufficiently deliver lessons incorporating inquiry-based learning.

The enactment of CAPS for Life Sciences in the Further Education and Training Phase (Grades 10–12) (Department of Basic Education, 2011) represented an important paradigm shift from the previous National Curriculum Statement (NCS) (Department of Education, 2002). The NCS was characterised by a microscopic understanding of scientific literacy that portrayed science as a static body of knowledge. Biology syllabus obliged learners to learn portions of biological evidence that is regurgitated as part of summative assessments such as tests and examinations (Le Grange, 2008). Thus, Le Grange (2008) contends that Biology concentrated mainly on the study of vegetation and animal life form with no emphasis on fact and value. Mnguni (2013) describes this emphasis as the academic ideology that deals with training learners by transmitting discipline particular knowledge. As observed by Lederman (2007), the scientific insight represented by NATED 550 curriculum was out of sync with NOS tenets. The NCS for Life Sciences puts particular emphasis on learners' conceptualisation of NOS (Department of Education, 2002) and this emphasis resonated with the quest for meaningful understanding of NOS tenets. Despite robust NCS focus on the NOS, teachers received inadequate support to implement instruction and develop materials to facilitate authentic view of NOS. The teachers' inability to improvise curriculum resource material created a heavy reliance on the textbook as a primary resource for implementing the intended curriculum (Malcolm & Alant, 2004).

It is against this background that this research study primarily focused on the analysis of the representation of the nature of science in South African Grade 12 Life Sciences textbooks with a view to examine the extent to which they exhibit themes associated with NOS. The key findings of the study will therefore assist in the development and reconfiguration of science textbooks for integrating NOS, designing and implementation of NOS tenets, and building a knowledge base upon which teachers and textbooks authors can make strategic contributions towards meaningful curriculum reform. In addition, this study provides contextually appropriate recommendations for science teachers to implement when using science textbooks as instructional resources to enhance science teacher professional development. Furthermore, the study develops a realisation of the impact of implementing NOS tenets during instruction in Life Sciences classrooms to help teachers develop scientific skills and meaningful understanding of NOS. The findings of the study have the potential to initiate the much needed intellectual discourse on how science textbooks should be designed to meet the key goals of meaningful curriculum reform.

Accordingly, the following research questions were formulated:

- To what extent do South African Grade 12 Life Sciences textbooks exhibit themes associated with the nature of science?
- How do South African Grade 12 Life Sciences textbooks compare in the extent to which they cover themes associated with the nature of science?

## 1.5 Aims and objectives of the study

The aim of this study was to carry out a comparative analysis of the representation of nature of science in South African Grade 12 Life Sciences NCS and CAPS textbooks. The research study was underpinned by the following concomitant objectives:



- To analyse the depiction of NOS aspects in South African Grade 12 Life Sciences NCS and CAPS textbooks using a conceptual framework for textbook analysis?
- To identify differences and commonalities in the depiction of NOS aspects in South African Grade 12 Life Sciences NCS and CAPS textbooks.

## 1.6 Research design and methodology

This study adopted a qualitative document analysis approach. South African CAPS and NCS Grade 12 Life Sciences textbooks were analysed using a conceptual framework developed by Chiappetta, Fillman and Sethna (1991) underpinned by associated scoring rubric for textbook analysis developed by Abd-El-Khalick, Waters and Le (2008). I investigated the extent to which South African Grade 12 Life Sciences textbooks exhibit the themes associated with the nature of science as an essential tenet in science education. The investigation primarily focused on the identification of the differences and commonalities exhibited by Grade 12 Life Sciences textbooks in terms of the coverage of the themes associated with the nature of science. These textbooks were essentially instructional resources that formed an integral part of the enactment of the National Curriculum Statement and the Curriculum and Assessment Policy Statement promulgated by the Department of Basic Education in South Africa.

South African CAPS and NCS Grade 12 Life Sciences textbooks were identified and chapters and sections were selected for analysis of representation of the nature of science. The selection of the textbooks was based on the period during which NCS and CAPS were implemented. The selected textbooks essentially represented instructional resources utilised during the implementation of NCS and CAPS. The first 10% of pages for each textbook were examined to develop competence and familiarity with the use of the framework as recommended by Chiappetta and Fillman (2007). Furthermore, a sliding scale was applied based on the quantity of pages allocated per content area to calculate the content area found in each page (Chiappetta & Fillman, 2007). The strands that were examined constituted four core content areas, namely: Life at molecular, cellular, and tissue level; Life processes in plants and animals; Diversity, change and continuity; and Environmental studies.

Three CAPS Grade 12 Life Sciences textbooks and three NCS Grade 12 Life Sciences textbooks were analysed for depiction of NOS. As observed by Krippendorff (2004), these textbooks are extensively used as instructional resources in classrooms throughout South Africa. The three textbooks chosen for CAPS Life Sciences had the highest number of orders and they collectively constituted close to 75% of all book orders for Grade 12. Similarly, NCS Life Sciences textbooks chosen were the three most popular curriculum resources. The textbooks were analysed in two phases. In the first phase, representative samples of the textbooks were analysed to provide an outline of the themes covered in the textbooks. In the second phase of analysis, textbooks were scrutinised by focusing on units of analysis chosen using the framework validated during the first round of the analysis. Analysis specifically focused on complete paragraphs, questions and statistics, tables with captions, marginal remarks, and comprehensive steps to conduct an activity in a laboratory or inquiry activity. The framework was refined for purposes of organizing and collecting units according to classifications, formulating classifications, and relating the formed classifications to views presented in the research. A comprehensive scoring rubric developed by Abd-El-Khalick, Waters and Le (2008) was used for analysis. The score allocated to specific NOS elements within a textbook is based on an analysis of all materials relevant to that element within the scrutinised textual materials. Scores are provided as follows:

(a) 3 points = Explicit, informed, and consistent representation of the target NOS aspect: (i) explicit statements that convey an informed representation, (ii) consistency across the selected chapters or sections in addressing the target NOS aspect, and (iii) consistency in addressing other directly related NOS aspects.

(b) 2 points = Explicit, partially informed representation of the target NOS aspect: (i) explicit statements that convey an informed, but incomplete representation, and (ii) consistency across the selected chapters or sections in representing the target NOS aspect. An incomplete representation derives from the textbook materials remaining silent in terms of addressing other related NOS aspects that ensure a complete informed representation.

(c) 1 point = Implicit, informed, and consistent representation of the target NOS aspect: (i) an informed representation of the target NOS aspect could be inferred from the textbook materials (e.g., relevant explanations, activities, examples, or historical episodes lacking structured, reflective prompts or explicit statements), and (ii) absence of other explicit or implicit messages that are inconsistent with the inferred implicit representation.

### 1.7 Validity and reliability

A validated analytical framework developed by Chiappetta, Fillman and Sethna (1991) was used to analyse South African Grade 12 Life Sciences textbooks. The validity of the adopted rubric is rooted in conceptual and empirical knowledge. The NOS framework and elements targeted by the rubric have been emphasized in current science education reform documents and are central to developing functional levels of scientific literacy (National Research Council, 2012). The reliability of the results in this study was measured using Cohen’s kappa coefficient (κ) (Cohen, 1990). The coding agreement was established by calculating Cohen’s kappa coefficient to reach the level of inter-coder reliability. The agreement in interpreting coding was analysed as follows: the values of Cohen’s kappa larger than .75 imply excellent agreement; the values of Cohen’s kappa between .40 and .75 represent reasonable to good agreement; and values of Cohen’s kappa smaller than .40 imply fair to poor agreement. Cohen's kappa coefficient (κ) is a statistic which measures inter-rater agreement for qualitative (categorical) items. It is generally thought to be a more robust measure than simple percent agreement calculation as κ takes into account the possibility of the agreement occurring by chance.

## 1.8 Ethical considerations

Prior to collecting data for the research, I applied for the ethical clearance (Appendix A) from the Faculty of Education at the University of Johannesburg. Other ethical requirements pertaining to the execution of the research study were adhered to.

## 1.9 Structure of the minor dissertation

Consistent with the epistemological framework that underpins this research study, the breakdown in terms of the structure of the minor dissertation is provided below.

**Chapter 2** provides a review of relevant literature related to the study.

**Chapter 3** reflects on the research design and the justification of the research methods employed in this study.

**Chapter 4** provides the results emanating from the research study.

**Chapter 5** reflects on key findings, conclusion and recommendations arising from the study.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Introduction

This chapter provides the theoretical underpinnings of the research carried out in this study and a review of literature relevant to the study. A broad reflection on the nature of science as a key construct investigated in this study is provided coupled with a discussion of the significance of the role of science textbooks as instructional resources. A validated analytical framework developed by Chiappetta, Fillman and Sethna (1991a) is presented as an underlying theoretical framework which essentially serves as a research lens through which the representation of the nature of science in South African Grade 12 Life Sciences textbooks is analysed.

## 2.2 Nature of science

Lederman (2004) defines nature of science (NOS) as the "epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge or the development of scientific knowledge" (p. 303). The nature of science essentially encapsulates scientific knowledge, method and a way of conceptualising natural phenomena (Lederman, 2007. According to McComas and Almazroa (1998), NOS incorporates other disciplines apart from science such as sociology, philosophy, history and psychology which encapsulate the importance of science and the interaction of humans with science. The NOS is an individual and societal perspective that influences beliefs, opinions, and insights into conducting science investigations (Vhurumuku & Mokeleche, 2009). Vhurumuka (2010) asserts that NOS is premised on ideas and opinions that individuals possess about scientific knowledge and procedures and further cautions that NOS does not rely on the mastery of scientific skills and knowledge. There is thus a distinct understanding between NOS and the scientific process (Abd-El-Khalick & Akerson, 2009).

The NOS is largely regarded as an abstract and difficult construct in schools and has generally created fundamental challenges for science teachers in the classrooms (Ryan & Aikenhead, 1992). NOS demystifies how scientists explain natural phenomena as it distinguishes between observation and scientific conclusions, highlights how scientific concepts are subject to change, and describes how culture and society impact on science. McComas and Almazroa (1998) argue that NOS is significant in assisting the science teachers to identify scientific content in the curricula aligned with elements of NOS. Lederman (2004) postulated seven tenets of NOS, namely:

- Scientific knowledge involves human creativity and imagination
- There is a dissimilarity between observations and scientific conclusions
- There is a dissimilarity between scientific laws and theories
- Scientific knowledge is tentative
- Scientific knowledge is partially subjective
- Science is inclined by social and cultural elements
- Scientific knowledge is empirical based

Reflecting on NOS tenets postulated by Lederman (2004), Hanuscin and Lee (2009) posit that NOS is rooted in creativity and imagination as this element produces scientific knowledge that is informed by NOS. For instance, amalgamation of scientific observations, scientific conclusions, learner-centred activities, hands-on practical work and explanations engender a better understanding of science (Hanuscin & Lee, 2009). However, Vhurumuku (2010) adds that science cannot be achieved by following a single scientific procedure as the framework treats NOS and scientific inquiry as two separate entities that produce knowledge contributing to the body of science. Moreover, Vhurumuku (2010) stipulates that science content is beneficial in making knowledgeable decisions on societal and environmental crisis such as diseases, global warming, pollution, population, food security and so forth. The raging discourse about the nature of science underscores its significance. A reflection on the significance of the nature of science in science education is provided in the next section.

