AN ANALYSIS OF GRADE 12 PHYSICAL SCIENCES TEXTBOOKS FOR THE INCLUSION OF SCIENCE PRACTICES

by

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This study is dedicated to

"Almighty God"

Who has given me the wisdom and strength

And seen me through this study

May HIS name alone be glorified in Jesus' Name.

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DECLARATION

I, Emmanuela Ndumanya, declare that this report titled:

"An analysis of grade 12 Physical Sciences textbooks for the inclusion of science practices"

is my own work and all the sources I have used or quoted have been indicated and acknowledged by means of complete reference. This report is being submitted to the University of Johannesburg in fulfilment of the requirements for the degree of Masters in Science Education.

E. Ndumanya Date: 31 January 2019

SYNOPSIS

The crucial role of textbooks in determining to a large extent what is taught and learned in the classroom is highly imperative in reflecting the aims of the curriculum and recent science education reform. As a result, science teachers globally heavily depend on the textbooks as a fundamental tool to guide teaching of content knowledge and skills prescribed in the curricula (Chiappetta & Fillman, 2007). The recent education reform interest has shifted to engaging learners to participate in science practices emphasized in the Next Generation Science Standard (NGSS) (NRC, 2012). This shift calls for rebranding the learning of science as inquiry from the previous *National Science Education Standards* to science practices in the recent *K-12 Framework* of science education (NRC, 1996; NRC, 2012). The National Research Council (NRC, 2015) thus calls for design of textbooks to support teachers and learners in accomplishing the vision of the new science education *Framework* and NGSS.

The purpose of this study is to explore the inclusion of science practices in three grade 12 Physical Sciences textbooks. The research process involved two phases. The aim of Phase One was to develop a rubric grounded on the eight NGSS science practices to analyse the three Physical Sciences textbooks. The aim of Phase Two was to analyse the extent to which the grade 12 Physical Science textbooks include the science practices suggested in the NGSS. The methodology of qualitative content analysis was employed in the analysis of the three textbooks. The textbooks were read and coded based on analytical framework identified in new *K-12 Framework* using the eight NGSS science practices (NRC, 2012). The findings on Phase One showed that the developed (SPCR) rubric was feasible for analysing science textbooks for the inclusion of science practices after it was practically used in a pilot study. Phase Two indicated that although all the eight science practices were identified in the textbooks, they are not adequately addressed in each textbook. The results also show a varied representation of the inclusion of science practices across the textbooks. The majority of the inclusions are at lower level (i.e. teacher-directed approach). As a result, the textbooks do not provide learners with autonomy to fully participate in the science practices as emphasized in new *Framework* and NGSS to enable improvement in new generation learners' literacy in science. Consequently, the results suggest that the textbooks should be modified to adequately include all the science practices at high level recommended in the NGSS for science learning.

Keywords: **Textbook analysis, inquiry-based learning, NGSS science practices.**

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LIST OF ABBREVIATION

AAAS	American Association for the Advancement of Science
CAPS	Curriculum and Assessment Policy Statement
DBE	Department of Basic Department
IBL	Inquiry-based Learning
LO	Lesson outcome
NGSS	Next Generation Science Standards
NRC	National Research Council
NSES	National Science Education Standards
PS	Physical sciences
SA	South Africa
SI	Scientific Inquiry
SPCR	Science Practices Continuum Rubric

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CHAPTER ONE

INTRODUCTION AND BACKGROUND TO THE STUDY

1.1 INTRODUCTION

The significant role played by textbooks in translating the purposes of a curriculum into classroom practices is imperative in reflecting the objectives of recent science education reforms, such as the developing science content knowledge and inquiry skills in learners (Albach & Kelly, 1998). Research conducted in different educational stages has revealed that science teachers depend solely on textbooks in driving teaching and learning (Niaz & Maza, 2011; Ramnarain & Chanetsa, 2016). In this view, the interest of research efforts in science education in various education systems has immensely shifted in exploring the quality of textbooks (Aldahmash, Mansour, Alshamrani & Almohi, 2016; Dunne, Mahdi, & O'Reilly, 2013).

The previous science education reforms endorsed the concept of inquiry as a common curricular goal and instructional strategy in different science education landscapes [National Research Council] (NRC, 1996; 2000). The vision of science education reforms is to advance learners' literacy in science to enable them make an informed and reasonable decisions on science issues at personal and societal level (Lederman, Lederman, Bartos, Bartels, Antink-Meyer & Schwartz, 2014; National Research Council [NRC], 1996, 2000). In this significant view, the *National Science Education Standards* (NSES) in the United States emphasized that learners should be exposed to experiencing authentic science learning as a means of developing inquiry abilities and at the same time to gain a better understanding of science contents and concepts in science education (Asay & Orgil, 2009; Lederman, Lederman & Antink-Meyer, 2013; NRC, 2000). Consequently, it calls for the holistic learning of science through engaging in processes of inquiry known as the inquiry-based learning (IBL) approach.

Inquiry-based learning has become the most prominent theme of science curriculum reforms across the globe. It strongly emphasizes learners' construction of scientific knowledge through active learning rather than acquisition or rote learning (Anderson, 2007; Ramnarain & Hlatswayo, 2018).

Therefore IBL refers to an educational strategy that provides the learner with opportunities to engage actively in scientific processes that occur in an investigation (Minner, Levy & Century, 2010).

In addition, it applies to practices similar to those of scientists in order to make sense of the construct of scientific knowledge (Pedaste, Maeots, Siiman, de Jong, van Riesen, Kamp, Manoli, Zacharia & Tsourlidaki, 2015; Tairab & Al-Naqbi, 2017).

Basically, inquiry is "a complex and multifaceted activity that incorporates both cognitive and physical activities such as describing objects or events through observation; asking questions; constructing explanations through investigation; testing those explanations against current knowledge and communicating the ideas/result" (Ramnarain & Kibirige, 2010).

Furthermore, an IBL approach has been recommended by the science education community at national and international level as an effective teaching and learning approach for meaningful and authentic learning of science contents and concepts in schools. This is because it is driven by questions formulated or posed by learners, thereby increasing learners' autonomy over their own learning (Ramnarain & Hobden, 2015); foster learners' conceptual understanding of scientific concepts and ideas (Yang & Liu, 2016); and addresses learners' motivation in science education (Harlen, 2013). It also helps to improve learners' achievement in science, which is important in the advancement of industrial and economic success (Aldahmash et al., 2016; Crawford, 2014). In this regard, the National Science Education Standards proposed that the five essential features of inquiry should be included in curriculum material, in order to support science teachers in using scientific inquiry in school science teaching and learning.

In the past two decades, significant commitments have been made to improve science education by organisations such as the American Association for the Advancement of Science (AAAS), the National Science Foundation (NSF) and National Research Council (NRC) at school, district and state levels globally. Currently, the National Research Council has proposed a K-12 *Framework* for science education that emphasized engaging learners in scientific practices to improve the quality of scientific literacy for all learners (NRC, 2012). The new *Framework* expectation is that all inquiry-based approaches should engage learners to fully experience practices of science themselves and not only to learn about them "second-hand". Science practices hence are the major practices in which real life scientists engage while they study and construct models and theories about the natural world (NRC, 2012).

These scientific practices thus are expected to be integrated into science textbooks as a means of supporting teachers and learners in actualising the vision of the new K-12 *Framework* and Next Generation Science Standards (NRC, 2015). The quality of textbooks has a huge impact on the quality of instruction. Improving the quality of textbooks is therefore, an essential factor in achieving the implementation of curriculum reforms.

Considering the over-reliance of teachers on using textbooks as the primary tool in driving teaching and learning in classrooms, this study targeted the inclusion of science practices in Physical Sciences textbooks. The significance of science practices is discussed in the next section. Through the content analysis of three Grade 12 Physical Sciences textbooks, this study explores how the reforms emphasis on science practices is being represented and communicated in South African science textbooks.

1.2 BACKGROUND TO THE STUDY

The concept of inquiry has been endorsed as a curricular goal and pedagogy in Science Education by numerous science education reforms documents in countries other than the United States of America (USA) (Barrow, 2006; Crawford, 2014). For example, this is also evident in South Africa's current science education curriculum policy document (DBE, 2011). However, this recent national curriculum document, known as the Curriculum and Assessment Policy Statement (CAPS) specific to Physical Sciences, has prescribed an inquiry-based learning approach in doing and learning school science (Department of Basic Education [DBE], 2011:6). This was specified in Specific Aim 1, where the use of scientific inquiry to engage learners in investigating skills relating to physical and chemical phenomena was stressed. Examples of such skills include classifying, designing an investigation, drawing and evaluating conclusions, formulating hypothesis and models, identifying and controlling variables, observing and comparing, problem solving and reflective skills.

It further highlighted the promotion of high knowledge and high skills in scientific inquiry in learning a Physical Sciences subject, which helps prepare the learners for future learning, careers and citizenship (DBE, 2011). The analysis of the CAPS (Physical Sciences) document therefore reveals examples of most knowledge and skills related to science practices.

Spillian and Callahan (2000) argue that teaching practices often focus on inquiry processes and skills (hands-on) but neglect learner engagement in developing scientific explanations and knowledge (mind-on) through inquiry. As a result, the Next Generation Science Standards (NGSS) of the USA call for a shift towards science practices as presented in the NGSS which stress the scientific knowledge feature of inquiry which is often separated from the inquiry processes in the implementation of teaching science as inquiry; as a way of rebranding inquiry (Reiser, 2013).

In this view, the new *Framework for K-12 Science Education* and NGSS of the USA advocate "authentic school science experience" where learners should be taught in a way consistent with the way modern scientists work (NRC, 2012; NGSS Lead States, 2013). This means a real-life situation in science education to enhance developing a better understanding of science content and concepts, including scientific processes (National Research Council, 2012; NGSS Lead States, 2013). The essence of this vision thus, presents an incomparable opportunity to transform science education for all students. For this reason, the new science education *Framework for K-12* integrated three dimensions: Scientific and Engineering Practices, Crosscutting Concepts and Disciplinary Core Ideas, with the intention of improving learners' expected performance for K-12 science education (National Research Council [NRC], 2012).

Furthermore, in the new *Framework for K-12 Science Education*, instead of "skills" the term "practices" is used to highlight that appropriate understanding of science ideas and concepts requires integration of knowledge of scientific explanation (content knowledge) and the practices needed to participate in scientific inquiry simultaneously (National Research

Council [NRC], 2012). The outlined "scientific practices" include: *asking questions; developing and using models; planning and carrying out investigations; analysing and interpreting data; using mathematical and computational thinking; constructing explanation; engaging in argument from evidence*; and *obtaining, evaluating and communicating information* (National Research Council, [NRC], 2012:42; NGSS Lead States, 2013).

An inquiry-based learning approach is promoted by science curriculum reforms, and the current framework aims to expand and enrich the learning and teaching of science through inquiry. Inclusion of practices in science curriculum material therefore has been found to influence the learning of school science, for instance improving learners' proficiency in science, understanding the scientific knowledge development process, understanding the nature of science and stimulating interest in learners, and using science ideas and concepts in interpreting phenomena, solving problems and making decisions (Duschl, Schweingruber and Shouse, 2007).

Textbooks often provide immense support to the teacher, as they become a framework and guide to ensure learners experience the world view of science (Aldahmash et al., 2016). Textbooks as instructional tools support teachers in planning lessons and delivering science instruction to meet local and national standards (Chiappetta & Fillman, 2007). According to Niaz and Maza (2011), textbooks not only influence what and how students learn, but also determine in large measure what is taught and learned in the classroom. Textbooks are therefore key factor in translating the objectives of the curriculum into classroom practices (Albach & Kelly, 1998).

The National Research Council (NRC, 2015), however, calls for the need for the design of curriculum materials (curricular and textbook) which aligns with the new *Framework* and NGSS science practices. An international study on textbook analysis for the inclusion of scientific practices revealed a varying degree of representation, which is not satisfactorily aligned with the recent science learning framework (Stavros, 2016).

1.3 RATIONALE

Science textbooks play a crucial role in supporting teachers, as they communicate the topic outline for the curriculum and hold a huge amount of the information implemented in the classroom (Aldahmash et al., 2016). The availability of textbooks which incorporate science practices is an important factor in ensuring that the recent science curricular reforms goals are met (NRC, 2015; Penuel & Reiser, 2018).

This is because the science teachers rely heavily on the textbook as a primary tool to guide the teaching of content and skills prescribed in the curricula (Chiappetta & Fillman, 2007, Ramnarain & Padayachee, 2015).

In addition, science teachers and learners both have misconceptions about teaching and learning science as inquiry. They usually focus on developing inquiry processes, while engagement in developing scientific explanation and knowledge through inquiry is neglected, and this negatively affect high school learners' advancement in scientific literacy (Spillian & Callahan, 2000). This has led to reinforcing rote learning in science education and insufficient performance in science subjects (Crawford, 2007).

Science practices have, however, become the recent focus in science teaching and learning over the last few decades with the intention of improving learners' development and utilisation of science knowledge and practices for citizenry, workforce and future learning (NRC, 2012). Integrating the science practices into the science textbooks therefore has the potential of supporting teachers in facilitating inquiry-based learning and actualising the vision of the new science education *Framework* and NGSS (NRC, 2012).

1.4 PROBLEM STATEMENT

Despite the curricular prominence given to learning of science through an inquiry-based learning approach, in its implementation there has been a lack of coordination between science content knowledge and inquiry processes, with heavy emphasis being placed on processes development, while engagement in developing scientific explanation and knowledge through inquiry is neglected (Spillian & Callahan, 2000; Ramnarain, 2014). This is because of the inconsistency in various views of science as inquiry by science teachers and curriculum developers (Crawford, 2014). In addition, most research interests in science education have focused on teachers and learners, with less effort in improving curriculum materials (textbooks) that support teacher and learner in actualising the reforms goals (Banilower, Smith, Weiss, Malzahn, Campbell & Weis, 2013; NRC, 2015).

However, Stavros (2016) claim that the analysis focusing on science practices representation in textbook content is rare. Hence there is a need for research to analyse school science textbooks for science practices, especially in a South African context, in order to improve the availability of high-quality science textbooks in high schools nationwide.

1.5 RESEARCH QUESTIONS

Due to teacher reliance on the textbook in implementing an inquiry-based pedagogy, and the call for engaging learners in science practices, this study centred on the analysis of school science textbooks for science practices. In particular, this study focused on the analysis of three grade 12 Physical Sciences textbooks use in South African classrooms. The research is guided by the following questions:

Main Question

- To what extent do grade 12 Physical Sciences textbooks reflect the science practices suggested by the NGSS?

Sub-Question

- What levels of included confirmatory, structured, guided and open-ended science practices are present in the three analysed Physical Sciences textbooks?
- How are these science practices addressed within the knowledge areas of Physical Sciences across the three textbooks?

1.6 RESEARCH AIM AND OBJECTIVES

Aim

The aim of this study is to determine the extent to which Physical Sciences textbooks depict the science practices suggested by the NGSS.

Objective

The objectives of this study include:

1. To develop a rubric for analysing the three grade 12 Physical Sciences textbooks for science practices.

2. To apply this rubric for the analysis of the three grade 12 Physical Sciences textbooks for the inclusion of science practices.

1.7 CONCEPTUAL FRAMEWORK OF SCIENCE PRACTICES

Recently science education reforms considered it worthwhile that learners should develop scientific practices, and as a result it has become the main objective in various education landscapes (NRC, 2012). The National Research Council defines scientific practices as the main practices in which scientists are engaged while studying and constructing models and theories about the world. It also applies to providing opportunities that engage learners in the process of science practices as real scientists in developing and utilising science concepts and ideas, to gain a better understanding of their society (NRC, 2012). This study therefore adopted the conceptual framework of eight science practices identified in the US science education *K-12 Framework* and NGSS (NRC, 2012; NGSS Lead States, 2013) namely:

- *Asking Questions*

Scientific questions often lead to explanations of how the natural and human-built world works. They can be tested empirically, using evidence.

- *Developing and Using Models*

Models are abstract representations of phenomena or events that can be used to explain and predict the world.

- *Planning and Carrying out Investigations*

Investigation applies to a systematic way of collecting data about the world, either in the field or the laboratory.

- *Analysing and Interpreting Data*

This includes using tables and graphs in making sense of data produced during scientific investigation.

- *Using Mathematics and Computational Thinking*

This involves using tools and concepts of mathematics in addressing a scientific question.

- *Constructing Explanation*

Constructing explanation in science refers to explanatory accounts that articulate how or why a phenomenon occurs, and is supported by evidence and science ideas.

- *Engaging in Argument from Evidence*

This refers to engaging learners in debates and discussion to evaluate and critique competing argument. An argument involves supporting or refuting a claim using evidence and reasoning

- *Obtaining, Evaluating and Communicating Information*

This involves reading and writing text, and communicating orally. Often information from science needs to be evaluated and persuasively communicated to others in order to support other engagement in the practices of science.

1.8 METHODOLOGY

This study is characterised as qualitative research, and it involved two research phases.

1.8.1 Phase One

This phase involved the process of developing a rubric for this study. This process adapted aspects of the McNeill, Katsh and Pelletier (2015) assessment tool known as Science Practices Continuum-Student Performance Tool and Drafted Inquiry Rubric, developed by the Council of State Science Supervisors (2001). The developed Science Practices Continuum Rubric (SPCR) consists of eight science practices distributed across four levels, with each level defining the amount of confirmation, structure, guidance and openness provided by the textbook or teacher (Aldahmash et al., 2016; Banchi & Bell, 2008). Three science education experts in the field of scientific inquiry research validated the rubric for theoretical underpinning and practical use. It was then piloted in the analysis of a knowledge area in Physical Sciences textbook to establish its feasibility in use.

1.8.2 Phase Two

The study is characterised as a qualitative content analysis approach that explored the extent to which Physical Sciences textbooks represent the science practices. Content analysis is a systematic, rigorous approach to analysing documents by analysing the units such as paragraphs, worked examples, activities, figures with captions, tables with captions and marginal comments (Mouton, 2008). The analysis involves transforming the raw textual material into standardised codes (Babbie, 2001). This approach is appropriate for this study in order to assign meaning to the various aspects of science represented in the textbooks and to interpret its meaning (Krippendorff, 2004).

Purposive sampling was used in selecting three grade 12 Physical Sciences textbooks to be analysed (Creswell, 2014). This study chose to focus on grade 12 textbooks because according to CAPS requirements, they provide more opportunities for science "practices" compared to other grades. The selection of textbooks is based on their inclusion in the list of Physical Sciences textbooks recommended by the South African Department of Basic Education (DBE) and their compliance with the Curriculum and Assessment Policy Statement [CAPS]. The textbooks chosen were the three most commonly used in Physical Sciences classrooms. The conceptual framework used for the textbook analysis incorporates the eight science practices described in the Next Generation Science Standards (National Research Council, [NRC], 2012). These "practices" identified in the previous section include the eight NGSS science practices and descriptions.

1.8.3 Reliability and validity of coding the textbook

In addressing reliability, the textbook was analysed independently by myself and another researcher with a PhD in science education. The reliability was also determined statistically using percentage agreement and Cohen's kappa formula (Cohen, 1990). The results were then presented in the forms of frequencies and percentages for each of the eight science practices in the science textbooks and workbooks. To ensure the validity of the results, the process of coding was based on the analytical framework that coexisted with the valid conceptual framework of science practices in the new *K-12 Framework* for science education (NRC, 2012).

1.9 PRESENTATION OF STUDY REPORT

This study report will include in-depth discussion in the following chapters:

Chapter One has provided an introduction, background to the study, rationale, aims and objectives. I went further to provide a brief explanation of how the study was conducted in regards to the methodology and reliability.

Chapter Two of this study continues with an evaluation of South African education and science education reforms, a review of literature and presentation of a proposed analytical, theoretical and conceptual framework. My study discussion on literature includes science as inquiry, science as practices, the role of textbooks and the significance of inclusion of science practices in textbooks. I went further to highlight previous studies on textbook analysis for the inclusion of science practices.

Chapter Three presents in-depth discussion of the selected research methodology, research design, and data analysis procedures employed for this study. It also includes calculations and tables on the percentage agreement and Cohen kappa.

Chapter Four presents my study findings on the analysis of textbooks for the inclusion of science practices. This includes the table of developed rubric and tables of data collected from my study of analysis of three Physical Sciences textbooks for the inclusion of science practices, comparing the inclusion across the entire textbooks and how the inclusion is being addressed within the knowledge areas in the textbooks, which are presented in graphs as well.

Chapter Five, finally, presents the summaries of the findings, recommendations, limitation and implication of study, suggestions on future research and conclusion.

CHAPTER TWO

LITERATURE REVIEW ON TEXTBOOK ANALYSIS AND SCIENCE PRACTICES

2.1 INTRODUCTION

A review of literature is an important part of research that helps broaden the researchers' understanding of the topic or concept studied, and to know what has been done about the topic already by other researchers, how it has been researched, and to provide insight into the major issues that need to be addressed by further research. A literature review is therefore "the analysis, critical evaluation and synthesis of existing knowledge relevant to your research problem" (Hart, 1998). This chapter of research addresses what other researchers found on textbook analysis, the core concepts and findings from different countries and educational context.

In this study, the literature review discussed the following aspects: context of South African school phases, trend in curriculum reforms, science as inquiry, and the move from inquiry to science practices. It also addresses the theoretical and conceptual framework, the roles of textbooks, previous studies on textbook analysis and, finally, the implication of inclusion of science practices in science textbooks.

2.2 CONTEXT OF THE CURRICULUM REFORMS IN SOUTH AFRICA

2.2.1 Phases of South African Education

The South African general education and training band is subdivided into four phases: foundational; intermediate; senior; and further education training band (FET) (Department of Education [DOE], 2007a). The lower school, "primary education", which lasts for seven years, includes the foundation phase (grade R plus grade 1 to 3) and the intermediate phase (grade 4 to 6). The higher school is "secondary education", usually known as high school, and lasts for five years. This includes the senior phase (grade 7, continued in secondary school in grades 8-9). Finally, is the further education and training that lasts for three years (grade 10-12). Science as a subject is taught in all phases of general education and training and is made compulsory. In the primary school phase, science is taught as a general science course.

In the secondary school phase it is taught as a general course known as Natural Science in the senior phase, but it is divided into two courses (Life Sciences and Physical Sciences) in the FET phase. The Life Sciences consists mainly of Biology, while Physical Sciences consist of Physics and Chemistry.

2.2.2 Curriculum reform in South Africa

According to Marsh and Wallis (1995), a curriculum as teaching and learning guide serves "to equip learners with knowledge and skills derived from surrounding society that can be applied to assist them in obtaining necessities such as food, clothing and shelter" (p. 42).

Some major transitions in developing a South African school curriculum document have occurred since the post-apartheid era in 1994, with the intention of using education as a tool to redress inequities and injustices (Bantwini, 2010; Erduran & Msimanga, 2014). It also aims to achieve the goal of producing active and informed scientific citizens who can contribute positively towards national and international economic growth. The school curriculum review in South Africa has proceeded in four major transitions:

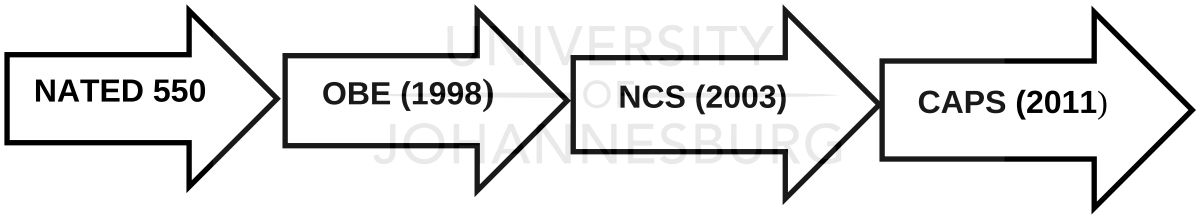

Figure 2.1: Trend in South African curriculum reforms

The first transition involved transforming the apartheid regime's NATED 550 curriculum, which held a narrow perception of scientific literacy where science subject matter was depicted as a "static body of knowledge" (Padayachee, 2012). The reviewed process aimed to set down a foundation on the principle of teacher-centred education and present the national core syllabus in a participatory and representative-manner. The purpose of the change was to get rid of the racial language and old content of the school syllabus (Bantwini, 2010).

The second transition, in 1997, involved the launch of curriculum 2005 (C2005), which was based on the framework of outcomes-based education (OBE) and driven by a learner-centred education process and activity-based learning. The aim of this revision was to “unlock the potential of the child” through a self-discovery process by means of teachers’ efficiency and deliberate facilitating or guiding role (Padyachee, 2012). This transition is grounded by social values such as individual equity and human rights.

The third curriculum transition, in 2002, involved a review of C2005 leading to the introduction of the Revised National Curriculum Statement based on an OBE framework, with the vision and values of the National Constitution. In this view, this curriculum review remains on the foundation of learner-centred education and aligned with learners’ achievement (DoE, 2000). In this version, the science curriculum courses and contents (such as Natural Sciences and Physical Sciences) were specified but not graded.

Finally, the fourth transition involved the review of the RNCS in 2011 with the aim being to modify major areas such as core content, redesign of the continuous assessment programme, discontinuation of lesson outcomes (Los) and inclusion of specific aims. This led to the introduction of the Curriculum and Assessment Policy Statement (CAPS), which is specific for all science courses and content (Physical Sciences, Life Sciences and Natural Sciences) per grade (Department of Basic Education [DBE], 2011). The new National Curriculum and Assessment Policy Statement thus prescribes the use of an inquiry-based learning approach in helping learners develop high knowledge and high skills in school science (DBE, 2011:6).

2.2.3 Reflection of science practices in the national curriculum document

The new curricular policy document known as the Curriculum and Assessment Policy Statement (CAPS) is designed specifically for all subjects and grades. For example, the subject of Physical Sciences is described as one that ‘investigates physical and chemical phenomena. This is done through scientific inquiry and application of scientific models, theories and laws, in order to explain and predict events in the physical environment’ (DBE, 2011:6).

The recent National Curriculum document for Physical Sciences has prescribed the use of an inquiry-based learning approach in doing and learning science. This was specified in Specific Aim 1, where it states that the “purpose of Physical Sciences as subject aims to equip learners with investigating skills relating to physical and chemical phenomena. Examples of such skills include classifying, designing an investigation, drawing and evaluating conclusions, formulating hypotheses and models, identifying and controlling variables, observing and comparing, problem solving and reflective skills" (DBE, 2011: 6-7).

It further highlighted in Specific aim 2 and 3 that high knowledge and high skills are being promoted in scientific inquiry and problem-solving in learning Physical Sciences, as well as to prepare learners for future learning, careers and citizenship (DBE, 2011:6). The analysis of the CAPS (Physical Sciences) document, therefore, reveals examples of most of the knowledge and skills related to science practices.

2.3 TRACING HISTORY OF SCIENCE EDUCATION TRANSFORMATION

Historically, in the 1960s, science education reforms' main reason for innovation was to introduce the *processes* of science, which served to replace *method* of science (Schwab, 1960). The processes of science in the reform indicate that the learning of school science should move away from learners memorising the five steps in the scientific method to learning basic processes particular to science, such as questioning, observing, classifying, measuring, analysing, inferring, predicting, explaining and communicating (Bybee, 2011).

In the view to complement this, the earlier science education reforms grew interest and support for teaching and learning of science using a scientific inquiry approach in the period of 1960-1990. The National Science Education Standards (NSES) thus emphasized using inquiry as an effective strategy to teach and learn concepts and ideas specific to science (American Association for the Advancement of Science [AAAS], 1993; NRC, 1996). This means that the goal of the science *Standards* is to develop fundamental abilities to scientific inquiry in all K-12 learners, and there should be a shift in learning from teacher-directed to learner-directed instruction (NRC, 2000). The NSES suggested, therefore, that learners should play an active role in their own construction of science knowledge based on their prior knowledge. Again, the science curriculum documents and textbooks should integrate the five essential features of inquiry to facilitate implementation in science classrooms (AAAS, 1993; NRC, 1996).

Similarly, South African science education has gone through some major transitions in developing the new curriculum statement document (CAPS) since the apartheid regime. During the apartheid, the general philosophy promoted strong control of the fundamental strategies in education. Science method was considered to be the only way learners could be engaged in learning science, and as a result learners were taught facts and theories.

However, there was a narrow conception of scientific knowledge that promoted transmission of science knowledge. During the Post-apartheid, the science curricular document has changed with strong emphasis on the need to develop learners' literacy in science. In this regard the use of learner-centred and activity-based approaches has been promoted in South African science education reforms (Ramnarain & Modiba, 2013).

In recent years the transformation of science teaching and learning prompted the design and creation of a new science education *Framework* with the view of improving the quality of learners' literacy in science. This new *K-12 Framework* for Science Education integrates the coexistence of three dimensions of learning: science and engineering practices, core ideas and cross-cutting concepts. This has resulted in development of the Next Generation Science Standards (NGSS), with the intention of engaging learners in science and engineering practices to develop and use disciplinary core ideas and cross-cutting concepts to explain phenomena and solve problems in real life (NRC, 2012). Consequently, this has led to rebranding the learning of science from memorising five phases of the scientific method to mastering specific and fundamental processes of science (Bybee, 2011). The new K-12 *Framework* and NGSS therefore, advocated for eight practices of science and engineering in order to promote learners' advancement in scientific content knowledge and inquiry abilities simultaneously (NRC, 2012; NGSS Lead States, 2013).