## 2.3 The significance of the nature of science in science education

Contemporary science education standards across the globe have put considerable emphasis on the significance of supporting students to become scientifically literate individuals (Lederman, Antink-Meyer, & Bartos, 2012). This notion is predicated on the fact that the development of an adequate level of understanding of the nature of science concepts remains one of the prerequisites required for scientific literacy (Allchin, 2014; Leung, Wong, & Yung, 2015; Van Dijk, 2014).The purpose of teaching NOS in schools is to create scientifically literate learners (Donovan-White, 2006). Teachers need to make the elements of NOS part of classroom instruction (Hanuscin, Lee & Akerson, 2010) in order to enable learners to make informed decisions about the nature of science (Lederman, 2003). According to Lederman (2003), teachers do not give due consideration to NOS tenets when preparing for activities, investigations, practical worksheets and lessons in science. Teachers with professional resilience to include NOS in science classrooms help learners develop deeper interest in science (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2001). Lederman (2003) posits that teachers' understanding of NOS does not influence classroom instruction in science education. The interrelation among teachers' values and beliefs, learners' cognitive development and classroom instruction in science education remains significant (Lederman, 2003). Teachers with good understanding of NOS help learners to utilise scientific investigations to learn science. This key attribute serves to inspire learners to be reflective participants in their own learning (Vhurumuku, 2010). Clough (2006) argues that teachers with a good understanding of NOS are required to assist learners develop scientific investigations skills. I argue that if teachers do not hold plausible and informed conceptions of NOS, they will not be able to create and deliver meaningful lessons that are responsive to the tenets of NOS. My view is informed by the critical need to foster teacher professional identity in relation to meaningful enactment of inquiry-based learning as a contemporary pedagogic approach. The development of teacher professional identity in this regard would certainly invoke teachers' conceptions of the nature of science as an essential tenet in science education.

## 2.4 Teachers' conceptions of the nature of science

A research study conducted by Jain, Lim and Abdullah (2013) revealed that pre-service teachers perceived science as about truth and scientific ideas are proven facts with certainty. Lederman (2004) emphasises the need for teachers to have a good understanding of NOS and the ability to assimilate it with scientific inquiry during instruction. In support of this notion, Donovan-White (2006) implores teachers to employ instructional strategies that encourage the development of NOS in the science classroom. Lederman (2004) argues that science teachers are perceived to possess knowledge and skills needed to implement effective learning. However, Lederman (2004) recommends that teachers ought to attend continuing teacher professional development programs to improve their knowledge and scientific skills in order to advance learners' understanding of NOS and scientific literacy. Majority of teachers in South Africa hold naïve conceptions of NOS and this predicament is perceived to stifle teachers' ability to create inclusive interactive lessons and activities that enhance learners understanding of NOS (Lederman, 2004). Thus, teachers are hesitant to critically reflect on their own teaching in order to identify challenges associated with the teaching of science concepts. Teachers' naïve conceptions of NOS may potentially result in learners developing misconceptions (Clough, 2006).

The objective to develop a better understanding of NOS in practising science teachers is significant to improve the science reforms in South Africa (Abd-El-Khalick, 2012). Furthermore, Abd-El-Khalick (2012) reiterates the centrality of NOS development in delivering science content. It is envisaged that the centrality of NOS development in delivering science content can encourage the development of scientific literacy, inquiry-based teaching and learning and NOS (Monk & Osborne, 1997). Mock and Osborne (1997) advocate that science teachers should target to focus on the history of scientific knowledge during instruction. This can serve to accentuate the significance of empirical evidence of how and where scientific knowledge is invented and teachers will realise that scientific concepts are based on physical manipulation of evidence (Mock & Osborne, 1997).

The teacher training programmes provided by higher education institutions in South Africa must aim to develop teachers who are conversant with NOS by integrating teaching strategies that combine NOS tenets and inquiry-based teaching and learning in science classrooms. Most teacher training programmes provide teachers with theoretical science knowledge without opportunities for meaningful exposure to practical investigations resulting in teachers' inadequate understanding of NOS (Abd-El-Khalick, 2012). Matthews (1994) recommends that teacher training programmes must aim to include NOS tenets to create informed science teachers that are skilled and equipped to recognise misconceptions learners bring into science classrooms and to promote inclusive education. To this end, the enhancement of teachers' pedagogical content knowledge is paramount.

## 2.5 Nature of science and pedagogical content knowledge

Teachers feel overwhelmed by science content workload and this creates instructional discomfort in covering science content aligned to the NOS tenets (Peters, 2006). This constraint makes it increasingly difficult for teachers to identify advantageous and pertinent information as science knowledge is constantly refined and may pose difficulties to learners if such restructured knowledge is not always available (Lewis & Leach, 2006). The teachers' incompetence to engage learners in scientific inquiry activities results in learners being taught generic science that does not focus on achieving the basic tenets of science. Thus, science teachers are obligated to engage learners in inquiry-based teaching and learning activities (Harlow, 2009). To achieve the outcomes of inquiry learning, teachers should be competent in delivering content and knowledgeable in the subject matter to effectively deliver an inquiry-based lesson. Harlow (2009) argues that if the ability to conduct an inquiry activity is inadequate, this may eventually restrict the potential development of learners' cognitive ability. For instance, science teachers can use models to stimulate active learner engagement to facilitate the acquisition of the knowledge of NOS tenets.

Thye and Kwen (2004) evaluated the perspectives of pre-service teachers in Singapore and concluded that most experienced teachers in the study revealed inadequate understanding of NOS. This research finding does not augur well for effective teaching and learning as there is an interrelationship between learners' performance and teacher competency (Sadler, Sonnert, Coyle, Cook-Smith & Miller, 2013). Teachers need to improve their pedagogical content knowledge (PCK) in science education to ensure learner academic progress in science subjects in particular (Sadler et al., 2013). The teachers' pedagogical content knowledge should be enforced to deliver meaningful lessons that are aligned with inquiry and NOS to meet the specific aims of the curriculum (Hanuscin, Lee & Akerson, 2010). Teachers with well-developed PCK should be able to identify misconceptions that learners bring to the classroom and use pedagogic tools to address these misconceptions (Sadler, Sonnert, Coyle, Cook-Smith & Miller, 2013).

It is imperative for teachers to stimulate learners' interest in interacting with NOS and inquiry (Hanuscin, lee, & Akerson, 2010). In South Africa, it is debatable whether science teachers are competent to evaluate their learners' NOS understanding (Hanuscin, Lee & Akerson, 2010). According to Vhurumuku (2010), teachers' reflections on NOS and cross-examination of their personal views of NOS and science can assist teachers to reposition their views on science and literacy. To this end, teachers should be able to identify personal shortcomings and areas of difficulty experienced with scientific concepts (Vhurumuku, 2010).Teachers with well-developed PCK in science education tend to be conversant with current science trends in practice. These teachers are capable of applying useful ways to represent science concepts to facilitate meaningful conceptual understanding. The research study conducted by Dudu (2014) found that few teachers have informed views about NOS. A study conducted by Linneman, Lynch, Kurup, Webb and Bantwini (2003) with teachers in the Eastern Cape Province of South Africa also demonstrated that teachers hold naïve conceptions of NOS. Dudu (2014) contends that while South African science teachers have a reasonable understanding of science, they find it difficult to develop learners' scientific understanding as a result of their naïve conceptions of NOS. There is thus a critical need to train South African teachers on the enactment of NOS with a view to inculcate scientific knowledge and inquiry-based skills required to develop a better understanding of scientific literacy. The accomplishment of this mission requires science educators to critically unpack the connection between the nature of science and scientific literacy.

## 2.6 Nature of science and scientific literacy

Rai (2018) alludes to the significance of the nature of science as an educational outcome in relation to curricular guidelines for school education within a clearly defined context. Clough (2011) stipulates four reasons for the inclusion of NOS in science teaching and learning. These reasons are: NOS inclusion encourages an interest in science among learners; promotes a curiosity among learners in activities and encourages learners to pursue prominent science careers; encourages greater involvement of learners in doing biological evolution; increases an understanding of concepts and assists learners to identify strengths and limitations of science, the influence of science in social decision-making and environmental crisis. Teachers' inadequate understanding of NOS may potentially stifle learners' meaningful involvement in scientific investigations to generate scientific knowledge (Schwartz, Lederman & Crawford, 2004). Once learners are involved in the process to understand NOS, they can be able to distinguish between the authenticity and restrictions of scientific knowledge (NRC, 1996). However, learners who are not engaged in the scientific process develop misconceptions and lack resilience to understand science (Schwartz, Lederman & Crawford, 2004). Scientific literacy is defined as the capability of learners to participate in issues that arise from the construction of science irrespective of NOS (Lewis & Leach, 2006). However, it is debatable to conclude that science provides sufficient knowledge and skills needed for learner cognitive development such as decision-making skills, logic and understanding of natural phenomena (Lewis & Leach, 2006).

Teachers ought to teach science that is aligned with NOS tenets by engaging learners in activities that will allow them to gain an indisputable view of NOS (Lederman, Lederman & Antink, 2013). Given the fact that involvement of learners in activities such as scientific investigations will improve the development of scientific literacy, it is thus significant that learners are involved in inquiry-based instruction to acquire a well-developed understanding of NOS. This can be achieved when science instruction is underpinned by careful planning and meaningful integration of the understandable and reflective aspect of science (Abd-El-Khalick, 2012). In South Africa, science teachers work in clusters to develop effective teaching skills and PCK. I argue that teachers with adequate understanding of NOS can be assertive professionals in the practice of science teaching. These teachers can also demonstrate ability to recognise science teaching resources aligned with NOS and correct misconceptions associated with the instructional material. The demonstration of envisaged professional competence in this regard would be predicated on the coherent utilisation of science textbooks as instructional resources.

## 2.7 The use of science textbooks as instructional resources

Textbooks are essential instructional resources for both teachers and learners. In particular, science textbooks are the primary source of scientific knowledge that learners draw on. McComas (2002) alludes to contradicting perspectives of sciences as “myths of science”. The prevalence of these contradictions can partly be attributed to the views teachers and textbooks authors hold on NOS which can be transferred to learners during instruction. If science teachers do not hold informed views about NOS, it would be increasingly difficult for them to identify misconceptions in science textbooks. Science teachers increasingly use textbooks when implementing the curriculum. Abd-El-Khalick, Waters and Le (2008) observed that in populated classrooms, a textbook becomes a centre that determines what has to be learned and which materials will be employed.

Science textbooks usually classify scientific knowledge, assist in scientific inquiry and contain activities that assist learners to understand NOS (Chiappetta, Genesh, lee & Philips, 2006). DiGiuseppe (2014) recommends structural changes in these textbooks to ensure coherent learner participation. Science textbooks play a crucial role in the improvement of the quality of science education across the globe as key sources of information and facilitates the acquisition of knowledge that assists learners to understand scientific literacy (Chiappetta, Fillman & Sethna, 1991b). A study conducted by McComas (2003) revealed that biology textbooks provided applicable information about scientific laws and theories and this can serve to encourage science textbook authors to align textbooks with NOS tenets to enable learners to acquire a meaningful understanding of NOS. (DiGuiseppe, 2013)

Chiappetta, Fillman and Sethna (1991b) perceive science textbooks as instructional resources aimed at providing learners with scientific and technological skills with a view to foster cognitive development of learners. More specifically, a study conducted by Chiappetta, Fillman and Sethna (1991b) on the examination of the depiction of NOS in chemistry textbooks showed particular focused attention on science as a body of knowledge as an NOS theme. Chiappetta and Fillman (2007) call for a consistent balance between science content knowledge and scientific inquiry in science textbooks. Given the fact that science textbooks are direct reflections and representations of science subject matter, science textbook authors must provide clear information that can assist learners in acquiring a meaningful understanding of NOS. Thus, it is imperative for science textbooks to incorporate NOS to facilitate the meaningful development of scientific literacy in science education. This key strategic imperative calls for the elimination of misconceptions in science textbooks.

### 2.8 Misconceptions in science textbooks

Chiappetta, Fillman and Sethna (1991b) posit that science teachers depend on textbooks for their teaching without realising that some textbooks contain inappropriate information about NOS. Most science textbooks present information as facts as opposed to science as a body of knowledge. As observed by DiGiuseppe (2013), science textbooks are not coherently arranged in terms of the layout of scientific phenomena and have a large quantity of excess information that is not related to NOS. The consequence of this structural deficiency associated with science textbooks is that learners master science terminologies and vocabulary without understanding the implication of those words and the importance of science (Chiappetta, Fillman & Sethna, 1991b).

Ruis (1988) claims that science textbooks used in classrooms do not provide a clear understanding of scientific concepts and activities to enhance learner understanding. In addition, the textbooks contain inaccurate scientific facts and colourful pictures (Ruis, 1988). Some science textbooks used in schools provide learners with superficial and insufficient explanations of science concepts leading to misconceptions about science. Textbooks ought to serve as essential resources for addressing misconceptions as teachers with naïve conceptions of NOS will find it increasingly difficult to demystify factual inaccuracies associated with scientific content (McComas, 2003). In a similar vein, the science textbooks used in South African schools have to adequately respond to this key strategic imperative.

### 2.9 The Life Sciences textbooks used in South African schools

Textbooks are useful in providing inclusive education (McKinney, 2005). South African Life Sciences textbooks introduce learners to abstract scientific concepts and terminologies from Grade 10 and this creates a learning barrier stifling meaningful development of informed understanding of NOS (McKinney, 2005). Life Sciences textbooks should stimulate learners' interest to do science and provide opportunities for involvement in inquiry-based activities to gain an informed understanding of NOS (Wababa, 2009). Lemmer, Edwards and Rapule (2008) examined the criteria used by 16 South African science teachers in identifying and evaluating science textbooks used at their schools and found that few participant science teachers excluded significant issues relating to NOS in science textbooks. They further found that the extent to which scientific concepts were addressed and the historical knowledge about science were largely ignored with science teachers choosing to utilise science textbooks with prescribed instructions. Swanepoel (2010) suggests that science textbooks should be used to improve and develop learners' understanding of science as the quality of science textbooks affects science teaching and learning. Ramnarain and Padayachee (2015) found that South African Grade 10 Life Sciences textbooks reflected skewed coverage of NOS themes. The analysis of the representation of the nature of science in South African Grade 12 Life Sciences textbooks was carried out using the conceptual framework for textbook analysis developed by Chiappetta, Fillman and Sethna (1991a). The description of the underlying framework is provided in the next section.

## 2.10 Adopted framework for analysing Life Sciences textbooks

This study adopted the conceptual framework developed by Chiappetta, Fillman and Sethna (1991a) to analyse the representation of NOS in South African Grade 12 Life Sciences textbooks. The framework is underpinned by four NOS themes as depicted in Table 1 below.

*Table 1: Analytical framework for NOS*

| NOS Theme | Descriptor: NOS Categories |
|---|---|
| Science as a body of knowledge | a) Knowledge presented as facts, concepts, laws, and principles<br>b) Hypothesis, theories, and models<br>c) Factual recall of information<br>d) tentativeness and durability of scientific knowledge<br>e) distinctness of scientific knowledge |
| The investigative nature of science | a) Learns through the use of materials<br>b) Learns through the use of tables and charts<br>c) Makes calculations<br>d) Reasons out an answer<br>e) Participates in thought experiments<br>f) Gets information from the internet<br>g) Uses scientific observation and inference<br>h) Analyses and interprets data |
| Science as a way of thinking | a) Description of how a scientist discovered or experimented<br>b) Historical development of an idea<br>c) Empirical basis of science<br>d) Use of assumptions<br>e) Inductive or deductive reasoning<br>f) Cause and effect relationship<br>g) Evidence and/or proof<br>h) Presentation of scientific method(s) or problem solving<br>i) Scepticism and criticism<br>j) Human imagination and creativity<br>k) Characteristics of scientists (subjectivity and bias)<br>l) Various ways of understanding the natural world |
| Interaction of science, technology and society | a) Usefulness of science and technology<br>b) Negative effects of science and technology<br>c) Discussion of social issues related to science and technology<br>d) Careers in science and technology<br>e) Contribution of diversity<br>f) Societal or cultural influences<br>g) Public or peer collaboration<br>h) Limitations of science<br>i) Ethics in science |

Source: Adapted from Chiappetta & Fillman (2007)

The stipulated dimensions serve to enable contemporary science education purpose in textbooks aligned with NOS aspects (Chiappetta, Fillman & Sethna, 1991a). The analytic framework provides a holistic emphasis on NOS aspects. This analysis technique is chosen as it provides dissemination of different themes of scientific literacy. The guidance manual developed by Chiappetta, Fillman and Sethna (1991a) affords a direct and reliable method of assessing the four themes of scientific literacy. In the guidance manual, the four themes are described as follows:

### 2.10.1 Science as a body of knowledge (Theme I)

The purpose of the text in this classification is to contemplate, discuss, or request the learner to recall information, evidences, concepts, principles, scientific laws, theories, etc. It symbolises the transferring of scientific knowledge to naïve learners to acquire this knowledge. This classification of knowledge in most textbooks represents information to be learned by the learner.

### 2.10.2 The investigative nature of science (Theme II)

The purpose of this theme is to initiate active learning by probing learners to discover information. It symbolises the active aspect of inquiry learning which engages the learners in the scientific methods and processes of science for example, to observe, measure, classify, infer, record information, interpret, and investigate natural phenomena. Inquiry learning includes hands-on activities and construction of models. The theme advocates for the provision of opportunities for learners to be involved in a cognitive activity and application of cognitive skills.

### 2.10.3 Science as a way of thinking (Theme III)

The purpose of this theme is to demonstrate how science in general or scientists in particular make inferences. This feature of scientific literacy embodies thinking, reasoning, and reflecting and learners are guided in the operations of scientific literacy. Science textbook as a resource in this classification delineates how a scientist experiments, demonstrates the historical development of science, highlights the empirical nature and neutrality of science, exemplifies the use of conceptions, how science develops inductive and deductive reasoning, provides the impact between humans and the environment, or debates evidence.

### 2.10.4 Interaction of science, technology and society (Theme IV)

This feature of scientific literacy involves the application of science and technology as it can assist or hinder the development of individuals. This theme signifies the effectiveness of science and technology in society in relation to the impact of technology and social issues related to science.

## 2.11 Chapter summary

Chapter two describes the underlying analytical framework that underpins this research study and a review of relevant literature. In addition, this chapter provided a reflection on the nature of science as a key construct under investigation and the role of science textbooks as instructional resources. Chapter 3 then provides a broad overview of the research methodologies used to analyse the representation of the nature of science in South African Grade 12 Life Sciences textbooks.

# CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

## 3.1 Introduction

This chapter describes the research design and methodology adopted in this study. It also reflects on the justification of the research methods employed in executing the research. The purpose of the study was to analyse the representation of the nature of science in South African Grade 12 Life Sciences textbooks. Accordingly, the following research questions were formulated:

- To what extent do South African Grade 12 Life Sciences textbooks exhibit themes associated with the nature of science?
- How do South African Grade 12 Life Sciences textbooks compare in the extent to which they cover the themes associated with the nature of science?

The aim of this study was to carry out a comparative analysis of the representation of the nature of science in South African Grade 12 Life Sciences NCS and CAPS textbooks. The research study was underpinned by the following concomitant objectives:

- To analyse the depiction of NOS aspects in South African Grade 12 Life Sciences NCS and CAPS textbooks using a conceptual framework for textbook analysis?
- To identify differences and commonalities in the depiction of NOS aspects in South African Grade 12 Life Sciences NCS and CAPS textbooks.

## 3.2 Research design and methods

This study adopted a qualitative document analysis approach. A qualitative design provides the researcher with a holistic view of the concern that is being investigated (Hancook, 1998). According to Mayring (2000), a qualitative design specifies guidelines to assist the researcher to identify the units to be analysed and also to eliminate the content that does not form part of science literacy. Krippendorff (2004) defines content analysis as a method used to make valid and reliable scientific conclusions from the text within a specific context. This method comprises of structured technique that guides the procedure of data analysis and it is considered to be a scientific tool used to measure the quality of the text (Krippendorff, 2004).

South African CAPS and NCS Grade 12 Life Sciences textbooks were analysed using a conceptual framework developed by Chiappetta, Fillman and Sethna (1991a) (see Table 2 below) underpinned by an associated scoring rubric for textbook analysis developed by Abd-El-Khalick, Waters and Le (2008).

**Table 2: Analytical framework for NOS**

| NOS Theme | Descriptor: NOS Categories |
|---|---|
| Science as a body of knowledge | a) Knowledge presented as facts, concepts, laws, and principles<br>b) Hypotheses, theories, and models<br>c) Factual recall of information |
| The investigative nature of science | a) Learns through the use of materials<br>b) Learns through the use of tables and charts<br>c) Makes calculations<br>d) Reasons out an answer<br>e) Participates in thought experiments<br>f) Gets information from the internet<br>g) Uses scientific observation and inference<br>h) Analyses and interprets data |
| Science as a way of thinking | a) Description of how a scientist discovered or experimented<br>b) Historical development of an idea<br>c) Empirical basis of science<br>d) Use of assumptions<br>e) Inductive or deductive reasoning<br>f) Cause and effect relationship<br>g) Evidence and/or proof<br>h) Presentation of scientific method(s) or problem solving<br>i) Scepticism and criticism<br>j) Human imagination and creativity<br>k) Characteristics of scientists (subjectivity and bias)<br>l) Various ways of understanding the natural world |
| Interaction of science, technology and society | a) Usefulness of science and technology<br>b) Negative effects of science and technology<br>c) Discussion of social issues related to science and technology<br>d) Careers in science and technology<br>e) Contribution of diversity<br>f) Societal or cultural influences<br>g) Public or peer collaboration<br>h) Limitations of science<br>i) Ethics in science |

Source: Adapted from Chiappetta & Fillman (2007)

I investigated the extent to which South African Grade 12 Life Sciences textbooks exhibit the themes associated with the nature of science as an essential tenet in science education. The investigation primarily focused on the identification of the differences and commonalities exhibited by Grade 12 Life Sciences textbooks in terms of the coverage of the themes associated with the nature of science. These textbooks were essentially instructional resources that formed an integral part of the enactment of the National Curriculum Statement and the Curriculum and Assessment Policy Statement promulgated by the Department of Basic Education in South Africa.

South African CAPS and NCS Grade 12 Life Sciences textbooks were identified and chapters and sections were selected for analysis of representation of the nature of science. The selection of the textbooks was based on the period during which NCS and CAPS were implemented. The selected textbooks essentially represented instructional resources utilised during the implementation of NCS and CAPS. The first 10% of pages for each textbook were examined to develop competence and familiarity with the use of the framework as recommended by Chiappetta and Fillman (2007). Furthermore, a sliding scale was applied based on the quantity of pages allocated per content area to calculate the content area found in each page (Chiappetta & Fillman, 2007). As depicted in Table 3 below, the strands that were examined constituted four core content areas, namely: Life at molecular, cellular, and tissue level; Life processes in plants and animals; Diversity, change and continuity; and Environmental studies.