2.4 SCIENCE AS INQUIRY

During the 1960s Joseph Schwab protested against science education as a presentation of scientific facts and theories (Schwab, 1962). As a result there was a need for fundamental transformation in learning and teaching of science, and Schwab proposed that a science curriculum for schools should reflect the work of real scientists such as posing questions, designing experiments, observing, collecting, analysing and interpreting data and drawing

conclusions. This has led to a shift of science learning from passive acquisition of science knowledge to active and collaborative knowledge construction (Barrow, 2006).
The *National Science Education Standards* hence call for inquiry-based science education in the education system globally (Anderson, 2007; NRC, 1996; 2000).

In the past few decades, inquiry has been placed at the forefront of science curriculum reforms globally, as an innovative instructional approach and learning aim to improve the learning of science in schools and to promote learners' literacy in science (Aldamash et al., 2016; Lewis, 2012). The National Science Education Standards therefore, define inquiry as:

> the process scientists use to build an understanding of the natural world based on evidence. It is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse and interpret data; proposing answers, explanations and predictions; and communicating the results. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (NRC, 1996:23).

According to Anderson (2002), the notion of "inquiry" is employed in three different ways based on the context:

Firstly, *scientific inquiry* is what real-life scientists do. It simply means the various ways scientists use to understand the natural world by conducting scientific investigation of phenomena and proposing explanation depending on the evidence derived from their study and practice. In this view, inquiry sheds light on how science knowledge proceeds, which is independent of processes of science education (Anderson, 2002:2).

Secondly, *inquiry learning* simply refers to the learning process whereby learners engage in activities that provide valuable opportunities to experience the real work of professional scientists (Anderson, 2002). Engaging learners in the inquiry process gives them the chance to actively participate in a range of activities with a focus on describing objects and events, asking questions, constructing explanations, testing those explanations against current knowledge and communicating ideas to others. This process is characterised as the five essential features of inquiry-based learning (NRC, 2000; Asay & Orgill, 2009). During this process, learners exercise more autonomy in their own learning because they formulate their own questions, free in making a decision pertaining to what and how they are learning, in which critical thinking and collaborative learning are necessities (Ramnarain & Hlatswayo, 2018). In this perception, learners develop how to incorporate inquiry abilities and science content knowledge into the learning of science in order to gain a deeper conception of science content, concepts and ideas (Haug, 2014).

Thirdly, *inquiry teaching* refers to the instructional strategy and a kind of learning activity by which teachers engage learners through the process of inquiry (Anderson, 2002). During this process of teaching, the teacher guides the learners through the inquiry process of learning as they answer teacher-provided or presented questions or learner-generated questions based on their observations. Crawford (2014) outlined some of the various inquiry teaching variations, such as project-based, problem-based, authentic science, citizen science and model-based inquiry.

2.5 LEARNING SCIENCE USING INQUIRY-BASED LEARNING APPROACH

The *National Science Education Standards* strongly emphasize teaching and learning of science through inquiry as a means to achieve the distinguished goal of science education transformation across the globe (NRC, 1996; 2000). In addition, the scientists, researchers, policymakers and science teachers universally agreed that learners should experience authentic science learning through an inquiry-based learning approach in order to meaningfully build scientific knowledge and progressively develop inquiry skills based on the knowledge they already have (Aldamash et al., 2016; Asay & Orgill, 2009; Lederman, 2007).

In this view, the South African science education system has prescribed the use of the inquiry-based learning approach in the latest national curriculum document (CAPS) as an acceptable and effective teaching and learning instructional strategy for Physical Sciences, with the specific aim of promoting high knowledge and skills in scientific inquiry and problem-solving. Furthermore, the purpose of the Physical Sciences subject is "to equip learners with investigating skills relating to chemical and physical phenomena. Such skills include classifying, observing, designing an investigation, identifying and controlling

variables, comparing, measuring, interpreting, formulating models, communicating and reflective skills" (DEB, 2011:6).
This is important for the learners' holistic development and their preparation for further learning, the work force and citizenship (Department of Basic Education [DBE], 2011).

The science *Standards* and research community hence specified a shift in their interest in developing a science curriculum and textbooks that integrate the essential features of inquiry-based learning (Aldalmash et al., 2016; Chabalengula & Mumba, 2012; NRC, 2000). These include:

Learners are engaged in scientifically oriented questions

Learners give priority to evidence in responding to questions

Learners formulate explanations based on evidence

Learners evaluate their explanations against scientific understanding

Learners communicate and justify their explanation (NRC, 1996, 2000).

Learning science through inquiry-based approach inspires the engagement of learners in solving problems, answering questions, formulating learner-own questions, designing and conducting experiments, collecting data, interpreting data, discussion, explanation, debating and communicating during class (NRC, 2000). An IBL approach therefore calls for a move from a didactic traditional instructional method to an active learning strategy (AAAS, 1993; Aldamash et al., 2016). This is to accomplish the unique goal of science education reforms globally in terms of developing understanding of the nature of science, high-order thinking, problem-solving skills, positive attitude, interdependence and individual accountability in science learning that is imperative for enriching learning of science, and learners' literacy in science as well (Lederman, Lederman & Antink-Meyer, 2013).

Unfortunately, studies have revealed that many science teachers have a false conception of inquiry and are not implementing the idea of an inquiry-based approach as recommended in the national curriculum document in science classrooms (Mokiwa & Nkopodi, 2014; Crawford, 2000). More often, there is a lack of coordination between inquiry skills and knowledge construction in the learning of science, with heavy emphasis being placed on skill development because of some reasons (Ramnarain & Hobden, 2015). This is due to common constraints such as lack of clarity with respect to what inquiry constitutes; lack of examples of how to facilitate inquiry-based learning instruction in a real science class; lack of explicit integration of inquiry with science content; lack of time; and learners' inadequate knowledge and skills (Crawford, 2014).

Consequently, the new K-12 *Framework* of science education, with the resulting Next Generation Science Standard (NGSS) in the USA, proposed the rebranding of inquiry-based learning to scientific practices, in order to address the confusion over various meanings of inquiry in the classroom (NRC, 2012; Crawford, 2014).

2.6 THE MOVE FROM SCIENCE INQUIRY TO SCIENCE PRACTICES

Considering the fact that "science is more than a body of knowledge to be learned, it also involves the method or process to learn" (Dewey, 1910:14). The learning of science through inquiry thus requires both the "doing" of inquiry (knowing how) and learning about the "nature of science" (knowing what and why). This simply means integrating the scientific skills with the science content knowledge for a richer and deeper understanding of science concepts and ideas (Crawford, 2014; Osborne, 2014). Unfortunately, both science teachers and learners misinterpret the concept of inquiry. The teachers' view of inquiry is more as a process instead of as a vehicle for learning science content, and will integrate science content knowledge with skills simultaneously (Asay & Orgill, 2009; Ramnarain & Hobden, 2015). Consequently, this has resulted in poor implementation of inquiry-based learning in the school science classrooms (Crawford, 2014).

Much attention has therefore been placed on engaging learners in hands-on activities (skills) while the minds-on activities that are a process to seek explanations (content knowledge) are neglected (Crawford, 2014; Spillane & Callahan, 2000). Moreover, the reflection of the five essential features of inquiry-based learning has been revealed to be misappropriated in science curricula and textbooks, in a manner that most of the activities were presented at a lower level of inquiry; that is, a teacher-directed approach to learning. In other words, it does not align with the *National Science Education Standards* which advocate a shift to learner-directed learning of science (Aldamash et al., 2016; Chabalengula & Mumba, 2012; Abd-El-Khalick et al., 2008). Furthermore, there is lack of agreement by researchers on what classroom inquiry entails and how it should be implemented. This has resulted in huge confusion among many science researchers and teachers as well as learners (Crawford, 2014).

As a result, the latest USA K-12 *Framework* of Science Education and Next Generation Science Standards calls for reframing the five essential features of an inquiry-based approach to the eight science practices in order to address the dilemma with different views of inquiry. The new science education K-12 *Framework* is, however, distinguished from previous NSES, which proposed science inquiry in terms of the a) strong emphasis on scientific modelling and argumentation, and b) explicit integration of scientific content knowledge with science practices (NRC, 2012; NGSS Lead States, 2013). The perception is therefore, to make the notion of learning and teaching science using inquiry explicit, and to advance the quality of science learning.

2.7 SCIENCE AS PRACTICES

The latest vision of science education, grounded in the idea that science is both a body of knowledge and a set of combined practice, hence advocates learning of science to engage learners in developing science and engineering practices, utilising disciplinary core ideas and cross-cutting concepts in explaining phenomena and problem solving (NRC, 2012; Krajcik et al., 2014). The National Research Council defined science practices as:

> the major practices the scientists employed while investigating and constructing models and theories about the natural world. These include: asking questions; developing and using models; planning and carrying out investigations; analysing and interpreting data; using mathematical and computational thinking; constructing explanation; engaging in argument from evidence; and obtaining, evaluating and communicating information (National Research Council, [NRC], 2012).

Scientists and learners utilise science practices in studying and developing new knowledge about the natural world as well. The learning science as practices therefore involves reframing science learning expectations away from the rote memorization of science information to active and progressive participation in the real work of scientists. In this way, the NGSS proposed that the learner is expected to be provided with opportunities to participate in authentic practices of scientists (such as asking questions, conducting investigations, formulating and revising scientific explanations and models using logic and evidence, and communicating and defending science arguments) in order to make sense of society (Schwartz, Passmore & Reiser, 2017; Stroup, 2015).

Furthermore, it is important to highlight that the practices of scientists can be framed into three spheres of activity: a) investigation and empirical inquiry; b) developing explanations and solutions using creative thinking models and reasoning; and c) evaluating using debate and analysing (NRC, 2012).

The investigating sphere is characterised by the science practices of *Asking questions, Planning and carrying out investigation* and *using mathematics and computational thinking*. The developing explanation sphere is characterised by science practices of *Developing and using models, analysing and interpreting data*, and c*onstructing explanation.* The science practices identified in the evaluating sphere include *Engaging in argument* and o*btaining, evaluating and communicating information* (McNeill, Katsh- Singer & Pelletier, 2015). The perspective portrayed by the recent *Framework* is therefore not to replace inquiry; rather it is an idea of expanding and advancing the teaching and learning of science. In essence, science inquiry is one aspect of science practices (NRC, 2012).

Considering 21st century society, which is driven by improved science and technology, current learning of school science should encourage learners to think and engage in using the same practices as modern scientists. The essence of this is to accomplish the common goal of the science education K-12 *Framework* and NGSS in improving learners' literacy in science (NRC, 2012; NGSS Lead States, 2013). It is thus imperative to provide learners with opportunities to integrate science content knowledge with scientific practices in order to gain a deeper understanding of science concepts and ideas, as well inquiry abilities. This is important for participating positively in making informed decisions and contributions to science-related issues in society and daily life.

2.8 SIGNIFICANCE OF INCLUSION OF SCIENCE PRACTICES IN SCIENCE TEXTBOOKS

The recent purpose of science education reforms is to equip learners in developing and using appropriate scientific content knowledge and practices through engagement in the process of science practices (NRC, 2012). The significance of inclusion of science practices in science textbooks is thus discussed below.

2.8.1. Support teaching and learning process

Considering the pivotal role science textbooks play in ensuring that the aims of curriculum reforms are met in the classroom, and over-reliance of science teachers and learners on textbooks to determine what and how to learn and teach, has made design of textbooks that align with NGSS a necessity. As result, the National Research Council (NRC, 2015) calls for the need to design new textbooks that conform to the NGSS, since the recent attention of science education has shifted towards engaging learners in science practices. This is to enrich and expand teaching and learning of science through inquiry-based approaches. Integrating science practices in textbooks therefore has the potential of supporting teachers and learners in realising the ultimate vision of the new Framework and NGSS in this new era of science education (Penuel & Reiser, 2018).

2.8.2. Developing science proficiency

Proficiency in science entails scientific knowledge and process skills that learners need to acquire to enable them to participate as educated citizens in society. Duschl, Schweingruber and Shouse (2007) outlined proficiency in science to include the ability to know, use and interpret science explanation of the world; generate and evaluate science evidence; comprehend the nature and development of science knowledge; and participate effectively in science discourse and practices. In essence, the science practices help to improve science literacy in learners as they actively engage to experience authentic practices of scientist. In this way learners are prepared for citizenry, the work force and future learning (NRC, 2012).

2.8.3. Deeper understanding on how scientific knowledge is developed

Learners developing an understanding of core science concepts and ideas, as well as an appreciation that science is a way of knowing about the natural world, has been a consistent purpose of science education in past decades. Learners' participation in science practices requires providing a learning environment for them to imitate those practices of real scientists during their learning of science (Pedaste et al., 2017). Such direct active engagement gives learners an appreciation of the wide range of strategies used to investigate, model and explain the world. In this way learners are able to make a connection of what they learn in school science with every-day life experience. The learners are thus able to develop and use an understanding of science core ideas and concepts to interpret phenomena, solve societal problems and make decisions related to persons or society (Schwartz et al., 2017; NRC, 2012).

2.8.4. Attracting young learners' curiosity and interest in science

Studies revealed that many learners lose interest in studying science especially during their formative age of 10 to 14 years, because they think that science is knowledge of facts and theories (Schwab, 1960; Crawford, 2014). As a result, the new *Framework* and NGSS vision of science education emphasises that learners should engage in active participation to experience science learning as "the centrepiece". In other words, the learners are supposed to be provided with opportunities to engage in the authentic practices of real-life scientists in learning school science. The learners will stand to gain a deeper understanding of scientific knowledge and scientific practices during engagement in science practices such as asking questions, constructing investigations, developing models and constructing explanations. Learners will come to appreciate the work of professional scientists through this experience as well. Integrating science practices in textbooks thus will help motivate learners in studying science, because it accommodates diverse learning interests in science class, which is a vital goal of science education to motivate and include all learners in learning science (Duschl, Scweingruber & Shouse, 2007; Ramnarain & Hlatswayo, 2018).