**Table 3: Core content areas in textbooks**

| Core content area | Topics |
|---|---|
| Life at molecular, cellular, and tissue Cell division and mitosis | DNA code of Life<br>RNA and protein synthesis<br>Meiosis |
| Life processes in plants and animals Food production | Reproduction in vertebrates<br>Human reproduction<br>Nervous system<br>Senses<br>Endocrine system<br>Homeostasis |
| Diversity, change and continuity | Darwinism and Natural Selection<br>Human evolution |
| Environmental studies | Human impact on environment |

Source: Adapted from CAPS Life Sciences document (Department of Basic Education, 2011)

Three CAPS Grade 12 Life Sciences textbooks and three NCS Grade 12 Life Sciences textbooks were analysed for depiction of NOS. As observed by Krippendorff (2004), these textbooks are extensively used as instructional resources in classrooms throughout South Africa. The three textbooks chosen for CAPS Life Sciences had the highest number of orders and they collectively constituted close to 75% of all book orders for Grade 12. Similarly, NCS Life Sciences textbooks chosen were the three most popular curriculum resources. The textbooks were analysed in two phases. In the first phase, representative samples of the textbooks were analysed to provide an outline of the themes covered in the textbooks. In the second phase of analysis, textbooks were scrutinised by focusing on units of analysis chosen using the framework validated during the first round of the analysis. Analysis specifically focused on complete paragraphs, questions and statistics, tables with captions, marginal remarks, and comprehensive steps to conduct an activity in a laboratory or inquiry activity. The framework was refined for purposes of organizing and collecting units according to classifications, formulating classifications, and relating the formed classifications to views presented in the research. A comprehensive scoring rubric developed by Abd-El-Khalick, Waters and Le (2008) was used for analysis. The score allocated to specific NOS elements within a textbook is based on an analysis of all materials relevant to that element within the scrutinised textual materials. Scores are provided as follows:

(a) 3 points = Explicit, informed, and consistent representation of the target NOS aspect: (i) explicit statements that convey an informed representation, (ii) consistency across the selected chapters or sections in addressing the target NOS aspect, and (iii) consistency in addressing other directly related NOS aspects.

(b) 2 points = Explicit, partially informed representation of the target NOS aspect: (i) explicit statements that convey an informed, but incomplete representation, and (ii) consistency across the selected chapters or sections in representing the target NOS aspect. An incomplete representation derives from the textbook materials remaining silent in terms of addressing other related NOS aspects that ensure a complete informed representation.

(c) 1 point = Implicit, informed, and consistent representation of the target NOS aspect: (i) an informed representation of the target NOS aspect could be inferred from the textbook materials (e.g., relevant explanations, activities, examples, or historical episodes lacking structured, reflective prompts or explicit statements), and (ii) absence of other explicit or implicit messages that are inconsistent with the inferred implicit representation.

A list of South African Life Sciences textbooks selected for analysis is provided in Table 4 below. The key features provided include title of the textbook, authors, publishers and date of publication. The selected Life Sciences textbooks are increasingly used as instructional resources at South African schools.

**Table 4: Grade 12 Life Sciences textbooks selected for analysis**

| ***Identification Code*** | ***Textbook*** | ***Date of Publication*** |
|---|---|---|
| A | Textbook 1 (CAPS) | 2013 |
| B | Textbook 2 (CAPS) | 2013 |
| C | Textbook 3 (CAPS) | 2013 |
| D | Textbook 4 (NCS) | 2007 |
| E | Textbook 5 (NCS) | 2010 |
| F | Textbook 6 (NCS) | 2007 |

Table 5 below shows how the number pages identified in each textbook was determined.

**Table 5: Number of pages identified in each textbook**

| Life Sciences strands | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Life at molecular, cellular, and tissue Cell division and mitosis | 102x0.15 (15 pages) | 57x 0.15 (9 pages) | 112x0.15 (17 pages) | 75x0.15 (11 pages) | 86x 0.15 (13 pages) | 68x0.15 (10 pages) |
| Life processes in plants and animals Food production | 83x 0.15 (12 pages) | 154x0.15 (23 pages) | 146x0.15 (22 pages) | 161x0.15 (24 pages) | 65 x 0.15 (page number) | 58x0.15 (9 pages) |
| Diversity, change and continuity | 55x0.15 (8 pages) | 55x 0.15 (8 pages) | 90x0.15 (14 pages) | 42x0.15 (6 pages) | 87 x 0.15 (13 pages) | 54x0.15 (8 p ages) |
| Environmental studies | 55x0.15 (8 pages) | 8x0.15 (1 page) | - | 62x0.15 (9 pages) | 68 x 0.15 (page numbers) | 34x.15 (5 pages) |

The number of pages analysed per strand is indicated in Table 6 below.

**Table 6: The number of pages analysed per strand**

| Life Sciences strands | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Life at molecular, cellular, and tissue Cell division and mitosis | 102x0.15 (15 pages) | *57x 0.15 (9 pages)* | *112x0.15 (17 pages)* | *75x0.15 (11 pages)* | *86x 0.15 (13 pages)* | *68x0.15 (10 pages)* |
| Life processes in plants and animals Food production | *83x 0.15 (12 pages)* | *154x0.15 (23 pages)* | *146x0.15 (22 pages)* | *161x0.15 (24 pages)* | *65 x 0.15 (page number)* | *58x0.15 (9 pages)* |
| Diversity, change and continuity | *55x0.15 (8 pages)* | *55x 0.15 (8 pages)* | *90x0.15 (14 pages)* | *42x0.15 (6 pages)* | *87 x 0.15 (13 pages)* | *54x0.15 (8 pages)* |
| Environmental studies | *55x0.15 (8 pages)* | *8x0.15 (1 page)* | - | *62x0.15 (9 pages)* | *68 x 0.15 (10 pages)* | *34x.15 (5 pages)* |

### 3.3 Validity and reliability

A validated analytical framework developed by Chiappetta, Fillman and Sethna (1991a) was used to analyse South African Grade 12 Life Sciences textbooks. The validity of the adopted rubric is rooted in conceptual and empirical knowledge. The NOS framework and elements targeted by the rubric have been emphasized in current science education reform documents and are central to developing functional levels of scientific literacy (National Research Council, 1996). The reliability of the results in this study was measured using Cohen's kappa coefficient (κ) (Cohen, 1990). The coding agreement was established by calculating Cohen's kappa coefficient to reach the level of inter-coder reliability. The agreement in interpreting coding was analysed as follows: the values of Cohen's kappa larger than .75 imply excellent agreement; the values of Cohen's kappa between .40 and .75 represent reasonable to good agreement; and values of Cohen's kappa smaller than .40 imply fair to poor agreement. Cohen's kappa coefficient (κ) is a statistic which measures inter-rater agreement for qualitative (categorical) items. It is generally thought to be a more robust measure than simple percent agreement calculation as κ takes into account the possibility of the agreement occurring by chance. The identified units for analysis were individually numbered and coded.



### 3.4 Chapter summary

This chapter reflected on the research design and the justification of the research methods employed in this study. In addition, the epistemological framework that underpins this study has been adequately described to set the tone for subsequent chapters. This framework served to ensure the conceptual coherence in relation to this minor dissertation as it provided the intellectual space to broadly reflect on the research tools used in this study.  In particular, this chapter provided a reflection on the research methodologies used to analyse the representation of the nature of science in South African Grade 12 Life Sciences textbooks. Chapter 4 then provides a reflection on the results in this research study.

# CHAPTER 4: RESULTS

## 4.1. Introduction

This Chapter reflects on the key findings that emerged from the study. The analysis of the representation of the nature of science in South African Grade 12 Life Sciences textbooks was guided by the conceptual framework developed by Chiappetta, Fillman and Sethna (1991a). In addition, a reflection on the differences and commonalities exhibited by the selected textbooks in terms of the representation of the nature of science as a structural characteristic feature is provided.

## 4.2 Findings

Table 7 below illustrates the depiction of "Science as a body of knowledge" in terms of the concomitant nature of science categories in selected South African Grade 12 Life Sciences textbooks.

**Table 7: Depiction of "Science as a body of knowledge"**

| | | **Frequencies** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **NOS Theme** | **NOS Category** | **Textbook 1 (CAPS)** | **Textbook 2 (CAPS)** | **Textbook 3 (CAPS)** | **Textbook 4 (NCS)** | **Textbook 5 (NCS)** | **Textbook 6 (NCS)** | **Total** |
| Science as a body of knowledge | a) Knowledge presented as facts, concepts, laws, and principles | 22 | 16 | 34 | 14 | 22 | 16 | 124 |
| | b) Hypotheses, theories, and models | 16 | 2 | 13 | 4 | 8 | 4 | 47 |
| | c) Factual recall of information | 380 | 126 | 224 | 58 | 267 | 341 | 1396 |
| | d) tentativeness and durability of scientific knowledge | 22 | 18 | 32 | 6 | 54 | 33 | 165 |
| | e) distinctness of scientific knowledge | 18 | 16 | 14 | 8 | 11 | 31 | 98 |

Depiction of "Science as a body of knowledge" in selected textbooks reflected a predominant emphasis on factual recall of information as an NOS category. However, factual recall of information was covered to a limited extent in Textbook 4 (NCS). The coverage of hypotheses, theories, and models across the selected textbooks was extremely inadequate as compared to other NOS categories. While knowledge was largely presented as facts, concepts, laws, and principles, particular emphasis was also placed on tentativeness and durability of scientific knowledge as well as distinctness of scientific knowledge. Table 8 below provides a depiction of "Science as a way of investigation". It is striking to note that getting information from the internet and the use of scientific observation and inference were completely omitted in some of the selected textbooks. The implication of the omission is that the affected textbooks do not provide opportunities for learners to take advantage of digital transformation thereby stifling meaningful development of practical investigation skills. There is a crucial need for textbooks as instructional resources to develop learners' capacity to use the internet as a vital tool to access information to empower themselves. This would pave the way for learners to fully embrace the opportunities associated with the advent of the Fourth Industrial revolution.

**Table 8: Depiction of "Science as a way of investigation"**

| | | **Frequencies** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **NOS Theme** | **NOS Category** | **Textbook 1 (CAPS)** | **Textbook 2 (CAPS)** | **Textbook 3 (CAPS)** | **Textbook 4 (NCS)** | **Textbook 5 (NCS)** | **Textbook 6 (NCS)** | **Total** |
| Science as a way of investigation | a) Learns through the use of materials | 114 | 28 | 88 | 54 | 32 | 111 | 427 |
| | b) Learns through the use of tables and charts | 27 | 4 | 27 | 2 | 14 | 11 | 85 |
| | c) Makes calculations | 20 | 8 | 56 | 20 | 12 | 10 | 126 |
| | d) Reasons out an answer | 83 | 32 | 92 | 52 | 64 | 75 | 398 |
| | e) Participates in thought experiments | 43 | 10 | 18 | 6 | 12 | 14 | 103 |
| | f) Gets information from the internet | 2 | - | 2 | 2 | - | - | 6 |
| | g) Uses scientific observation and inference | 12 | 10 | 8 | 2 | - | 12 | 44 |
| | h) Analyses and interprets data | 11 | 10 | 10 | 8 | 7 | 6 | 52 |



Learning through the use of materials as an NOS category was sufficiently covered in Textbook 1 (CAPS), Textbook 3 (CAPS) and Textbook 6 (NCS). This NOS category was, however, inadequately covered in other textbooks. Reasoning out an answer was also sufficiently covered although its coverage in Textbook 2 (CAPS) represented an anomaly. Other NOS categories that were covered to a reasonable extent included learning through the use of tables and charts, making calculations and participation in thought experiments.