2.8.5. Developing scientific reasoning and critical thinking abilities

Engaging learners to participate in argumentative discourse is one ultimate goal of the recent K-12 *Framework* and NGSS. This is because it creates a learning environment that encourage collaborative learning, such as small group discussions and science debates to support or refute a scientific claim using evidence and reasoning (Osborne, 2014; NRC, 2012), consequently, advancing learners' conceptual understanding as they talk science (Berland & Hammer, 2012; Osborne, 2014). Research has proved that learners' active participation in scientific argument increases their performance in science, rather than participation as passive recipients of knowledge (Mercer, Dawes, Wegerif & Sams, 2004). Furthermore, this unique science practice helps learners make science of a phenomenon (Berland & Hammer, 2012), improve verbal reasoning (Mercer et al., 2004), develop meta-knowledge of science, as it requires competencies of critical thinking, including comparison and contrast (Kuhn, 1993)

2.9 THEORETICAL FRAMEWORK OF SOCIOCULTURAL THEORY

Theoretical framework is an important aspect of the research process that provides a grounding base for literature review, especially research methods and analysis. According to Eisenhart (1991), theoretical framework is defined as "a structure that guides research by relying on a formal theory ... constructed by using an established, coherent explanation of certain phenomena and relationship" (p. 205). The recent science education transformation emphasizes engaging learners in science practices that provide them the opportunities to directly experience how scientists really work in the laboratory, as they share and critique each other's ideas to build knowledge about the natural world and drive innovation in science (Furtak & Penuel, 2018).

NGSS science practices are grounded on the sociocultural theory of learning that arises from the field of educational psychology. This view of learning emphasizes the cultural (or situated) nature of the learning process as a defining theme. Lev Vygotsky, in his work, proposed a view of learning in a social context. The idea of Vygotsky on sociocultural theory is underpinned by a central principle that learners internalize higher cognitive functions from social and cultural interaction with more competent others (Vygotsky, 1978:52-56). In other words, learning is a semiotic process that requires participation in socially mediated activities. Another key principle of sociocultural theory is that learning takes place within the "zone of proximal development". This zone applies to the distance between the learners' actual developmental level of solving problems independently and the level of potential development of solving problems with guidance from adults (i.e. scaffolding) (Vygotsky, 1978). This theory appreciates the need for collaborative learning, where learners work together with others (such as teachers, peers) in developing higher cognitive functioning (Miller, 2011).

In view of sociocultural theory, the learning of science practices is recognised as a "cultural accomplishment" (NRC, 2012:283). This means that "just as within the realms of professional science, so too in science classrooms that learning has been defined as transforming participation in scientific communities of practices" (Furtak & Penuel, 2018: 172). During engagement in science practices, learners see how they fit with the larger science enterprise in developing scientific explanations about phenomena, as they collaborate with teachers and peers in the classroom context.

2.10 CONCEPTUAL FRAMEWORK OF NGSS SCIENCE PRACTICES

The conceptual framework is a crucial aspect of any information analysis that serves to guide the inquiry. This study adopted the eight science practices conceptual framework released in the new *Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas* (NRC, 2011) and presented in the Next Generation Science Standards (NGSS Lead States, 2013).

- *Asking questions*

Scientific questions are questions that can be tested empirically and are evidence-based. They often lead to explanations of how the natural world works. Science usually begins with formulating a question about a phenomenon, for instance “Why is the sky blue?” or “What causes cancer?” One fundamental practice of the scientist is the ability to formulate empirically answerable questions about phenomena to establish what is already known and to determine what other questions must be adequately answered.

- *Developing and using models*

Model refers to an “abstract representation of phenomena”, hence science as a discipline commonly involves the constructing and using of models such as 3 –D objects, diagrams, analogies or simulations used to assist developing explanations and make predictions concerning natural phenomena, and to better comprehend the content, process and nature of science, making it possible to go beyond observables and simulate a world not yet seen.

- *Planning and carrying out investigations*

An investigation in science is a systematic way to gather data about the natural world and may be conducted in the field or laboratory. One main practice of real scientists is planning and carrying out systematic investigations aimed at clarifying what counts as data and identifying variables in experiments.

- *Analysing and interpreting data*

Analysing and interpretation of data involves the combination of the raw materials observed during scientific investigation to provide answers to research questions and derive meaning. Often data do not speak for themselves, thus scientists use a range of tools such as tables, graphs and diagrams, including statistical analysis, to identify notable features and patterns in the data generated.

- *Using mathematical and computational thinking*

Mathematics and computation are basic tools in science for representing physical variables and their relationships or to address a scientific question. They can be used in a range of tasks, for instance in constructing simulations, statistical data analysis and recognizing, expressing, and applying quantitative relationships. The practice of mathematics and computation enables prediction of the behaviour of physical systems together with the testing of related predictions.

- *Constructing explanations*

Constructing theories that give explanatory accounts of the natural or man-made world has been identified as the goal of science. In other words, this practice enables making sense of the world and should be at the centre of what is taught and learned in the classroom. The scientific explanation gives an explanatory aspect that articulates how and why a natural phenomenon occurs, which is supported by evidence and ideas about science.

- *Engagement in argument from evidence*

Argumentation in science refers to a process that occurs when there are multiple ideas or claims (such as explanations and models) to be discussed or reconciled. An argument includes a claim supported by evidence and reasoning. In real life, scientists have to defend their explanations, formulate evidence based on a concerted foundation of data, evaluate their understanding in view of evidence and comments by peers, and search for excellent explanations collaboratively for the phenomena investigated. Learners also engage in debates to evaluate and critique competing arguments.

- *Obtaining, evaluating, and communicating information*

The practice of obtaining, evaluating and communicating information occurs through reading and writing as well as communicating orally. Scientists thus advance through communicating their findings clearly and convincingly, or study the findings of others. In this regard the discipline of science necessitates the ability to derive meaning from science texts such as magazines, papers, articles and the Internet. It also includes lectures that will enable evaluation of the validity of scientific information grasps, and to integrate such information into profound explanations.

2.11 ANALYTICAL FRAMEWORK

An analytical framework is an important aspect in research that supports research to approach issues with logic and in a systematic manner. This is because it sets a clear driving force behind the inquiry lines. The analytical framework for this study adapted the current *framework* for science education by the National Research Council (NRC, 2012) and the *Next Generation Science Standards* (NGSS, 2013). This includes the eight science practices with descriptions for each practice (NRC, 2012; NGSS Lead States, 2013). Table 2.1 presents the analytical framework for the NGSS science practices.

Table 2.1: Analytical framework for the NGSS Science practices (NRC, 2012)

NGSS Science Practices	Descriptions
SP1 Asking questions	1. Asking questions about the natural and human-built worlds. 2. Asking questions to determine relationships between variables. 3. Formulating and refining questions that can be answered through empirical research 4. Evaluate questions 5. Asking questions on the work of others
SP2 Developing and using models	1 Constructing drawings or diagrams as representations of events or systems 2. Representing a simple physical model of a real-world object to make prediction and explanation 3. Representing and explain phenomena with multiple types of models 4. Discussing the limitations and precision of a models 5. Evaluating the limits of models 6. Refining model(s) in light of empirical evidence or criticism 7. Using (provided) computer simulations or simulations developed as a tool for understanding and investigating aspects of a system
SP3 Planning and carrying out investigations	1. Formulating a question that can be investigated 2. Framing a hypothesis for an expected outcome based on a model or theory. 3. Deciding what data are to be gathered 4. Deciding what tools are needed to do the gathering 5. Deciding how measurements will be recorded. 6. Deciding how much data are needed to produce reliable measurements

	7. Considering any limitations on the precision of the data 8. Planning experimental or field-research procedures 9. Identifying relevant independent and dependent variables 10. Checking when appropriate and the need for controls 11. Considering possible confounding variables
SP4 Analysing and interpreting data	1. Using tables for comparison, a summary and data management 2. Using statistical analysis for comparison, summary and data management 3. Recognising salient patterns and trend in the data 4. Recognising when the data are in conflict with expectations and consider what revisions in the initial model are needed 5. Using spread sheets, tables, charts, graphs, statistics, mathematics, and information technology to collate, summarize and display data 6. Exploring relationships between variables, especially those representing input and output 7. Evaluating the strength of a conclusion that can be inferred from any data set, using appropriate grade-level mathematical and statistical techniques 8. Recognizing patterns in data that suggest relationships worth investigating further. 9. Collecting data from physical models and analyse the performance of a design under a range of conditions 10. Considering limitations of data analysis (e.g., measurement error, sample selection) when analysing and interpreting data.
SP5 Using mathematical and computational thinking	1.Recognizing dimensional quantities and use appropriate units 2. Expressing relationships and quantities in appropriate mathematical or algorithmic forms 3. Recognizing that computer simulations are built on mathematical models 4. Using simple test cases of mathematical expressions, computer programs, or simulations 5. Using grade-level appropriate understanding of mathematics and 6. Using statistics in analysing data.
SP6 Constructing explanations	1. Making a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. 2. Constructing and revising an explanation based on valid and reliable evidence obtained from a variety of sources 3. Constructing their own explanations of phenomena using their knowledge of accepted scientific theory 4. Linking their own explanations to models and evidence 5. Using scientific evidence and models to support or refute an explanatory account of a phenomenon 6. Offering causal explanations appropriate to their level of scientific

	knowledge. 7. Identifying gaps or weaknesses in explanatory accounts (their own or those of others).
SP7 Engaging in argument from evidence	1. Engaging in scientific argument for identification of possible strengths and weaknesses and discussing them using reasoning and evidence on best experimental design 2. Engaging in scientific argument for identifying possible strengths and weaknesses and discuss them using reasoning and evidence on appropriate set of data analysis and interpretation 3. Engaging in scientific argument showing how the data support the claim 4. Recognizing that the major features of scientific arguments are claims, data, and reasons and distinguish these elements in examples 5. Engaging in individual argument using reasoning and evidence to find the best explanation for phenomena individually 6. Engaging in collaborative argumentation using reasoning and evidence to find the best explanation for a phenomenon 7. Explaining how claims to knowledge are judged by the scientific community today 8. Read media reports of science critically so as identify strengths and weaknesses. 9. Articulating the merits and limitations of peer review and the need for independent replication of critical investigations. 10. Identifying flaws in their own arguments 11. Modifying and improving them in response to criticism
SP8 Obtaining, evaluating, and communicating information	1. Using words, tables, diagrams and graphs as well as mathematical expressions, to communicate their understanding 2. Communicating data, hypotheses and conclusions through peer discussion 3. Asking questions about a system under study. 4. Reading scientific text, tables, diagrams and graphs, commensurate with their scientific knowledge and explaining the key ideas being communicated 5. Recognizing major features of scientific writing and speaking and being able to produce written and illustrated text or oral presentations that communicate their own ideas and accomplishments 6. Engaging in a critical reading of primary scientific literature (adapted for classroom use) or of media reports of science 7. Evaluate the reliability of the scientific information

2.12 MODEL OF INQUIRY LEVEL

Learning of science using an inquiry-based approach allows learners to progress gradually in their development of fundamental scientific processes, which is endorsed as science practices in the science education *Framework* and NGSS (Gibson & Chase, 2002; NRC, 2012). Bell, Smetana and Binns (2005), synthesized for learners a model of four levels of inquiry in order to describe the amount or degree of support in terms of information on question, procedure and expected solution provided to the learners by teacher or textbook. This is also known as the continuum level of inquiry (Aldahmash et al., 2016; Banchi & Bell, 2008). This model of inquiry's levels includes *confirmation, structured, guided and open-ended inquiry*. The openness of inquiry level ranges from learning activities that are teacher-directed to learner-directed instruction. This model of inquiry is thus adapted for this study to enable the researcher to determine the extent to which textbooks include science practices.

At the first level, known as *confirmation inquiry*, learners are usually provided with the question and procedure (step-by-step method) to use in their science investigation and the solutions are known in advance (for example, Newton's laws of motion). In this view, learners are required to confirm a principle through their participation in an activity when the solution is known. At the second level, known as *structured inquiry*, the science teacher provides the learners with the question and procedure, and the learners generate an explanation based on the evidence they have collected during the investigation. For example, investigate the relationship between current and voltage using the procedure provided in the textbook. At the third level, known as *guided inquiry*, the teacher guides the learners in developing science concepts and ideas by providing them with only the research question and then learners design the procedure to be used in testing the question and to provide solutions or resulting explanations. For example, investigate the relationship between current and voltage by designing your own procedure to conduct the investigation. Finally, on the fourth and highest level, known as the *open-ended inquiry*, the learners have maximum opportunities to engage in activities, just like professional scientists, in their study to understand and construct knowledge of a phenomenon. The aim is "deriving questions, designing and conducting investigations, analysing and interpreting data, constructing explanations based on evidence and finally to communicate their results/information".

The confirmation and structured inquiry are described as a 'cookbook laboratory', which addresses the lower level of inquiry, teacher-directed instruction. In contrast, guided and open-ended are the prescribed standards for science learning which are known as the higher-level of inquiry, learner-directed instruction (Schwab, 1960). Therefore the higher levels of inquiry give the learners more opportunity to play a more active role in the learning process in terms of making decisions on what and how they are learning, with the teachers' guidance (Banchi & Bell, 2008). Figure 2.1 illustrates the extent of openness of the inquiry level that involves activities ranging from a teacher-centred approach to a learner-centred approach (Bell, Semetana & Binns, 2005).

Table 2.2: Model of four levels of Inquiry (adapted from Bell et al., 2005)

Levels of inquiry	Question	Method	Solution
1. Conformation Inquiry	Given	Given	Given
2. Structured Inquiry	Given	Given	Open
3. Guided Inquiry	Given	Open	Open
4. Open-ended Inquiry	Open	Open	Open

2.13 ROLE OF TEXTBOOKS IN LEARNING AND TEACHING PROCESS

Textbooks are primary resources needed in the science teaching and learning process in order to ensure that curriculum goals are achieved (Albach & Kelly, 1998; Abd-El-Khalick, Waters & Le, 2008). Various educational research conducted has indicated that most teachers universally depend much on the textbook to determine to a huge extent what is taught and learned in learning environments (Chiappetta & Fillman, 2007; Niza & Maza, 2011). In addition, the studies done by McKinney (2013) and Weiss (1993) revealed that textbooks offer teachers comfort and convenience in planning lessons and in helping learners develop informed NOS perception as a concern in science reform. At the same time they are the most readily available information tool for learners' reading and homework. Textbooks are therefore extremely important in the school system as material that aids teaching and as a source of instruction technique (Aldahmash et al., 2016). Most importantly, the policy reform in K-12 science education laid emphasis on developing science textbooks that will facilitate scientific inquiry, as it has become a central focus of science education in the past few decades, and improve learning quality of science subjects (NRC, 2012; NGSS Lead States, 2013).

Similarly, this is especially true within the South African education landscape, where science teachers' lack of readiness in implementing an inquiry-based approach and other curriculum reform goals has resulted in teachers being heavily dependent on school science textbooks in advancing curriculum aims (Malcolm & Alant, 2004; Ramnarain & Chanetsa, 2017; Ramnarain & Padayachee, 2015). The quality of science textbooks is thus important because of their great influence on the quality of instruction strategy in the class (Swanepoel, 2010).

Due to the key role played by textbooks in teaching and learning science, the research interest in analysing textbooks has increased so as to promote more effectual inquiry-based learning in science classrooms, and therefore provide guidelines to educational stakeholders for future textbooks that will align with NGSS science practices. As a result, this study has considered it worthwhile to explore the Physical Sciences textbooks to know if the "science practices" identified in the new science *Framework* and NGSS (NRC, 2012; NGSS Lead States, 2013) are represented in these educational resources.

The efforts of science research on analysing learning material such as textbooks and curriculum have recently increased globally, with the aim of refining the quality of learning and teaching of school science, as textbooks are considered an essential source in science classrooms (Chiappetta & Fillman, 2007; Doran & Sheard, 1974). Textbook analysis is imperative because it serves as a guide for science teachers and administration in evaluation and selection of appropriate science textbooks, and informs the modification of future textbooks (Doran & Sheard, 1974). Nevertheless, textbook analysis assists the accomplishing reform goal and curricular aim, for example in encouraging the facilitation of implementing an inquiry-based learning approach and engaging learners in science practices (Aldahmash et al., 2016; Stavros, 2016).

2.14 PREVIOUS STUDIES ON TEXTBOOK ANALYSIS

Various researchers in science education from different countries, educational context and stages have shown immense interest in exploring the levels of inquiry reflected in the science curriculum or textbooks (Kahveci, 2010; Lewis, 2012; Asay & Orgill, 2009). Previous studies conducted on science textbooks analysis used the five essential features of inquiry, of which the most recent studies were reviewed for this study. For example, the Chabalengula and Mumba (2012) study on Zambia's high school science curriculum, including the textbooks and practical exams, revealed a discrepancy in the coverage of inquiry levels in syllabi, and the inquiry tasks and skills in school textbooks and exams reflected more on lower inquiry. In addition, the content analysis of inquiry in British third grade science textbooks reported that the activities in the textbooks were identified as inquiries, but inquiry features were partially represented (Lewis, 2012). This study claimed lack of the five essential features of inquiry within the science textbooks. The Dunne et al. (2013) study analysed Irish primary school textbooks used in science classrooms in order to evaluate their capability to support the vision of inquiry-based science education (IBSE). This study postulated that textbooks analysed had the capability to support IBSE, but the inclusion of IBSE utilising the textbooks would rely strongly on teaching strategies (pedagogies) and teachers' conception of the notion of IBSE. Moreover, a recent study by Aldahmash et al. (2016) developed a rubric known as Scientific Inquiry Skills Analytic Rubric (SISAR) in order to explore the inclusion of essential features of inquiry in Saudi Arabian middle-school textbooks and workbooks used for science learning. The findings revealed that almost all the essential features were reflected in the science activities (approximately 59%) but they are mainly teacher-centred instructions. This means that the activities involved a lower level of inquiry.

Furthermore, few studies have utilised the new conceptual framework for K-12 science education that advocated eight science practices in analysing science textbooks and learning objects in order to rethink the application of inquiry in the learning of science. For example, Stavros (2016) was the first study to analyse the science textbooks using the new scientific inquiry practices. In this study, the Greek 5th grade school science textbook was explored in order to determine the reflection of the eight scientific practices in the textbook. The result reported that the articulation of these science practices in science textbooks is not satisfactorily aligned with the new science education *Framework* because important aspects of scientific practices (such as asking questions and argumentation) were not visible in the unit of analysis. Moreover, Saltidou and Skoumios (2017) reported the study of science practices in the Greek science learning object (known as "Digital learning Object Respiratory").

The result confirmed that only some of the science practices were engaged in the learning object, while the other science practices were not represented.

Similarly, in the South African context, research on textbook analysis has been done on how school science textbooks represent the nature of science (Ramnarain & Padayachee, 2015; Ramnarain & Chanetsa, 2016), but no studies have been done on the analysis of textbooks for the inclusion of science practices as emphasised in the new science education *K-12 Framework* and NGSS. Hence this heightens the need for research into school science textbook analysis for the inclusion of eight science practices, especially in South Africa's context as means of improving learners' conceptual understanding of the nature of science, and advances their literacy in science.

2.15 CONCLUSION

Both the USA policy documents and the South African curriculum statement have endorsed the need for learning and teaching of science through inquiry-based learning as a means of achieving 21st century science education goals in learning science as practices. This chapter has discussed the important aspects of literature review such as the reform trends in the South African curriculum, the concept of inquiry in science, science practices, frameworks, role of textbooks, significance of inclusion of science practices in science textbooks and previous studies on textbook analysis.

Chapter Three follows with discussion of the research method, design and procedures employed in this study.

CHAPTER THREE
RESEARCH METHODOLOGY AND PROCEDURE

3.1 INTRODUCTION

Chapter One of this study provided the introduction and background, rationale, research problem, aims and objectives, as well as the research question in relation to this study on textbook analysis for the inclusion of "science practices". In Chapter Two, the researcher provided a review of literature on the South African curriculum reform trend, discussed basic concepts and ideas in relation to inquiry-based learning and science practices, role of textbook and textbook analysis in science education, including previous studies on textbook analysis. In Chapter Three the research methodology and procedures employed in this study will be presented and organised into two phases: (a) explaining the development and validation of the rubric, and (b) providing details of explanation on research design and method, sampling, data collection, data analysis procedure and reliability and validity of results.

3.2 QUALITATIVE RESEARCH METHOD

Qualitative research refers to the study of participants in their natural setting, including the researcher as a participant rater (Yin, 1994). Qualitative research approach and a deductive content analysis design are specifically selected for this study because it will help the researcher gain deeper understanding of the extent to which Physical Sciences textbooks reflect science practices, as suggested in NGSS.

The distinguishing feature of qualitative research includes "….an emphasis on the qualities of entities and on the processes and meaning" (Denzin & Lincoln, 2008:8). This study requires evaluation of the unit of analysis in the textbook based on the quality of their contribution towards science practices in school science. Therefore, these units in the textbooks analysed are directed in a manner that portrays a meaningful picture of how the science practices are reflected in each Physical Sciences textbook.

3.3 RESEARCH PROCESS FOR THE STUDY

As indicated in the research aims and objectives in chapter one, the research process involved two phases:

1. To develop a rubric for analysing three grade 12 Physical Sciences textbooks for science practices emphasized in the NGSS.

2. To apply this rubric in the analysis of the three grade 12 Physical Sciences textbooks for the inclusion of NGSS science practices.

3.4 PHASE ONE

3.4.1 Development and validation of a rubric for analysing inclusion of science practices in Physical Science textbooks

The first phase of this study involved developing the rubric which starts by reviewing relevant literature on the recent science education Framework and Standards in order to gain insight into the concept of "science practices" (National Research Council [NRC], 2012; Next Generation Science Standard [NGSS], Lead States, 2013). Next was a further search with the focus on identifying instruments that are already being used in assessing learners' performance in science practices and in defining the levels of confirmatory, structure, guidance and coaching inherent to the science practices provided for the learners by the teacher or textbook. Then, aspects of the McNeill, Katsh and Pelletier (2015) assessment tool known as Science Practices Continuum-Student Performance and a Drafted Inquiry Rubric developed by the Council of State Science Supervisors (2002) were adopted and adapted in the development of a science practices rubric. Three science education experts in the field of scientific inquiry research validated the developed Science Practices Continuum Rubric (SPCR) for theoretical underpinning and practical use. Based on their recommendations, minor changes were made in this version of the rubric. In the final version, the rubric was comprised of eight science practices distributed across four levels, with each level defining the amount of confirmatory, structure, guidance and coaching provided by the textbook or teacher, and an example for each level of the science practices (Aldahmash et al., 2016). The second stage involved applying the rubric developed in analysing Physical Sciences textbooks for the inclusion of science practice.

3.5 PHASE TWO

3.5.1 Qualitative content analysis

The study employed a qualitative content analysis approach in understanding the extent to which Physical Sciences textbooks represent NGSS science practices. Content analysis is a systematic, rigorous approach to analysing documents by analysing the units such as paragraphs, worked examples, activities, figures with captions, tables with captions, and marginal comments (Mouton, 2008). This approach is appropriate for this study in order to assign meaning to the various science practices represented in textbooks and to interpret its meaning (Krippendorff, 2004).

In this study, the Physical Sciences textbooks were analysed using a scoring rubric- Science Practices Continuum Rubric (SPCR) developed for determining the levels of science practices included in textbooks. The rubric indicates gradual progression from the teacher-directed approach to the learner-directed approach. In the case of this study, the procedure for content analysis involves standard procedure for analysing the contents and activities involved in the textbook (Aldahmash et al., 2016; Ramnarain & Padayachee, 2015; Asay & Orgill, 2009). This procedure was employed in coding the units of analysis, which includes full paragraphs, worked examples, activities, figures with captions, tables with captions, and marginal comments. Each analysable unit was coded (SP1, SP2, SP3, SP4, SP5, SP6, SP7, and SP8) using the Science Practices Continuum Rubric (SPCR) developed for this study by placing a check in the appropriate conceptual framework of science practices indicated in the analytical framework adapted (Table 2.1). This entails studying a unit, and identifies the science practice to which the analysed unit can best be related. The coding of the analysable unit in the textbook employed a deductive process (Chiappetta, Sethna & Fillman, 1991). Then, each science practice check was counted and the results presented in the form of frequency, percentage and mean for each Physical Sciences textbook analysed. Examples of units that corresponded to the science practices are provided in the result section.

The content analysis of this study involves transforming the raw textual material into standardised codes (Babbie, 2001). This means that the researcher collected qualitative data using the qualitative data collection procedures and the data was transformed into quantitative data by counting the number of codes. The units of analysis in the textbooks were paragraphs, worked examples, activities, figures with captions, tables with captions, and marginal comments. The unit of analysis were therefore all texts and information on each page of the selected textbook. Creswell (2007) identified the inclusion of quantitative procedures of analysis in QCA as a "grey area" with typical content analysis involving only collection of qualitative data for the study. Hence this study cannot be classified as a mixed method design, despite the fact that the researcher used features of both qualitative and quantitative research approach. This is because the researcher did not collect both qualitative and quantitative data, which classifies my study as inclusive of the indeterminate area in research methodology (Padayachee, 2012)

3.6 SAMPLING AND PROCEDURES USED FOR SELECTING SAMPLE PAGES

Purposive sampling was used in selecting three grade 12 Physical Sciences textbooks to be analysed (Creswell, 2014). This study chose to focus on grade 12 textbooks because according to CAPS requirements, they are expected to provide learners with more opportunities to engage in science practices compared to other grades (DBE, 2011). The textbooks selection was based on their inclusion in the list of Physical Sciences textbooks recommended by the South African Department of Basic Education (DBE) and their compliance with Curriculum and Assessment Policy Statement [CAPS]. The textbooks chosen are the three most commonly used in Physical Sciences classrooms by science teachers and learners.

The CAPS defines Physical Sciences as a subject that "investigates physical and chemical phenomena. This is done through scientific inquiry, application of scientific models, theories and laws in order to explain and predict events in the physical environment" (DBE, 2011: 6). The textbook analysis focused on the six major knowledge areas that made up the Physical Sciences subject suggested in the South African national curriculum document, and each knowledge area consists of the topics. These include:

1) **Mechanics**

A) Momentum and impulse

B) Vertical projectile motion in one dimension

C) Work, energy and power

2) **Waves, sound and light**

A) Doppler Effect

3) **Electricity and magnetism**

A) Electric circuits

B) Electrodynamics

4) **Matter and materials**

A) Organic molecules

B) Optical phenomena and properties of material

5) **Chemical system**

A) Chemical industry

6) **Chemical change**

A) Rate and extent of reaction

B) Chemical equilibrium

C) Acids and bases

D) Electrochemical reactions

In selecting the sample pages from each Physical Sciences textbook, three grade 12 learners' books were selected and were analysed for science practices so as to reveal the degree to which the science practices were reflected, and to compare how each "science practice" was represented in each textbook. The textbooks were specifically named Textbook A, Textbook B and Textbook C for this study. The various chapters and pages of these textbooks were firstly organised and categorised into major knowledge areas of Physical Sciences listed above, and as identified by the Department of Education.

In sampling, this study adopted the recommendation of Chiappetta and Fillman (2007) whereby 10% of pages were selected for analysis. However, this study used 20% of pages of each knowledge area in each Physical Sciences textbook selected for this study. This slight adjustment in this technique was made to ensure maximum reliability of the result and to avoid bias in unit sample selection for each textbook. The pages were then selected randomly using an online computer random number generator for each of the textbooks (www.psychicscience.org/random.aspex, accessed 9 August 2010). This computer programme was chosen for the random sampling because it guaranteed high-quality random number generation. The table below shows the number of pages per knowledge area from which the sample pages were selected.

Table 3.1: Number of pages per knowledge area for each Physical Sciences textbook

Knowledge area	Textbook A	Textbook B	Textbook C
Mechanics 1	47	71	42
Matter and material 1	75	79	70
Mechanics 2	33	45	23
Waves, sound and light	9	13	13
Chemical change 1	95	100	74
Electricity and magnetism	31	68	43
Matter and materials 2	13	36	18
Chemical change 2	39	46	35
Chemical system	21	21	22
Total number of pages	363 (20% = **73**)	479 (20% = **96**)	340 (20% = **68**)

Table 3.2: Sample pages per knowledge area from each Physical Sciences textbook generated

Knowledge area	Textbook A	Textbook B	Textbook C
Mechanics 1	71 49 45 64 58 72 37 47 71	70 83 62 78 78 83 38 58 47 76 70 69 79 61	54 53 31 57 47 47 59 68
Matter and material 1	123 120 146 80 116 145 100 97 100 123 143 122 146 100 121	133 162 96 124 141 100 126 112 123 149 121 116 107 121 101 118	112 144 87 129 139 103 127 109 120 82 119 78 86 77
Mechanics 2	175 182 174 162 178 167 164	172 187 182 186 205 182 199 189 187	163 167 149 165 155
Waves, sound and light	196 188	216 212 212	183 174 170
Chemical change 1	204 206 270 237 242 272 289 271 199 227 270 256 284 212 224 252 208 213 232	232 247 226 282 315 266 240 251 229 291 235 309 257 239 273 246 265 314 307 253	237 246 225 229 218 217 200 240 215 194 222 195 254 224 244
Electricity and magnetism	316 304 295 321 323 310	376 346 336 378 340 364 328 376 329 343 383 374 389 381	298 281 298 273 296 264 293 281 291
Matter and	333 327 337	422 421 406 426 407 424 420	314 319 321 313

materials 2			
Chemical change 2	345 375 351 351 352 369 355 360	461 433 461 466 442 474 463 446 461	343 339 341 330 350 338 338
Chemical system	384 394 394 383	486 492 500 486	380 370 368 370
Total number of pages generated	**73**	**96**	**68**

3.7 DATA ANALYSIS AND COLLECTION

Qualitative data analysis is the "classification and interpretation of linguistic or (visual) materials to make statements about implicit and explicit dimensions and structure meaning-making in the materials and what is represented in it" (Flick, 2008). In this study, the researcher and a post-doctoral research fellow in the field of science education served as the two independent raters used in coding the units of analysis; this is to ensure the reliability of the analysis. The two raters have in-depth knowledge of science practices and were familiar with how to code textbooks for the essential features of inquiry-based learning. The co-rater studied the developed rubric (SPCR) for coding the textbooks before the actual coding. After studying the developed rubric, the researcher further clarified the co-rater on how to use the rubric in coding the units of analysis. Thereafter, both raters had discussion on the use of rubric in order to ensure that they all had a similar interpretation of the rubric and units to analyse. Each rater coded each unit of analysis independently as to which science practice it included. Next, the degree of agreement was calculated statistically with my result and the co-rater result and using the Cohen's kappa formula (Cohen, 1990). Then the two raters had a discussion to resolve the coding differences and eventually consensus was reached before the researcher proceeded with data analysis and collection. Table 3.3 shows how the analysed units in the Mechanics knowledge area from one of the analysed textbooks were collected. Appendix 1 also shows how the data were collected from the three analysed textbooks with extracts from the textbook in Appendix 2.