Table 9 below provides the depiction of "Science as a way of thinking". The overall coverage of "Science as a way of thinking" in terms of the NOS categories across the selected textbooks was largely inadequate. Presentation of scientific method(s) or problem solving was the only NOS category that received some measure of emphasis. NOS categories that were completely omitted in some of the selected textbooks included description of how scientists discover or experiment, historical development of an idea, inductive or deductive reasoning, characteristics of scientists (subjectivity and bias) and various ways of understanding the natural world. This grim reality should serve as a wake-up call to reconfigure Grade 12 Life Sciences textbooks to do justice to the depiction of "Science as a way of thinking".

**Table 9: Depiction of "Science as a way of thinking"**

| | | Frequencies | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **NOS Theme** | **NOS Category** | **Textbook 1 (CAPS)** | **Textbook 2 (CAPS)** | **Textbook 3 (CAPS)** | **Textbook 4 (NCS)** | **Textbook 5 (NCS)** | **Textbook 6 (NCS)** | **Total** |
| Science as a way of thinking | a) Description of how scientists discover or experiment | 2 | - | - | 6 | 10 | 2 | 20 |
| | b) Historical development of an idea | 4 | 2 | 2 | 2 | - | 2 | 12 |
| | c) Empirical basis of science | 8 | 4 | 14 | 11 | 8 | 18 | 63 |
| | d) Use of assumptions | 9 | 4 | 14 | 8 | 4 | 2 | 41 |
| | e) Inductive or deductive reasoning | 3 | 4 | - | 4 | 2 | - | 13 |
| | f) Cause and effect relationship | 14 | 8 | 14 | 6 | 6 | 5 | 53 |
| | g) Evidence and/or proof | 10 | 4 | 4 | 2 | 2 | 2 | 24 |
| | h) Presentation of scientific method(s) or problem solving | 32 | 30 | 11 | 22 | 15 | 24 | 134 |
| | i) Scepticism and criticism | 3 | 14 | 7 | 5 | 10 | 12 | 51 |
| | j) Human imagination and creativity | 2 | 8 | 6 | 2 | 2 | 2 | 22 |
| | k) Characteristics of scientists (subjectivity and bias) | 3 | - | 2 | 6 | - | - | 11 |
| | l) Various ways of understanding the natural world | 8 | - | 6 | 2 | - | 5 | 21 |



Table 10 below provides the depiction of the "Interaction of science, technology and society". The overall coverage of the "Interaction of science, technology and society" in terms of the concomitant NOS categories across the selected textbooks was largely inadequate. This depiction is disconcerting given the significance of scientific and technological innovation in the information age. Lack of emphasis on careers in science and technology is yet another disservice done by the textbooks as scientific and technological expertise is crucially important for the progressive realisation of socio-economic development in society. Little emphasis on societal and cultural influences paints a gloomy picture in terms of the development of public understanding of the complex ramifications associated with progressive realisation of broad societal goals. The textbooks provided limited opportunities for discussions of social issues related to science and technology and this structural deficiency does not augur well for the development of a scientifically literate citizenry. Inadequate attention given to the contribution of diversity would potentially serve to stifle fundamental appreciation of biodiversity as a key component of a sustainable ecosystem. While science and technology provide immense benefits to humanity, negative effects of science and technology have to be fully understood in order to foster an eco-friendly and sustainable social co-existence. There is thus a crucial need to restructure South African Grade 12 Life Sciences textbooks to ensure equitable coverage of NOS categories related to the “Interaction of science, technology and society” as a key concomitant theme.

**Table 10: Depiction of the “Interaction of science, technology and society”**

| | | Frequencies | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **NOS Theme** | **NOS Category** | **Textbook 1 (CAPS)** | **Textbook 2 (CAPS)** | **Textbook 3 (CAPS)** | **Textbook 4 (NCS)** | **Textbook 5 (NCS)** | **Textbook 6 (NCS)** | **Total** |
| The interaction amongst Science, Technology and Society | a) Usefulness of science and technology | 4 | 7 | 6 | 4 | 12 | 2 | 35 |
| | b) Negative effects of science and technology | - | 6 | 4 | 1 | 4 | - | 15 |
| | c) Discussion of social issues related to science and technology | 8 | 4 | - | 11 | 2 | - | 25 |
| | d) Careers in science and technology | 2 | - | - | - | - | 5 | 7 |
| | e) Contribution of diversity | 4 | 2 | 2 | 2 | - | 2 | 12 |
| | f) Societal or cultural influences | 2 | 1 | 2 | - | - | 4 | 9 |
| | g) Public or peer collaboration | 10 | 4 | 2 | 8 | 8 | 6 | 38 |
| | h) Limitations of science | 7 | 2 | - | - | 2 | 2 | 13 |
| | i) Ethics in science | 12 | 4 | 2 | 8 | 10 | 10 | 46 |



Table 11 below provides overall coverage of NOS themes in the selected textbooks analysed. “Science as a body of knowledge” is sufficiently covered in the selected textbooks as compared to other themes. “Science as a way of thinking” and the “Interaction of science, technology and society” received limited coverage across the selected textbooks analysed. While “Science as a way of investigation” was fairly covered, more should be done to strengthen the coverage of this aspect with a view to provide meaningful opportunities for learners to indulge in inquiry-based learning. Hattie (2009) found that rich pedagogical experiences provided by inquiry-based approach result in improved learner performance in a number of learning areas. Hattie defines this approach as follows:

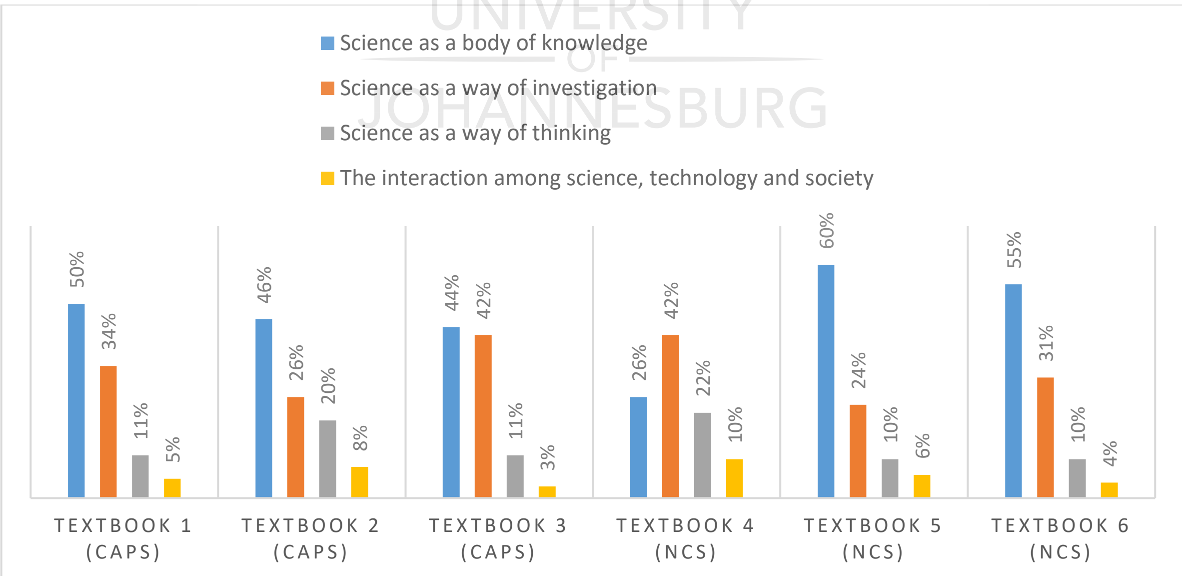
> Inquiry-based teaching is the art of developing challenging situations in which students are asked to observe and question phenomena; pose explanations of what they observe; devise and conduct experiments in which data are collected to support or contradict their theories; analyse data; draw conclusions from experimental data; design and build models; or any combination of these. (p. 208)

**Table 11: Overall coverage of NOS themes in selected textbooks**

| Textbook | Frequencies | | | |
|---|---|---|---|---|
| | **Science as a body of knowledge** | **Science as a way of investigation** | **Science as a way of thinking** | **The interaction among science, technology and society** |
| Textbook 1 (CAPS) | 458 | 312 | 98 | 49 |
| Textbook 2 (CAPS) | 178 | 102 | 78 | 30 |
| Textbook 3 (CAPS) | 317 | 301 | 80 | 18 |
| Textbook 4 (NCS) | 90 | 146 | 76 | 34 |
| Textbook 5 (NCS) | 362 | 141 | 59 | 38 |
| Textbook 6 (NCS) | 425 | 239 | 74 | 31 |
| **Total** | **1830** | **1241** | **465** | **200** |

The overall depiction of NOS themes in selected textbooks is illustrated in Figure 1 below. The overall picture points to the fact that concerted efforts by Life Sciences textbook authors are required to ensure equitable coverage of key NOS themes as a key curriculum reform imperative.

**Figure 1: Overall coverage of NOS themes in selected textbooks**




The representation of NOS themes in Grade 12 CAPS and NCS Life Sciences textbooks is depicted in Table 12 below. The representation of NOS themes appeared to be consistent across Grade 12 Life Sciences CAPS and NCS textbooks with "Science as a body of knowledge" receiving substantial coverage as compared to other NOS themes. This consistent representation pattern is a commonality characterising the depiction of NOS themes across the selected Grade 12 CAPS and NCS Life Sciences textbooks analysed.

**Table 12: Representation of NOS themes in Grade 12 CAPS and NCS Life Sciences textbooks**

| Textbooks | Science as a body of knowledge | Science as a way of investigation | Science as a way of thinking | The interaction among science, technology and society | Total |
|---|---|---|---|---|---|
| Grade 12 CAPS Life Sciences textbooks | 47% | 35% | 13% | 5% | 100 |
| Grade 12 NCS Life Sciences textbooks | 51% | 31% | 12% | 6% | 100 |

The pattern characterising the representation of NOS themes in Grade 12 CAPS Life Sciences textbooks is illustrated in Figure 2 below.

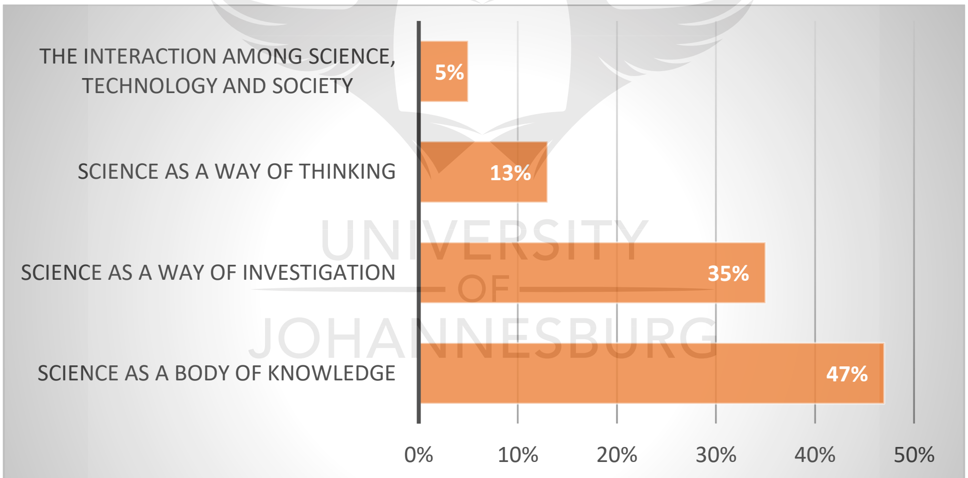



**Figure 2: Representation of NOS themes in Grade 12 CAPS Life Sciences textbooks**

Figure 3 below illustrates the pattern characterising the representation of NOS themes in Grade 12 NCS Life Sciences textbooks.