Table 3.3: Sample of analysis of Mechanics knowledge area units in one textbook

- **Mechanics (1)**

Unit	Topic	Level	Question	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
1	Momentum & Impulse	1 2 3	5 0 0	25 3 0	0 5 0	0 3 4	14 15 3	15 10 7	0 3 0	0 6 1

		4	0	0	0	0	0	0	0	0
2	Vertical projectil e motion	1 2 3 4	0 0 0 0	5 0 3 0	0 0 0 0	5 1 2 0	5 5 0 0	5 4 1 0	0 0 0 0	0 1 0 0
	Total		**5**	**36**	**5**	**15**	**42**	**42**	**3**	**8**

3.8 DETERMINING THE LEVEL OF INCLUDED SCIENCE PRACTICES

In this research, the *five step-by-step guides* suggested for the process of qualitative data analysis was adapted (Ritchi & Spencer, 1994). This involves familiarisations, indexing, charting, mapping and interpretation.

Step 1: Familiarization entails the situation where each of the raters worked through the procedure for analysing the units. The conceptual framework of science practices was established as a *priori* **category** and they were used to develop the Science Practices Continuum Rubric (SPCR) for analysing purposes. In addition, the units of analysis were determined from the textbooks to be analysed.

Step 2: Indexing involves the main process of coding each unit of analysis (i.e. the science practices represented in the textbooks) explained earlier, using the SPCR analytical tool developed independently by the raters.

Step 3: Charting involves use of statistical analysis (frequency, percentage and mean) in the form of tables, to display how each of the science practices is represented in the three textbooks.

Step 4 & 5: Mapping and interpretation were attributed in the form of graphs, and this enabled the researcher to evaluate the study discussion and conclusion. The tables and graphs were used to show:

- The extent of the inclusion of science practices in each textbook
- Comparison of the articulation of science practices across the three textbooks
- Percentage per science practice represented in the three textbooks

3.9 RELIABILITY AND VALIDITY OF CODING THE THREE TEXTBOOKS

The reliability of coding the three textbooks was guided by the recommended procedure to ensure reliability in qualitative content analysis. This procedure involved multiple coders, training on the use of analytical tools and double-checking findings (Padayachee, 2012; Wang, 1998). A deductive process was also employed in coding the units of analysis. To assure the reliability of coding the units and data collection in this study, the researcher and an expert in the field of science education and textbook analysis therefore served as raters. The textbook was therefore analysed independently by myself and another researcher with a PhD in science education. Next, it was determined statistically using percentage agreement and Cohen's kappa formula (Cohen, 1990). The tables 3.4 and 3.5 below display the calculation and result of the reliability test. The results were then presented in the form of frequencies, percentages and means for each of the eight science practices in the science textbooks and workbooks. To ensure the validity of the content analysis, the process of coding was based on the analytical framework that coexisted with the valid conceptual framework of science practices in the new *Framework* (NRC, 2012).

In addition, to ensure the validity of the research instrument used, a pilot study was conducted prior to the actual content analysis. This is achieved by determining how the science practices were addressed in the Matter and material knowledge area of the grade 10 Physical Sciences textbook. Then, the instrument was proved to be feasible before it was adopted for the actual research. The formulas below were used in calculating the percentage agreement and Cohen's kappa to assess the reliability of the data analysis.

Percentage of Agreement: $\frac{\text{Number of agreement between the two raters}}{\text{Total number of sample units coded}} \times 100$

Cohen's kappa (k): $p0 – pc \,/\, (1 - pc)$

p0: proportion of the analyses on which the two raters agree, and
pc: proportion of ratings for which agreement is reached by chance

Table 3.4: Percentage agreement and Cohen's kappa calculations to ensure reliability

Percentage of agreement	Cohen's kappa
TEXTBOOK A	

Total number of sample unit coded = 282 **Number of agreement between the two raters** = 222 Number of disagreement between the two raters = 60 **% agreement** = 222 / 282 X 100 = 0.787 X 100 = 78.7 = 79%	Cohen's kappa(k) = p0 – pc / (1 - pc) = 0.78
TEXTBOOK B **Total number of sample unit coded = 348** **Number of agreement between the two raters** = 278 Number of disagreement between the two raters = 70 **% agreement** = 278 / 348 X 100 = 0.798 X 100 = 79.8 = 80%	Cohen's kappa(k) = p0 – pc/ (1 - pc) = 0.79
TEXTBOOK C **Total number of sample unit coded = 221** **Number of agreement between the two raters** = 178 Number of disagreement between the two raters = 43 **% agreement** = 178 / 221 X 100 = 0.805 X 100 = 80.5 = 81%	Cohen's kappa(k) = p0 – pc/ (1 - pc) = 0.80

Table 3.5 Inter-coder reliability between two raters on the analysis of three Physical Sciences textbooks

	Textbook Sample	% agreement	Kappa
1)	Textbook A	79	0.78
2)	Textbook B	80	0.79
3)	Textbook C	81	0.80

The percentages of agreement values indicate a high degree of agreement between the research and co-rater in the content analysis for the levels of science practices in the Physical Sciences textbooks. According to Landis and Koch (1997) also, the calculated results by Cohen's kappa show a substantial level (0.61- 0.80) of inter-rater agreement across the three Physical Sciences textbooks.

3.10 CONCLUSION

In this chapter, the development and validity process of the rubric developed for this research was discussed in Phase one. The research design and method were further discussed in phase two. The reason for a qualitative research is to enable the researcher to gain deeper understanding of the representation of "science practices" in the textbooks.

The Physical Sciences textbooks analysis was conducted using the content analysis whereby the units of analysis were read, understood and then assigned to one of the eight science practices identified in Next Generation Science Standard.

The next session will be Chapter Four, discussing and interpreting the analysis of data collected and findings.

CHAPTER FOUR
RESULT OF THE ANALYSIS OF PHYSICAL SCIENCES TEXTBOOKS FOR THE INCLUSION OF SCIENCE PRACTICES

4.1 INTRODUCTION

The research process for the study on the analysis of Grade 12 Physical Sciences textbooks for the inclusion of science practices involved two phases. The first phase explained the development process of the rubric known as Science Practices Continuum Rubric (SPCR) created for the purpose of this textbook analysis. The second phase involved how the developed rubric was utilised to find out the extent to which science practices were reflected in three Physical Science textbooks. The data was gathered by coding the textual content of the analysed units in each textbook using the developed rubric, and then the coding differences were resolved between the two raters through discussion. Consensus was established after further reference to the textbooks. Thereafter, a scoring sheet designed for this study was used in gathering the data from each textbook. Finally, Chapter Four of this research includes the presentation and interpretation of the tables and graphs from both phase one and two of this study.

4.2 DEVELOPED SCIENCE PRACTICES CONTINUUM RUBRIC

Table 4.1 below shows the developed Science Practices Continuum Rubric for analysing the inclusion of science practices in textbooks. This rubric is comprised of eight science practices distributed across four levels, with each level defining the amount of confirmatory, structured, guided and openness provided in the textbook (or by the teacher) including the example for each level.

The level 1 implies that the included science practice is strongly teacher-directed instruction because the question, procedure and solution are clearly stated in the textbook, as the learner remains a passive recipient in confirming the knowledge while the textbook (or teacher) transmit the knowledge to the learner. The level 2 implies that the included science practice is moderately teacher-directed instruction because the analysis or activity provides learners with a predetermined question to clarify. It also provides a step-by-step method or data to use, but provides guidelines to possibly interpret the evidence to make argument and opportunity to choose a meaningful conclusion.

The level 3 implies that included science practice is moderately learner-directed instruction because of the increase in the level of science practice, as the analysed unit or the activity offers the learner the options to utilise prepared questions or to pose new investigative questions, to collect certain data. It also provides the learner the opportunity to utilise a variety of resources for the activity but makes the solution open for the learner to determine, and the opportunity to make decisions about reporting their data with less assistance. The last level, 4, implies that included science practices are strongly learner-directed instruction because the analysed unit or activity promotes leaners' full participation in science practices at the highest level. At this level, the learner is allowed to exercise freedom in formulating or posing both scientific and non-scientific question, and to design methods for gathering data. It also provides an opportunity to decide what evidence is needed to support arguments made, and to finally draw own-formulated conclusions based on findings and evidence.

Employing these characteristics of each level of inquiry, the researcher constructed a rating rubric with examples from the textbooks to explore the level of included science practices in each Physical Sciences textbook. Table 4.1 below shows the actual developed rubric.

Table 4.1: Science Practices Continuum Rubric for coding textbook

NGSS Science practices	**Variations**			
	1 (Strongly teacher-directed)	**2 (Moderately teacher-directed)**	**3 (Moderately learner-directed)**	**4 (Strongly learner-directed)**
1. Asking questions	Provide no opportunities for students to ask questions	Enable students to select among provided questions or to pose new questions.	Enable students to pose new questions for investigation without evaluating their feasibility	Enable students to pose new questions for investigation and evaluate the feasibility of their questions.
	Example: Activity 5: Answer questions on properties of matter. Practical activity: Investigate the pattern and direction of a magnetic field	Example: Select one of the questions in the topics listed below for your research. Activity 6: Make up a list of ten questions about the periodic table.	Example: State an investigative question/ hypothesis for this investigation.	Example: State an investigative question / hypothesis for this investigation. Review with peer if the research question can be answered through scientific investigation or not.
2. Developing and using model	Provide students with no opportunities to create , or use models	Engages students to create or use models provided in textbook. The models focus on describing phenomena rather than alluding to predictions and explanations	Engage students to create and use models focused on predicting or explaining phenomena with guidance	Engages students to create and use models focused on predicting or explaining phenomena and to independently evaluate the merit and limitations of the model.
	Example: Figure 2: A	Example: Make a	Example: Project to	Example: Use an atomic

	representation of liquid water. Illustration of characteristics of states of matter.	sketch of what an atom with an atomic number of 9 might look like. Include all the protons, neutrons and electrons in your drawing.	build a simple DC electric motor as show in Figure 10.3. with guidance. Describe how the electric motor works. (pg 376) Draw before & “after” diagram to show how ionic bonding take place in MgS.	model kit (or alternative materials) to build space-filling models or ball-and-stick models for the compound in the table. Explain their construction, and then indicate what you like and challenges about the model (pg 111)
3. Planning and carrying out investigation	Does not engage students in designing or conducting investigations.	Engage students in planning and conducting investigations, but these opportunities are typically teacher-driven.	Engage students in designing and conducting investigations to gather data with guidelines.	Engage students in designing and conducting investigation to gather data independently. Evaluate plans for research.
	Example: Practical demonstration to observe a precipitation reaction. Observation simulations of reactions (pg 99).	Example: Step-by-step method provided in the textbook to investigate current and voltage in series circuits. Observation the reaction.	Example: Design and perform experiments which investigate the corrosive nature of concentrated acids and bases (battery acids). Write up the experiment report: apparatus, methods and variables.	Example: Use your research to design an experiment/investigation that will answer the question. What are some sources of error for the experiment? Why might the result not be accurate? How to improve the result?
4. Analysing and interpreting data	Does not require students to use tables, graphs and charts to analyse and interpret data.	Engage students to work with data to organize or group the data in table or graphs with guidelines.	Engage students to work with data to organize or group the data in a table or graph, and to identify or recognize patterns or relationships in the data with minimal assistance.	Engage students to independently make decisions about how to analyse data (e.g. table or graphs), and to make sense of data by recognizing patterns or relations in the natural world.
	Example: Observe the velocity vs time graph provided in the textbook (Fig 2.21b) (pg 74).	Example: Use the data in the table to plot a graph of lime scale build up against the increase in energy consumption. Record result in table.	Example: Create and analyse data in the graph from an investigation on the purification and quality of tap water and bottled water.	Example: Draw up a suitable table to record your result, draw graph of the result and discuss the shape of the graph
5. Using Mathematical and Computational thinking	Does not enable students to use mathematical skills (e.g., calculating, measuring and estimating)	Engage students to use mathematical skills or concepts provided in answering scientific or non-scientific question.	Engage students to use mathematical skills or concepts to answer a scientific question with guidelines.	Engages students to make decisions about what mathematical skills or concepts to use independently.
	Example: Worked examples to calculate the difference in electronegativity of Beryllium and Fluorine.	Example: Use the velocity vs time graph provided to calculate the acceleration.	Example: Measure and record the voltage across each resistor. Use the graph plotted to calculate the instantaneous velocity at t=0,8s.	Example: Calculate the equivalent resistance of the parallel connection
6. Constructing Explanations	Provide no opportunities for students to create scientific explanations of phenomena.	Engage students to create scientific explanations but students’ explanations of phenomena are descriptive instead of explaining how or why a phenomena occurs	Engage students to create scientific explanations of phenomenon on how or why a phenomenon occurs.	Engage students to independently construct explanations that focus on explaining how or why a phenomenon occurs and use appropriate evidence to support their explanation.

		using evidence provided.		
	Example: Short paragraphs on thermal conductors and insulator provided in the textbook.	Example: Describe what an electric circuit is.	Example: Explain why the temperature does not change even though an energy change is taking place.	Example: Use the kinetic model to explain how a hot air balloon rises into the air when the gas is heated.
7. Engaging in Argument from evidence	Does not engage students in argumentation that uses appropriate evidence and reasoning to support claim.	Engage students in teacher – driven argumentation where they support their claims with evidence or reasoning.	Engage students collaboratively in student- driven argumentation where they support their claims with evidence or reasoning.	Engages students in student- driven argumentation that includes the use of evidence, reasoning that links the evidence of their claim, and critique of competing arguments.
	Example: Experiment idea- Test and classify the materials as: metals or non-metals; magnetic or non-magnetic; conductors, semiconductors or insulators. Textbook provides no opportunity for argument.	Example: Discussion- the voltage across the battery when no current is flowing is higher than when current is not flowing. Textbook provides the discussion.	Example. Discuss with peer or group discussion on the voltage across the battery when no current is flowing is higher than when current is not flowing.	Example: Debate on whether to connect ammeter in series or parallel across a circuit using enough information from research.
8. Obtaining, evaluating and communicating information.	Does not encourage students to read text for scientific information.	Encourage students to read text to obtain scientific information or communicate any aspects of their investigation by following prescribed procedures.	Encourage students to read and combine text to obtain scientific information or communicate some aspects of their investigation in their style and format.	Encourage students to read, combine, and evaluate multiple texts to obtain scientific information, or communicate all aspects of their investigation in their own style and format.
	Example: Conclusion provided in the textbook. Case study	Example: Visit this web site. Write up a scientific report. Copy the table and record your observations or results.	Example: Use the website listed alongside. Write a report. or record your observation. What conclusion can be reached from the investigation?	Example: Poster project on impact of a dam. Find literature about the dam; evaluate the information by comparing studies. Write up the practical investigation in form.
Less………………………………………………………………..More Focused on Scientific Evidence Learner Directed and Collaborative Approach				

4.3 TEXTBOOK CONTENT ANALYSIS

In this study, three Grade 12 Physical Sciences textbooks were analysed using the conceptual framework adopted from the National Research Council (NRC, 2012) and developed Science Practices Continuum Rubric (SPCR). The motivation for this study is to explore how the "science practices" identified in K-12 science education *Framework* and Next Generation Science Standards (NGSS) were represented within the textbooks in regards to the level of science practices inclusion, and within the knowledge areas highlighted in the national curriculum policy document (known as CAPS). The essence of the study is to improve the integration of these science practices into school science textbooks as a means of equipping learners to make sense of science content and to be aware of their environment and society in terms of science and technology, as they develop to be advanced science literacy citizenry (Aldahmash et al., 2016). The following questions guided the second phase of this research:

- To what extent do grade 12 Physical Sciences textbooks reflect the science practices?
- What levels of the included science practices are present in the three analysed textbooks?
- How are these science practices addressed within the knowledge areas across the three textbooks?

Each textbook was hence coded using the eight science practices, namely *Asking que*stion (SP1), *Developing and using models* (SP2), *Planning and carrying out investigation* (SP3), *Analysing and interpreting* data (SP4), *Using mathematical and computational thinking* (SP5), *Constructing explanations* (SP6), *Engaging in argument from evidence* (SP7) and *Obtaining, evaluating and communicating information* (SP8). The researcher and an expert in textbook analysis and field of science education analysed and coded the three textbooks. The reliability tests for each textbook were addressed, thereafter the data were collected and analysed. Finally, they were presented as indexing, charting, and mapping and interpretation according to framework analysis procedures (Padayachee, 2012).The Physical Sciences textbooks were named as Textbook A, Textbook B and Textbook C.

4.3.1 Indexing

The two raters independently coded each unit of analysis in the textbooks by allocating a science practices category (namely SP1, SP2, SP3, SP4, SP5, SP6, SP7 and SP8) to each analysed unit using the developed rubric (SPCR). Each unit analysed was also indexed with both alphabetical and numerical codes such as $SP3_2$. This implies that the analysed unit belongs to science practice of *Planning and carrying out investigation*, and level of inclusion is 2 (i.e. structured level) as illustrated in Table 3.3.

4.3.2 Charting

Each analysed unit per knowledge area was analysed according to science practices categories. This describes further on the extent each of the science practices can be reflected in the textbook. The data has be categorised by counting the frequencies and calculating the percentages displayed in tables to present how each science practice is reflected in the textbook separately.

4.3.3 Mapping and interpretation

The tables and graphs were used to show:

1. The extent of inclusion of science practices in Textbooks A, B and C.
2. Compare the articulation of the science practices across the three textbooks and within the knowledge areas in Physical Sciences.
3. The researcher further interpreted the tables and graphs through discussion on the findings of the result for Phase Two of the study on textbook analysis for the inclusion of science practices.

4.4 REPRESENTATION OF SCIENCE PRACTICES IN TEXTBOOKS A, B AND C

Table 4.2 below shows the representation of the eight science practices in Textbooks A, B and C. However, Textbook A included a total number of analysed units of 1444. The result shown in the table 4.2 reveals that textbook A reflects all the eight science practices. As shown in the table below, practice of *Constructing explanation*, was most representative (highest frequency of 435 out of 1444) of all the science practices. The high inclusion of this particular practice means that Textbook A supports the explanation practice. For example, engaging learners in activity to *explain why the temperature does not change even though an energy change is taking place*. This is followed by the practice of *Developing and Using models* (309) and Using *mathematical and computational thinking* (297). Next was the practice of *Obtaining, evaluating and communicating information* (162). On the other hand, the least represented were the practices of *Analysing and interpreting data* (92), *Asking questions* (56), *Planning and carrying out investigation* (55), followed by the practice of *Engaging in argument from evidence* (38). The low inclusion of these practices implies that Textbook A does not adequately support learners' engagement in Asking questions, Planning investigations and Argument from evidence. For example, activities that engage learners to discuss with peers or group *the voltage across the battery when no current is flowing is higher than when current is not flowing*.

The analysed Textbook B included 1485 sum of analysed units. Table 4.2 below shows that all the eight science practices were reflected in this textbook. Similarly, the frequency in table

4.3 shows that the practice of *Constructing explanation* was most represented (highest frequency of 458 out of 1485) all of the science practices in the textbook. This high inclusion of this particular practice reveals that Textbook B supports learners in constructing explanation. Next were the practices of *Developing and using modelling* (387) and *Using mathematical and computational thinking* (381). This is followed by the practice of *Obtaining, evaluating and communicating information* (92). On the contrary, the least represented practices include: *Asking questions* (66), *Analysing and interpreting data* (50), *Planning and carrying out investigations* (40), and *Engaging in argument from evidence* (6). The low inclusion of these practices means that Textbook B lacks activities that adequately engage learners in Asking questions, Planning investigations, Analysing data, and Argument. For example, activities that engage learners to design and perform experiments which investigate the corrosive nature of concentrated acids and bases (battery acids), and to write up the experiment in form of a scientific report as well.

Furthermore, in Textbook C, the sum of 1042 analysable units was analysed. Table 4.2 below shows that all the eight science practices were presented in this textbook. The frequency table shows that the practice of *Constructing explanations* was mostly represented (highest frequency of 318 out of 1042) of all the practices in Textbook C. The high inclusion of this practice means that Textbook C offers learners the opportunity to engage in activities that support constructing explanation. For example, to explain what is meant by the Doppler Effect for sound. The practice of *Developing and using models* and practice of *Using mathematical computational thinking* were also adequately represented in Textbook C. This is followed by the practice of *Obtaining, evaluating and communicating information* (85). In contrast, the least represented were the practices of *Planning and carrying out investigations* (51), *Asking questions* (49), *Analysing and interpreting data* (45) and *Engaging in argument from evidence* (11). The low inclusion of these practices also suggests that Textbook C does not provide learners adequate opportunity to engage in Planning and carrying out investigations, Analysing and interpreting data, Asking questions and Engaging in argument. For example, activities that engage learners in a group discussion and debate to evaluate the advantage and disadvantages of fertiliser in our society.

Table 4.2: Frequencies of science practices in the three textbooks

NGSS Science practices	Frequencies		
	Textbooks		
	A	**B**	**C**
SP1: Asking questions	56	66	49
SP2: Developing and using models	309	387	237
SP3: Planning and carrying out investigations	55	40	51
SP4: Analysing and interpreting data	92	50	45
SP5: Using maths and computational thinking	297	381	233
SP6: Constructing explanation	435	458	318
SP7: Engaging in Argument from evidence	38	6	11
SP8: Obtaining, evaluating, and communication information	162	92	85
TOTAL	**1444**	**1485**	**1042**

4.5 COMPARING THE INCLUSION OF SCIENCE PRACTICES ACROSS THE THREE TEXTBOOKS

To compare the extent of inclusion of science practices across the textbooks, the calculated percentage scores from the frequency table (Table 4.2) for each textbook were used. This is illustrated in Table 4.3, and then projected into a graph (Figure 4.1).

Table 4.3: Comparison of inclusion of the science practices across the textbooks using their percentage scores

Percentages (%)

Textbook	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
A	3.9	21.4	3.8	**6.4**	20.7	**30.1**	**2.6**	**11.2**
B	4.5	**26.1**	2.7	3.4	**25.7**	**30.9**	0.4	6.2
C	**4.8**	23.0	**5.0**	4.4	22.6	**30.9**	1.1	8.3

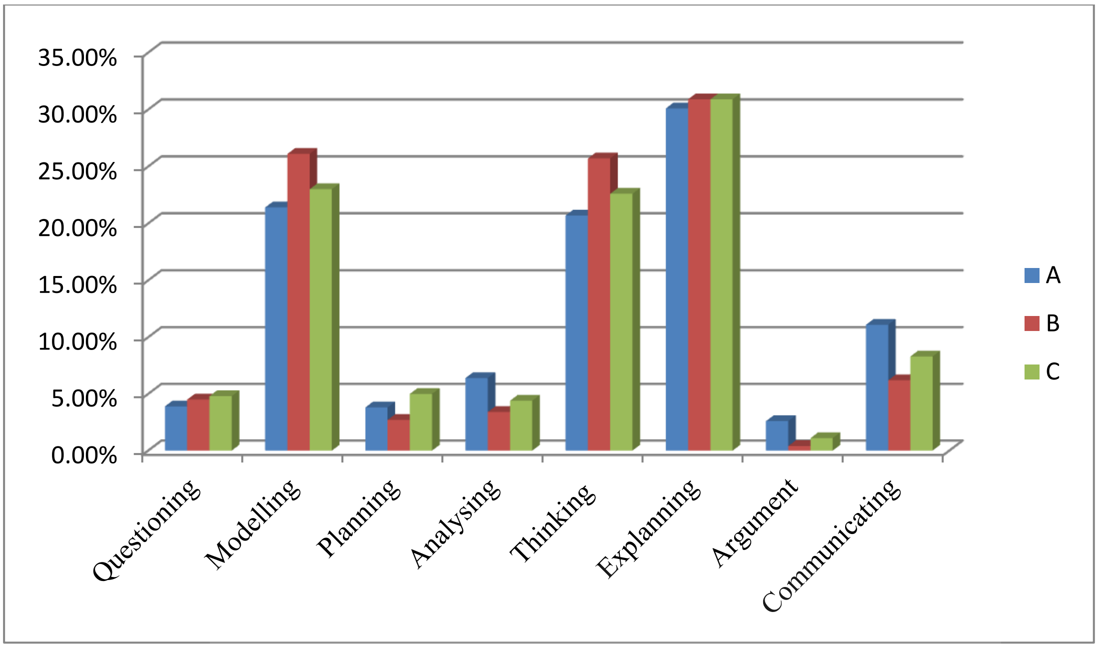

Figure 4.1: Comparison of Textbook A, B and C for the inclusion of science practices

The result of the analysis as displayed in Figure 4.1 reveals that all the eight science practices were reflected across the three textbooks, although the majority included were at lower level. It also indicates that the inclusion of the practice of Explaining was similar in the percentage score across the three textbooks. The inclusion also displayed most percentages for the practices of Modelling (26.1%) and Thinking (25.7%) in Textbook B. It was also revealed that Textbook A showed most inclusion of science practices in Analysing (6.4%), Argument (2.6%) and Communicating (11.2%) practices. While the inclusion in Textbook C displayed most percentages for the Questioning (4.3%) and Planning (5.0%) practices.

In general, the inclusion of practice of Explaining was predominantly presented in all the three textbooks, ranging from 30.9% to 30.1%. This is followed by practices of Modelling (21.4% to 25.7%) and Thinking (20.7% to 25.7%) most dominated in Textbook B. This means that the textbooks promote Explaining, Modelling and Thinking practices, but at lower level. The practice of Communicating was also evident in the inclusion across the textbooks ranging from 8.3% to 11.2%, although its inclusion was most visible in Textbook A by 11.2%. On the other hand, the practices of Analysing (3.4% to 6.4%), Questioning (3.9% to 4.8%) and Planning (2.7% to 5.0%) were least included in the textbooks. Then, the inclusion of the practice of Argument was also least represented across the textbooks ranging from 0.4% to 2.6%. This means the textbooks do not encourage learners in asking questions, planning investigations, analysing data and, most especially, in argument practices. The results of the textbook analysis therefore show that practices of *Constructing explanation, Developing and using models, and Using mathematical thinking* are in greater proportion than the other practices across the analysed textbooks.

4.6 LEVELS OF SCIENCE PRACTICES IN THE ANALYSED THREE TEXTBOOKS

4.6.1 Levels of science practices included in Textbook A

Table 4.4 displays the frequencies and percentages of each science practice in Textbook A according to their levels of inclusion (from level 1, teacher-directed approach, to 4, student-directed approach).

Calculation:

- Actual number of analysed unit = Number of unit per knowledge / Total number of unit per knowledge area in t/book A X 100

Example for Mechanics = 291 / 1444 x 100

= 2.02 x 100

= 20.2%

- SP (%) = Frequency of each science practice per knowledge area / Number of unit per knowledge area X 100

Example for SP1 = 6 / 291 X 100

= 0.0206 X 100

= 2.1%

The result shown in Table 4.4 indicates that although all of the eight science practices could be identified in Textbook A, the majority of these practices were present at lower levels. Looking at level 1, SP6, *Constructing explanation* has the highest frequency (118, 20.1%), followed by SP2, *Developing and using models* (67, 21.5%), and over half of the analysed units involved in these two practices are predominant at the lowest level. For example, a paragraph on hydrocarbon (p. 81): *Hydrocarbons are a group of organic compounds that contain only hydrogen and carbon atoms. They are considered to be the simplest organic* *compounds. Hydrocarbons are very useful and play a role in our everyday lives. We find them in gas cylinders of butane and propane (LPG fuel). Petrol, diesel fuel, paraffin oil for heating and candles (heavy hydrocarbon paraffin wax) are all examples of hydrocarbon.* At level 2, SP5, *Using mathematical and computational thinking* (72, 12.0%) and SP8, *Obtaining, evaluating and communicating information* (44, 7.3%) were the most frequent included in the textbook. For example, Activity 1: *If the box is initially at rest and, after moving 2m has a velocity of 0,75m.s-^{1}, calculate the frictional force acting on it* (p. 168). At level 3, very few analysed units were included in the textbook and SP6 *Constructing explanation* was the most frequent (23, 3.6%). For example, Activity 1 (p. 80): *Explain why the unique properties of the carbon atom have resulted in over 10 million different organic compounds.* The inclusion of science practice at level 4 was rare; the most frequent at this level is SP4, *Analysing and interpreting data* (3, 0.5%). For example, Question: *3) Draw a graph of rate (represented by 1/t on the vertical axis) against volume of sodium thiosulfate (on the horizontal axis). 4) What conclusion can be drawn from the graph? Explain fully* (p. 219).