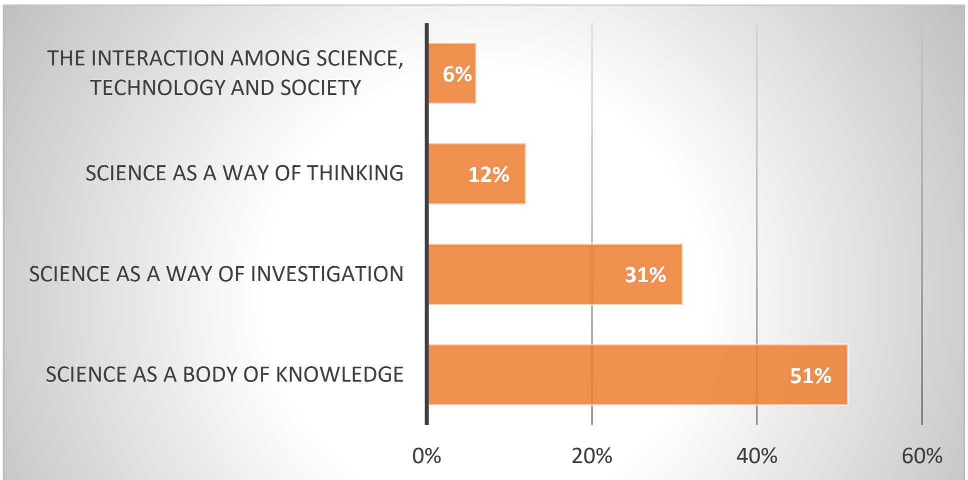



**Figure 3: Representation of NOS themes in Grade 12 NCS Life Sciences textbooks**

The illustrations depicted in Figures 2 and 3 provide a reaffirmation of the consistent representation pattern as a commonality characterising the depiction of NOS themes across the selected Life Sciences textbooks analysed. The reliability of the results in this study was measured using Cohen's kappa coefficient (κ) (Cohen, 1990). The coding agreement was established by calculating Cohen's kappa coefficient to reach the level of inter-coder reliability. Table 13 below provides the symmetric measures for Textbook 1 (CAPS).

**Table 13: Symmetric measures for Textbook 1 (CAPS)**

| | | Value | Asymptotic Standard Error[a] | Approximate T[b] | Approximate Significance |
|---|---|---|---|---|---|
| Measure of Agreement | Kappa | .659 | .033 | 29.958 | .000 |
| N of Valid Cases | | 224 | | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table 14 below provides the symmetric measures for Textbook 2 (CAPS).

**Table 14: Symmetric measures for Textbook 2 (CAPS)**

| | | Value | Asymptotic Standard Error[a] | Approximate T[b] | Approximate Significance |
|---|---|---|---|---|---|
| Measure of Agreement | Kappa | .750 | .023 | 46.214 | .000 |
| N of Valid Cases | | 406 | | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table 15 below provides the symmetric measures for Textbook 3 (CAPS).

**Table 15: Symmetric measures for Textbook 3 (CAPS)**

| | | Value | Asymptotic Standard Error[a] | Approximate T[b] | Approximate Significance |
|---|---|---|---|---|---|
| Measure of Agreement | Kappa | .825 | .018 | 50.539 | .000 |
| N of Valid Cases | | 508 | | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table 16 below provides the symmetric measures for Textbook 1 (NCS).

**Table 16: Symmetric measures for Textbook 1 (NCS)**

| | | Value | Asymptotic Standard Error[a] | Approximate T[b] | Approximate Significance |
|---|---|---|---|---|---|
| Measure of Agreement | Kappa | .750 | .031 | 38.389 | .000 |
| N of Valid Cases | | 204 | | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table 17 below provides the symmetric measures for Textbook 2 (NCS).



**Table 17: Symmetric measures for Textbook 2 (NCS)**

| | | Value | Asymptotic Standard Error[a] | Approximate T[b] | Approximate Significance |
|---|---|---|---|---|---|
| Measure of Agreement | Kappa | .801 | .023 | 39.351 | .000 |
| N of Valid Cases | | 347 | | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table 18 below provides the symmetric measures for Textbook 3 (NCS).

**Table 18: Symmetric measures for Textbook 3 (NCS)**

| | | Value | Asymptotic Standard Error[a] | Approximate T[b] | Approximate Significance |
|---|---|---|---|---|---|
| Measure of Agreement | Kappa | .697 | .023 | 37.512 | .000 |
| N of Valid Cases | | 438 | | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

The overall kappa for all measurements is depicted in Table 19 below.

**Table 19: The overall kappa for all measurements**

| | | Value | Asymptotic Standard Error[a] | Approximate T[b] | Approximate Significance |
|---|---|---|---|---|---|
| Measure of Agreement | Kappa | .759 | .010 | 100.735 | .000 |
| N of Valid Cases | | 2132 | | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.



## 4.3 Discussion

The findings of this study revealed that South African Grade 12 Life Sciences textbooks analysed reflected inadequate and inequitable coverage of NOS themes. Inadequate coverage of NOS themes is consistent with an empirical study conducted by McComas (2003) which found that Biology textbooks portray limited coverage of scientific laws and theories. In response to this structural deficiency, McComas (2003) recommends that science textbook authors ought to include more definite examples of laws and theories as they underpin science concepts and facts. In addition, science textbooks should foster the development of knowledge informed by scientific laws and theories to ensure adequate coverage of NOS aspects (McComas, 2003). Jiang and McComas (2004) are of the view that science textbooks should promote collaboration and peer learning while placing particular emphasis on all the aspects of NOS.

South African Grade 12 Life Sciences textbooks analysed in this study provided sufficient focus on factual recall of information and this structural emphasis could potentially encourage rote learning. Developing meaningful understanding of hypotheses, theories, and models as the NOS category has largely been given scant attention. Yet, meaningful understanding of hypotheses, theories, and models underpin the development of scientific literacy. "Science as a way of investigation" was inadequately covered in the selected textbooks analysed and this coverage serves to stifle the enactment of inquiry-based learning as a contemporary pedagogic approach. This finding is consistent with a study conducted by Jiang and McComas (2014) who found that Biology textbooks tend to compromise adequate inclusion of investigative activities. They further posit that these textbooks put emphasis on scientific content knowledge and inquiries without considering societal influence on science and technology within communities.

Chiappetta, Fillman and Sethna (1991b) found that "Science as a way of thinking" is poorly represented in Chemistry textbooks as evidenced by omission of scientific discoveries and historical development of ideas. Leite (2002) argues that science textbooks do not provide adequate information on how scientists make discoveries and develop scientific ideas. In my view, this structural deficiency may compromise the development of meaningful understanding of NOS themes as a key curriculum reform imperative particularly within the broader South African educational context. The key findings in this study are consistent with the findings of other studies on the analysis of Life Sciences and Natural Sciences textbooks conducted in South Africa. A study conducted by Ramnarain and Padayachee (2015) on the comparative analysis of South African Grade 10 Life Sciences textbooks for inclusion of the nature of science revealed that science is largely depicted as a body of knowledge while the representation of science as a way of investigation, science as a way of thinking, and the interaction of science, technology and society received limited coverage. A study conducted by Ramnarain and Chanetsa (2016) on the analysis of South African Grade 10 Natural Sciences textbooks for inclusion of the nature of science attained similar findings.

According to Chiappetta, Fillman and Sethna (1991b), emphasis on scientific vocabulary and life processes as contained in science textbooks serves to promote rote learning and stifles meaningful conceptual understanding. In order to address this structural deficiency, Chiappetta, Fillman and Sethna (1991b) recommend that science textbooks must provide accurate depiction of NOS aspects and relate to learners daily lives. Science textbooks are perceived to be instructional resources providing guiding principles that influence teaching (Idrees, Habib, & Hafeez, 2004). This implies that science textbooks should provide adequate information about scientific phenomena that is responsive to NOS tenets. Learners' understanding of and willingness to do science is refined by the quality of science textbooks used within their learning context (Idrees, Habib, & Hafeez, 2004).

İrez (2009) observed that secondary science textbooks do not reflect inclusion of aspects of NOS tenets required to improve scientific literacy. For instance, the role of creativity, subjectivity, scientific method and socio-cultural influences in science has largely been neglected. McComas and Olson (1998) scrutinised international science documents for representation of NOS and found that clear description of NOS was not provided. A research study conducted by Niaz (2000) revealed that in Chemistry curricula a clear distinction between law and theory is explained explicitly. A study conducted by Lumpe and Beck (1996) found that theories and laws are distinctively separated from the method and this conundrum leads to the utilisation of textbooks which do not foster self-regulation of cognitive development and prevent learners from understanding natural phenomena.

Abd-El-Khalick and Lederman (2000) argue that explicit-reflective strategy is the effective way of teaching NOS as the elements of NOS are interrelated with content knowledge. They further posit that the imbalance of NOS representation in textbooks is caused by curricula expectations and subjectivity of textbook writers. A research study conducted by Krajcik and Czerniak (2014) on the analysis of Physics textbooks in Greece revealed that NOS coverage accounts for two thirds of total textbook content. The key finding in this study with regard to inadequate depiction of the "Interaction of science, technology and society" is consistent with the findings of the study by Chiappetta and Fillman (2007) which revealed that this NOS theme is poorly represented in physical sciences textbooks culminating in learners acquiring naïve understanding of the integration of science and technology in the classroom.



## 4.4 Chapter summary

This Chapter provided a discussion of the key findings that emerged from this study. A reflection on the implications of the findings for the consolidation of curriculum reform efforts within the broader South African educational context has also been contemplated. Chapter 5 outlines summary of findings, conclusion and recommendations arising from the study.

# Chapter 5: SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

## 5.1 Introduction

This study aimed to analyse the representation of the nature of science in South African Grade 12 Life Sciences textbooks using the conceptual framework developed by Chiappetta, Fillman and Sethna (1991a). Three NCS and three CAPS South African Grade 12 Life Sciences textbooks were analysed. This Chapter provides summary of findings, conclusion and recommendations emanating from the study.

## 5.2 Summary of findings

South African Grade 12 Life Sciences textbooks analysed reflected inadequate and inequitable coverage of NOS themes. In particular, "Science as a body of knowledge" was given substantial coverage as compared to other concomitant themes. While considerable emphasis is placed on the significance of inquiry-based learning as a contemporary pedagogic approach, limited coverage was, however, given to "The investigative nature of science" and "Science as a way of thinking" as relevant themes required for meaningful enactment of inquiry-based learning. Science and technology play a pivotal role towards the fulfilment of societal and economic needs. Yet, the "Interaction of science, technology and society" was afforded limited coverage across the selected textbooks analysed. Overall, the textbooks reflected a consistent representation pattern as a key commonality characterising the depiction of NOS themes.

## 5.3 Insights gleaned from the key findings that emerged from the study

The dismal depiction of the nature of science in South African Grade 12 Life Sciences textbooks as revealed in this study may potentially be one of the key factors responsible for the erosion of the quality of basic education in South Africa. Development of meaningful scientific literacy underpinned by the creation of a scientifically literate citizenry ought to be the hallmark of the provision of quality education. This key strategic imperative hinges to a large degree on the development and provision of coherently aligned instructional resources which are geared towards progressive realisation of the envisaged key curriculum outcomes. At another pragmatic level, dismal depiction of the nature of science in science textbooks may hamper meaningful enactment of contemporary pedagogic approaches such as inquiry-based learning in science classrooms.

The complexity of the articulation gap between school and higher education in South Africa is a fundamental dilemma which requires far-reaching curriculum reforms. This fundamental dilemma serves to stifle smooth transitional and epistemological access to higher education in particular. Key challenges in this regard are manifested in the form of student underpreparedness for tertiary studies to which various institutions of higher learning responded by implementing extended curriculum programs. Thus, the restructuring of science textbooks to ensure meaningful and equitable representation of key constructs such as the nature of science would go a long way towards promoting plausible access to scientific literacy as a key curriculum goal.

### 5.4 Recommendations arising from the study

The dismal depiction of the nature of science in South African Grade 12 Life Sciences textbooks calls for immediate review of the textbooks to align them with the key imperatives of meaningful curriculum reform. The reconfiguration of Grade 12 Life Sciences textbooks to ensure equitable representation of the nature of science is imperative. This crucial step will serve to ensure that South Africa as a member of the global community of nations provides a globally competitive curriculum that is responsive to the acceleration of socio-economic development. Dispelling misconceptions by using the conceptual change model would be an extremely difficult and complex undertaking given the dismal depiction of the nature of science in South African Grade 12 Life Sciences textbooks. There is thus a critical need to create, evaluate, and revise policies and practices to encourage teachers to meaningfully engage in professional science learning. District and school administrators and other relevant key stakeholders ought to work together to establish viable and sustainable communities of practice which provide meaningful opportunities for teachers and learners to critically engage with curriculum content as encapsulated in the Life Sciences textbooks with a view to ensure conceptual and structural coherence.



Textbooks are essential instructional resources used to facilitate learning in science classrooms. Meaningful depiction of NOS in science textbooks is a key structural feature to be taken into cognisance by textbook authors. The need for the inclusion of NOS in a lesson is dependent upon teacher-oriented beliefs and interest towards science (Lederman & Lederman, 2004). Thus, Lederman and Lederman (2004) posit that meaningful provision of science instruction is achieved when teachers begin to develop intrinsic understanding of the elements of science and the role science plays in shaping realities faced by learners. The usefulness of Life Sciences textbooks in particular is predicated on the knowledge they provide to enable learners to develop cognitive skills and ability to complete assigned activities. The Life Sciences textbooks are generally made up of scientific concepts and practical investigative activities that aim to improve the understanding of scientific concepts.

The role of the teacher is to diagnose and rectify misconceptions learners bring to Life Sciences classrooms (Kesidou & Roseman, 2002). This mission can be accomplished when teachers explore learners' prior and current knowledge of concepts. To this end, textbooks have to be designed in such a way that they are able to provide a clear description and explanation of concepts to challenge learners' prior knowledge. The realisation of this key curriculum goal requires equitable depiction of NOS themes in science textbooks. Meaningful learning experience is achieved when learners are provided with learning opportunities that are centred on the realities they face in various instructional settings. These opportunities can take the form of formal and summative activities that allow learners to manipulate natural phenomena. In this regard, Life Sciences textbooks should serve to encourage learners to partake in thought experience and reasoning to develop higher-order thinking skills. Learners' participation in the investigation and manipulation of variables would serve to develop their understanding of "Science as a way of investigation" as the key NOS theme. The writers of Life Sciences textbooks need to provide a balanced and equitable representation of NOS themes in order to promote a better understanding of all NOS elements.  This mission can be accomplished through meticulous and coherent reconfiguration of Life Sciences textbooks.

### 5.5 The limitations of the study

The study only focused on the analysis of the representation of NOS in selected sample of South African Grade 12 Life Sciences textbooks. However, key findings emanating from the study may have profound implications for curriculum reform within the broader South African context.



### 5.6 Strengths and weaknesses of the study

The limited scope of the study is mitigated by the richness of the data obtained and the profound nature of the key findings that emerged. While teachers, learners and other key stakeholders with vested interest in education were not interviewed to solicit their opinions, the key findings emanating from the study would certainly serve as a call to action and inform the consolidation of curriculum reform efforts within the broader South African educational context.  While the analysis of the representation of the nature of science was based on a limited sample of South African Grade 12 Life Sciences textbooks, the key findings are comparable with the results of international studies and have profound implications for global curriculum reforms.

## 5.7 Recommendations for further study

The dismal depiction of the nature of science in South African Grade 12 Life Sciences textbooks has profound implications for meaningful curriculum reform. The development of teachers' pedagogical content knowledge remains a key curriculum reform imperative within the broader South African educational context. The use of textbook analysis as a professional development tool to enhance teachers' pedagogical content knowledge can be explored as part of further research studies. Further research studies can also explore how enhanced teachers' pedagogical content knowledge translate into tangible instructional benefits for learners in their quest to acquire a meaningful understanding of the nature of science as an essential tenet in science education.

## 5.8 Conclusion

South African Grade 12 Life Sciences textbooks analysed, reflected a dismal depiction of the themes associated with the nature of science as an essential tenet in science education. Consolidation of curriculum reform efforts within the broader South African context should refocus on the equitable representation of the nature of science in science textbooks with a view to enhance meaningful development of scientific literacy.

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# APPENDICES

*Appendix A: Ethics Clearance*

*NHREC Registration Number REC-110613-036*

UNIVERSITY
OF
JOHANNESBURG

**ETHICS CLEARANCE**

Dear Themba Egnatius Masilela

**Ethical Clearance Number: Sem 1 2019-071**

**The representation of the nature of science in South African Grade 12 Life Sciences textbooks**

Ethical clearance for this study is granted subject to the following conditions:

- If there are major revisions to the research proposal based on recommendations from the Faculty Higher Degrees Committee, a new application for ethical clearance must be submitted.
- If the research question changes significantly so as to alter the nature of the study, it remains the duty of the student to submit a new application.
- It remains the student's responsibility to ensure that all ethical forms and documents related to the research are kept in a safe and secure facility and are available on demand.
- Please quote the reference number above in all future communications and documents.

**The Faculty of Education Research Ethics Committee has decided to**

☒ Grant ethical clearance for the proposed research.
☐ Provisionally grant ethical clearance for the proposed research
☐ Recommend revision and resubmission of the ethical clearance documents

Sincerely,

Dr David Robinson
**Chair: FACULTY OF EDUCATION RESEARCH ETHICS COMMITTEE**
28 April 2020

*Appendix B: Analytic framework*

| NOS Theme | Descriptor: NOS Categories |
|---|---|
| Science as a body of knowledge | a) Knowledge presented as facts, concepts, laws, and principles<br>b) Hypotheses, theories, and models<br>c) Factual recall of information<br>d) tentativeness and durability of scientific knowledge<br>e) distinctness of scientific knowledge |
| The investigative nature of science | a) Learns through the use of materials<br>b) Learns through the use of tables and charts<br>c) Makes calculations<br>d) Reasons out an answer<br>e) Participates in thought experiments<br>f) Gets information from the internet<br>g) Uses scientific observation and inference<br>h) Analyses and interprets data |
| Science as a way of thinking | a) Description of how a scientist discovered or experimented<br>b) Historical development of an idea<br>c) Empirical basis of science<br>d) Use of assumptions<br>e) Inductive or deductive reasoning<br>f) Cause and effect relationship<br>g) Evidence and/or proof<br>h) Presentation of scientific method(s) or problem solving<br>i) Scepticism and criticism<br>j) Human imagination and creativity<br>k) Characteristics of scientists (subjectivity and bias)<br>l) Various ways of understanding the natural world |
| Interaction of science, technology and society | a) Usefulness of science and technology<br>b) Negative effects of science and technology<br>c) Discussion of social issues related to science and technology<br>d) Careers in science and technology<br>e) Contribution of diversity<br>f) Societal or cultural influences<br>g) Public or peer collaboration<br>h) Limitations of science<br>i) Ethics in science |

# Introduction

Scientists have known about the structure of cells for a long time. However, they did not understand how cells could make copies of themselves or how a living organism could inherit characteristics from its parents. This mystery was only solved in the middle of the 20th century, when the structure of DNA was discovered. DNA is short for deoxyribonucleic acid.

This topic explains how DNA instructs a cell to carry out its functions. You will look at ways in which scientists are now using this knowledge.

## Activity 1: Check what you already know

**Specific Aim 1: 1.1, 1.2**

Work on your own. Study the diagram of a cell nucleus in Figure 1.1; then answer the questions.

1. Identify and name parts A to E. (5)
2. 2.1 Identify the part that contains the cell's genetic material. (1)
   2.2 Name the structure formed in this part during cell division. (1)
   2.3 Name the molecule found in these structures that controls
   the cell's structure and functions of the cell. (1)

**[8]**

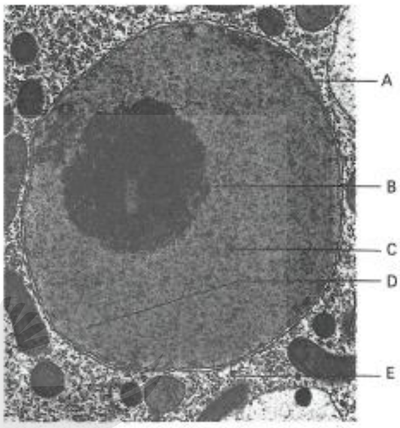


**Figure 1.1** Micrograph of the structure of the cell nucleus

## Careers focus — Forensic scientist

**Job description:** A forensic scientist carries out tests on evidence that is found by police officers or investigators at crime scenes. You might have seen television programmes about the work of forensic scientists. A forensic scientist also examines the bodies of crime victims in order find out the cause of injury or death. A forensic scientist does tests on DNA from samples of blood, skin and hair. He or she analyses the DNA from small fragments of tissue. This helps them to identify the person who committed the crime. Forensic scientists may also do tests to look for unnatural substances in the body. For example, when looking for drugs or poison, the forensic scientist might analyse the stomach contents of victims.

**Education:** Forensic scientists usually work for the police force after completing a degree in Medicine or Biomedical Technology. You will need a Grade 12 Bachelor's degree level pass with Mathematics, Physical Sciences and Life Sciences. Most universities of technology in South Africa offer a four-year degree in Biomedical Technology. You will need further training at a police laboratory.

**Skills:** You will need to pay careful attention to detail and be prepared to work under pressure at odd hours. You may also need good speaking skills, as evidence may be used in a courtroom.

## How long does evolution take?

Evolution occurs over very long periods of time. The Earth was formed about 4 500 million years ago. The first living organisms may have appeared about 3 000 million years ago, and the first humans walked on Earth about 2 million years ago. Modern humans like ourselves first appeared somewhere between 50 000 and 100 000 years ago.

It is difficult to imagine such long periods of time. But it might help you to understand these figures if you think of the history of the Earth as a single year, as shown in Figure 7.6.

1. On the 1st of January the Earth was formed.
2. On the 1st of April the very first organisms appeared.
3. The first fish swam in the sea in the third week of November.
4. A little lizard ran across the sand during the middle of December.
5. The earliest humans came on the scene at about 6 p.m. on December 25.
6. At 11.50 p.m. on the 31st December modern humans emerged.


**Figure 7.6** The history of the Earth as depicted in a single year

The diagram of the evolutionary tree in figure 7.7 shows when new groups of organisms first appeared and when some of them disappeared. Note that the first life forms evolved in water.

### Activity 2 Answer questions on the evolutionary tree
(individual)

**LO2 AS2.1**

Look at the evolutionary tree and then answer these questions.

1. When did the first living organisms evolve? What were these organisms?
2. Where did the first organisms live – on land or in the water?
3. a. Name any organisms shown on the evolutionary tree which do not exist today.
   b. When did these organisms become extinct?
4. During which geological period did the first land plants evolve?
5. How long ago did the first mammals appear on Earth?
6. When did the flowering plants evolve?

## Activity 3.5 Learning task

1. Draw a table in which you compare three characteristics of altricial and precocial offspring. (7)
2. Why is it important for young antelope to be precocial? (3)
3. Group the following animals, depending on whether they are precocial or altricial:
   gorilla, buffalo, rat, giraffe, lion, Egyptian goose, elephant, ostrich, dog, owl. (10)

## Parental care

altruism: behaviour by an organism that may be harmful to itself but favours the survival of its offspring that carries its genes

Parental care involves providing a nurturing and protected environment in which the young can grow and develop. Because of the helplessness of their young, this behaviour is better developed in altricial species. Parental care is considered to be a form of ***altruism***.

Birds and mammals show a greater degree of parental care than other vertebrates. In fish, amphibians and reptiles, there is hardly any parental care. In fact, parental care among these groups is the exception rather than the norm.

Birds, whether they are altricial or precocial, show a high degree of parental care for their young. One or both of the parents feed the chicks (Figure 3.17) and protect them from danger as best they can. Feeding chicks takes a lot of time and energy, so birds that produce altricial chicks tend to lay fewer eggs so that they can cope with caring for their offspring. Parent birds will also protect chicks from the weather and keep them warm. This is particularly important in species that breed in very cold environments like the Antarctic. One such bird is the Emperor Penguin shown in Figure 3.18. The egg and later, the newly hatched chick, of the Emperor Penguin must stay on the feet of the parent at all times. If it does not, the egg may fail to develop because of coming into contact with the ice. Without a high degree of parental care the chick would never survive. Each pair of Emperor Penguins produce only one egg per season because so much parental care is involved in looking after the egg and the chick.

*Fig. 3.17 A cattle egret feeds her young*

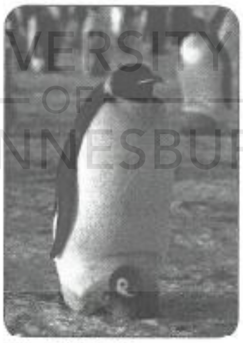

*Fig. 3.18 An Emperor Penguin keeping a newly hatched chick warm*

## Activity 2.4
**Practical Work**

### Practical Investigation of Meiosis

**What you need**

- The micrographs shown on the next page

**What you should do**

Examine the micrographs which show the various stages of meiosis. Note that the micrographs are not in the correct sequence in which they occur when the process of meiosis takes place.

*Answer the following questions:*

1. State TWO places each where this process will take place in:
   a. Plants (2)
   b. Animals (2)

2. Write down the numbers 2.1 to 2.8 and next to each, the answer that will best complete the table below.

| Micrograph | Name of Phase | Reason for Identification |
|---|---|---|
| C | 2.1 | 2.2 |
| D | 2.3 | 2.4 |
| G | 2.5 | 2.6 |
| H | 2.7 | 2.8 |

(12)

3. State ONE reason why you would identify:

   3.1 Micrograph A as Telophase
   3.2 Micrograph B as Metaphase
   3.3 Micrograph E as Prophase 2 (3)

4. List TWO reasons why meiosis is regarded as being very important, (2)

5. If the original cell undergoing meiosis had 14 chromosomes, how many chromosomes will be present in each cell in micrograph H? (1)

6. Explain your answer to question 5 above. (1)

7. Make a fully labelled drawing of the cell shown in micrograph F if the cell undergoing meiosis had 6 chromosomes at the beginning and this stage was in its first division. (7)

[30]

of

ristics that
ition/best
survive

ding to

atural selection

Ground Finch

bler Finch

**Did you know that....?**

The British economist Herbert Spencer first used the term "Survival of the Fittest" in1864.

In his 1869 edition of *On the Origin of the Species*, Charles Darwin used the term to describe that, in the competitive struggle for existence, only those organisms that are best adapted to the environment survive.

## Activity 4.1.2: Homework/ Classwork : Early Theories of Evolution

**Individual Work**

LO2: AS1; AS2; AS3
**LO3: AS1**

1. Give the correct name for each of the following:
   1.1 the ship on which Charles Darwin travelled on his five-year journey collecting specimens of plants and animals
   1.2 the islands off the west coast of Ecuador, where Darwin made many of his observations of plants and animals
   1.3 the group of birds in which Darwin noticed great variation in beak sizes and structures (3)
2. From the list given in Column II, select the name of the person which best fits the description given in Column I. Write only the letter next to each number: 5x2=(10)

| COLUMN I | COLUMN II |
|---|---|
| 2.1 law of use and disuse | A - Erasmus Darwin |
| 2.2 *On the Origin of Species* | B - Charles Darwin |
| 2.3 simultaneously, but independently of Charles Darwin, came up with theory of evolution by natural selection | C - Alfred Russell Wallace |
| 2.4 all life forms developed from a single filament or spermatozoon | D - Jean Baptiste de Lamarck |
| 2.5 all quadrupeds were branches of one family tree. | E - Gregor Mendel |
| | F - Comte de Buffon |

3. Why is Lamarck's theory of evolution by adaptation to the environment rejected by most scientists? (3)
4. Briefly explain Charles Darwin's theory of evolution by natural selection. (5)
5. What evidence do we have that indicates that Charles Darwin had worked within a strong code of ethics? (2)

/23/

## Advantages and Disadvantages of Sexual Reproduction

Sexual reproduction has two main advantages. Firstly, the offspring produced are genetically different from each other and their parents. This means that, if conditions in the habitat change drastically, at least some of the individuals might still find the conditions suitable and survive. Secondly, the zygote, in many cases, is covered by thick protective coat which allows it to survive unfavourable conditions. The main disadvantage of sexual reproduction is that the chances of sexual reproduction taking place is reduced if, as in many cases, two different individuals are required. This is especially true if the population size is small (i.e. there are only a few individuals in the habitat) and they are far apart. Where sexual reproduction can take place within the same individual, this disadvantage does not apply.

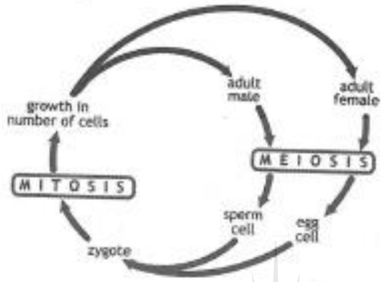


*Fig. 2.5.2. Life Cycle of a some plants and animals , showing the role of mitosis and meiosis*

### ACTIVITY 2.5.1. HOMEWORK/CLASSWORK : Asexual and Sexual Reproduction

Individual Work

**LO1: AS3**
LO2: AS1;AS2; AS3

1. Give the correct biological term for each of the following:
   1.1 The type of reproduction that results in genetically identical offspring.
   1.2 The re-growth of body parts from pieces of an organism.
   1.3 New individuals arise from outgrowths of existing ones. (3)
2.. State whether true or false. If false, correct the statement.
   2.2 The main purpose of meiosis is to bring about growth of the new individual
   2.2 The individuals formed from asexual reproduction are all clones
   2.3 Fragmentation does not always result in the formation of new individuals (3)

/6/

*Appendix D: Sample coded pages*

| Grade and Textbook | Strand | Page No. | No. of units identified | Coder A (researcher) NOS theme no as stated in content analysis framework | Coder B (independent coder) NOS theme no as stated in content analysis framework | Agreement |
|---|---|---|---|---|---|---|
| Focus CAPS | Life at the Molecular, Cellular ad Tissue level | 3 | 1 | 1c | 1c | 1 |
| | | | 2 | 1c | 1c | 1 |
| | | | 3 | 1c | 1c | 1 |
| | | | 4 | 1c | 1c | 1 |
| | | | | | | |
| Focus NCS | Diversity, change and continuity | 118 | 1 | 1c | 1c | 1 |
| | | | 2 | 1c | 1c | 1 |
| | | | 3 | 1c | 1c | 1 |
| | | | 4 | 1c | 1c | 1 |
| | | | 5 | 2a | 2a | 1 |
| | | | 6 | 2c | 2c | 1 |
| | | | 7 | 1c | 1c | 1 |
| | | | | | | |
| Solutions for all CAPS | Life processes in plants and animals | 56 | 1 | 2a | 2a | 1 |
| | | | 2 | 2a | 2a | 1 |
| | | | 3 | 2a | 2a | 1 |
| | | | 4 | 2a | 2c | |
| | | | 5 | 1c | 1c | 1 |
| | | | 6 | 1c | 1c | 1 |
| | | | 7 | 1c | 1c | 1 |
| | | | 8 | 2d | 2d | 1 |
| | | | | | | |
| | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Life at the Molecular, Cellular ad Tissue level | 31 | 1 | 1c | 1c | 1 |
| | | | 2 | 1c | 1c | 1 |
| | | | 3 | 2d | 2d | 1 |
| | | | 4 | 2d | 2d | 1 |
| | | | 5 | 2d | 2d | 1 |
| | | | 6 | 2d | 2d | 1 |
| | | | 7 | 2d | 2d | 1 |
| | | | 8 | 2d | 2d | 1 |
| | | | 9 | 2d | 2d | 1 |
| | | | 10 | 2d | 2d | 1 |
| | | | 11 | 2d | 2d | 1 |
| | | | 12 | 2d | 2d | 1 |
| | | | 13 | 2d | 2d | 1 |
| | | | 14 | 2d | 2d | 1 |
| | | | 15 | 2c | 2a | |
| | | | 16 | 2d | 2d | 1 |
| | | | 17 | 3h | 3h | 1 |
| | | | | | | |
| | Diversity, change and continuity | 249 | 1 | 1c | 1c | 1 |
| | | | 2 | 1c | 1c | 1 |
| | | | 3 | 1c | 1c | 1 |
| | | | 4 | 1d | 1d | 1 |
| | | | 5 | 1d | 1d | 1 |
| | | | 6 | 1d | 1d | 1 |
| | | | 7 | 1d | 1d | 1 |
| | | | 8 | 1d | 1d | 1 |
| | | | 9 | 4h | 4h | 1 |
| | | | 10 | 3a | 3a | 1 |
| | | | 11 | 4i | 4i | 1 |
| | | | | | | |
| | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Life processes in plants and animals | 158 | 1 | 1c | 1c | 1 |
| | | | 2 | 1c | 1c | 1 |
| | | | 3 | 1c | 1c | 1 |
| | | | 4 | 1d | 1d | 1 |
| | | | 5 | 1d | 1d | 1 |
| | | | 6 | 1d | 1d | 1 |
| | | | | | | |