On the other hand, the least frequent practices were SP4, *Analysing and interpreting data* (92); SP1, *Asking questions* (56); SP3, *Planning and carrying out investigation* (55); and SP7, *Engaging in argument from evidence* (38). Although the SP3 and SP7 were found with the highest frequency at level 2, the other two practices were at level 1. It also revealed a few and rare cases of inclusion of the science practices at level 3 and 4 in the textbook as well. This means that the level of science practices included in the textbook were most directed by textbook (or teacher) and not the learner, hence textbook analysed units do not adequately encourage learners in Planning and carrying investigations, Analysing data, Asking questions and Argument practices.

Table 4.4: Frequencies and percentages of inclusion of each level of science practices for each knowledge area in Physical Sciences Textbook A

			Frequencies (%)							
Knowledge area	**Actual number of units**	**Level**	**SP1**	**SP2**	**SP3**	**SP4**	**SP5**	**SP6**	**SP7**	**SP8**
Mechanics	291 (20.2%)	1	6(2.1)	52(17.9)	0(0)	5(1.7)	37(127)	39(13.4)	0(0)	2(0.7)
		2	0(0)	18(6.2)	6(2.1)	4(1.4)	49(16.8)	25(8.6)	4(1.4)	7(2.4)
		3	1(0.3)	6(2.1)	0(0)	7(2.4)	3(1.0)	13(4.5)	3(1.0)	4(1.4)
		4	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Matter and material	311 (21.5%)	1	13(4.2)	**67(21.5)**	2(0.6)	0(0)	20(6.4)	67(21.5)	0(0)	20(6.4)
		2	0(0)	21(6.7)	7(2.6)	2(0.6)	12(3.9)	21(6.7)	4(1.3)	18(5.8)

		3	2(0.6)	8(2.6)	2(0.6)	3(1.0)	0(0)	7(2.3)	4(1.3)	7(2.3)
		4	0(0)	0(0)	1(0.3)	0(0)	0(0)	0(0)	0(0)	0(0)
Waves, sound and light	35 (2.4%)	1	2(5.7)	8(22.9)	0(0)	0(0)	2(5.7)	10(28.6)	0(0)	2(5.7)
		2	0(0)	0(0)	1(2.9)	0(0)	2(5.7)	4(11.4)	0(0)	0(0)
		3	0(0)	0(0)	0(0)	0(0)	0(0)	3(8.6)	0(0)	1(2.9)
		4	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Chemical change	599 (41.5%)	1	**18(3.0)**	57(9.5)	2(0.3)	**30(5.0)**	51(8.5)	**118(20.0)**	0(0.0)	24(4.0)
		2	0(0.0)	16(2.7)	**18(3.0)**	18(3.0)	**72(12.0)**	48(8.0)	**14(2.3)**	**44(7.3)**
		3	6(1.0)	1(0.2)	9(1.5)	7(1.2)	5(0.8)	23(3.8)	0(0.0)	8(1.3)
		4	1(0.2)	0(0.0)	1(0.2)	3(0.5)	1(0.2)	1(0.7)	1(0.2)	2(0.3)
Electricity and magnetism	141 (9.8%)	1	5(3.5)	29(20.6)	0(0.0)	5(3.5)	9(6.4)	19(13.5)	0(0.0)	5(3.5)
		2	0(0.0)	12(8.5)	5(3.5)	2(1.4)	26(18.4)	1(0.7)	3(2.1)	4(2.8)
		3	0(0.0)	3(2.1)	1(0.7)	4(2.8)	3(2.1)	2(1.4)	2(1.4)	1(0.7)
		4	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Chemical system	67 (4.6%)	1	2(3.0)	8(12.0)	0(0.0)	0(0.0)	2(3.0)	26(38.8)	0(0.0)	2(3.0)
		2	0(0.0)	3(4.5)	0(0.0)	2(3.0)	3(4.5)	7(10.4)	0(0.0)	7(10.4)
		3	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(1.5)	3(4.5)	1(1.5)
		4	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Total			**56**	**309**	**55**	**92**	**297**	**435**	**38**	**162**

4.6.2 Levels of science practices included in Textbook B

Table 4.5 shows the frequencies and percentages of each science practice in Textbook B according to their levels of inclusion (from level 1, teacher-directed approach, to level 4, learner-directed approach). The method to calculate percentages is the same as the calculation method used for Textbook A.

The result displayed in Table 4.5 reveals that although all the eight were present in Textbook B, the majority of the practices were included at the lower levels. At level 1, SP6, *Constructing explanation* has the highest frequency (107, 26.9%), followed by SP2, *Developing and using models* (112, 26.1%) and SP8, *Obtaining, evaluating and communicating information* (19, 4.8%). It also shows that over half the analysed units were mostly included at lower level. For example, *Fig 3.3*: *Carbon atoms can form double and triple bonds, a) A hydrocarbon compound containing a double bond and b) A hydrocarbon compound containing a triple bond* (p. 87). At level 2, SP5, *Using mathematical and computational thinking* (86, 26.2%) was the most frequently included in the textbook. This means that inclusion of this practice is directed by the textbook (or teacher) and not learner. For example, Exercise 4.1: *A weight-lifter lifts a barbell through a vertical height of 2,5m by applying an upward force of 1 000N. Calculate the work done by the 1 000N force on the barbel* (p. 171). The inclusion of science practices at level 3 was few. SP6, *Constructing* *explanation*, was found to have the highest frequency (13, 5.6%). For example, Checkpoint 4: Explain *why the voltmeter reading decreases when the resistance is decreased.* (p. 337). Furthermore, the inclusion at level 4 was rare, only SP3, *Analysing and interpreting data*, has the frequency of (1, 0.3%).

In contrast, the least frequent practices were SP1, *Asking questions* (66), SP4, *Analysing and interpreting data* (50), SP3, *Planning and carrying out investigations* (40), SP7, and *Engaging in argument from evidence* (9), although SP3 and SP7 were included at the level 2, while the other two science practices were at level 1. This means that the analysed units were directed by the textbook (or teacher) and not the learner; hence the textbook does not adequately support the learner in Planning investigations, Analysing data, Asking question and Arguments. Although a few and rare cases of inclusion of the science practices were revealed at level 3and 4 as well in the textbook.

Table 4.5: Frequencies and percentage of inclusion of each level of science practices for each knowledge area in Physical Sciences Textbook B

			Frequencies (%)							
Knowledge area	**Actual number of unit**	**Level**	**SP1**	**SP2**	**SP3**	**SP4**	**SP5**	**SP6**	**SP7**	**P8**
Mechanics	328 (22.1%)	1	9(2.7)	51(15.5)	0(0.0)	2(0.6)	45(13.7)	30(9.1)	0(0.0)	6(1.8)
		2	0(0.0)	43(13.0)	2(0.6)	2(0.6)	**86(26.2**)	28(8.5)	2(0.6)	4(1.2)
		3	1(0.3)	9(2.7)	1(0.3)	1(0.3)	0(0.0)	4(1.2)	0(0.0)	2(0.6)
		4	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Matter and material	429 (28.9%)	1	**14(3.7)**	**112(26.1**)	0(0.0)	0(0.0)	38(8.9)	102(23.8)	0(0.0)	13(3.0)
		2	0(0.0)	30(7.0)	9(2.1)	1(0.2)	40(9.3)	36(8.4)	2(0.5)	9(2.1)
		3	0(0.0)	7(1.6)	1(0.2)	0(0.0)	0(0.0)	10(2.3)	0(0.0)	6(1.4)
		4	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Waves, sound and light	37 (2.5%)	1	1(2.7)	10(76.9)	1(2.7)	0(0.0)	5(13.5)	6(16.2)	0(0.0)	0(0.0)
		2	0(0.0)	0(0.0)	0(0.0)	0(0.0)	6(16.3)	3(8.1)	0(0.0)	1(2.7)
		3	0(0.0)	1(2.7)	0(0.0)	0(0.0)	0(0.0)	3(8.1)	0(0.0)	0(0.0)
		4	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Chemical change	398 (26.8%)	1	22(5.5)	31(7.9)	1(0.3)	**14(3.5)**	57(14.3)	**107(26.9**)	0(0.0)	**19(4.8)**
		2	1(0.3)	7(1.8)	**14(3.5)**	7(1.9)	48(12.1)	34(8.5)	1(0.3)	14(3.5)
		3	0(0.0)	1(0.3)	4(1.0)	3(0.8)	1(0.3)	5(1.3)	0(0.0)	5(1.3)
		4	0(0.0)	0(0.0)	1(0.3)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Electricity and magnetism	231 (15.6%)	1	6(2.6)	47(20.3)	3(1.3)	10(4.3)	19(8.2)	32(13.9)	0(0.0)	6(2.6)
		2	0(0.0)	19(8.2)	2(0.9)	9(3.9)	29(12.6)	19(8.2)	1(0.4)	3(1.3)
		3	1(0.4)	9(3.9)	0(0.0)	1(0.4)	1(0.4)	13(5.6)	0(0.0)	1(0.4)
		4	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Chemical system	62 (4.2%)	1	11(17.7)	10(16.1)	0(0.0)	0(0.0)	4(6.5)	21(33.9)	0(0.0)	0(0.0)
		2	0(0.0)	2(3.2)	0(0.0)	0(0.0)	2(3.2)	3(4.8)	**2(3.2)**	1(1.6)
		3	0(0.0)	1(1.6)	1(1.6)	0(0.0)	0(0.0)	1(1.6)	1(1.6)	2(3.2)
		4	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)

Total		**66**	**390**	**40**	**50**	**381**	**457**	**9**	**92**

4.6.3 Levels of science practices included in Textbook C

Table 4.6 shows the frequencies and percentages of each science practice in textbook C based on their levels of inclusion (from level 1, teacher-directed approach, to level 4, learner-directed approach). The method to calculate percentages is the same as the calculation method used for the Textbook A**.**

The result displayed in Table 4.6 below reveals that all the eight science practices were reflected in Textbook B but, most of the practices were included at the lower levels. At level 1, SP6, *Constructing explanation* has the highest frequency (80, 22.9%), followed by SP2, *Developing and using models* (71, 25.7%), SP5, *Using mathematical and computational thinking* (65, 33.7%), and SP8, *Obtaining*, *evidence*, *and communicating information* (23, 8.3%). The inclusion of these practices was mainly at lower level. For example 1 on SP6, the paragraph on rate of reaction: *The reaction rate (rate of reaction) or speed of reaction for a reactant or product in a particular reaction is defined as how fast or slow the concentration of that reactant or product changes. This definition is only valid for a single reaction in a closed system of constant volume. For example, if salt water is boiled in an open pot, the concentration of the solution increases as water evaporates, but no reaction takes place* (p. 185). Example 2 on SP8, the case study paragraph on Road safety - Importance of wearing seatbelts (p. 51). The inclusion of science practice found at level 3 was very few, and the most frequent at this level is SP6 *Constructing explanation* (9, 7.6%), followed by SP8, *Obtaining, evaluating and communicating information* (8, 2.3%). For example 1, Research project: *Research the reaction on when wine is left exposed to air, it goes 'off' and develops an unpleasant taste. This oxidation reaction was used in the photoelectric intoximeter that measured the alcohol level in a breath sample. Research the reaction and its applications and write a report on one page of your finding* (p. 87). For example 2, Activity 4: *Use atomic model kits, or marbles and Prestik, or jelly tots and toothpicks to build models of the following molecules. 1) Propane, propene and propyne. Note what happens to the number of hydrogen atoms as the single bond is replaced by a double bond, and then a triple bond* (p. 101). At level 2, SP3, *Planning and carrying out investigation* (20, 5.7%) was the most frequently included in the textbook. This means the inclusion of the practices at level 1 and 2 is directed by the textbook (or teacher) and not the learner.

In contrast, the least frequent practices were SP3, *Planning and carrying out investigations* (51), SP1, *Asking questions* (48), SP4, *Analysing and interpreting data* (45), and SP7, *Engaging in argument from evidence* (11). Although the inclusion of SP7 was found at level 3, for example, Activity 15: investigation (6) - *'The lack of potable water is the main stumbling block in sustainable development'. Comment on this statement* (p.352). While SP3 was at level 2, the other two practices (SP1 and SP4) were at level 1. This means that the textbook does not adequately encourage learner engagement in Planning and carrying out investigation, Analysing, Asking questions and Argument practices emphasized in the Science Education Standards. The representation of science practices, therefore, showed similar inclusion for all the analysed textbooks.

Table 4.6: Frequencies and percentage of inclusion of each level of science practices in each knowledge area in Physical Sciences Textbook C

			Frequencies (%)							
Knowledge area	**Actual number of units**	**Level**	**SP1**	**SP2**	**SP3**	**SP4**	**SP5**	**SP6**	**SP7**	**SP8**
Mechanics	193 (18.5%)	1	5(2.6)	25(13.0)	0(0.0)	6(2.1)	**65(33.7)**	31(16.1)	0(0.0)	3(1.6)
		2	0(0.0)	8(4.1)	4(2.7)	4(2.1)	14(7.3)	7(3.7)	2(1.0)	5(2.6)
		3	0(0.0)	3(1.6)	0(0.0)	1(0.5)	1(0.5)	6(3.1)	0(0.0)	2(1.0)
		4	0(0.0)	1(0.5)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Matter and material	276 (26.5%)	1	12(4.3)	**71(25.7)**	1(0.4)	2(0.7)	19(6.9)	79(28.6)	0(0.0)	**23(8.3)**
		2	0(0.0)	13(4.7)	12(4.3)	2(0.7)	11(4.0)	8(2.9)	1(0.4)	4(1.4)
		3	1(0.4)	1(0.4)	3(1.1)	1(0.4)	1(0.4)	3(1.1)	1(0.4)	7(2.5)
		4	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Waves, sound and light	43 (4.1%)	1	2(4.7)	13(30.2)	1(2.3)	1(2.3)	7(16.3)	12(27.9)	0(0.0)	3(7.0)
		2	0(0.0)	0(0.0)	0(0.0)	0(0.0)	2(4.7)	1(2.3)	0(0.0)	1(2.3)
		3	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
		4	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Chemical change	349 (33.5%)	1	**15(4.3)**	43(12.3)	2(0.6)	**12(3.4)**	45(12.9)	**80(22.9)**	0(0.0)	13(3.7)
		2	0(0.0)	9(2.6)	**20(5.7)**	9(2.7)	32(9.2)	19(5.4)	0(0.0)	16(4.6)
		3	2(0.6)	7(2.0)	2(0.6)	3(0.9)	1(0.3)	7(2.0)	2(0.6)	8(2.3)
		4	0(0.0)	0(0.0)	1(0.3)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(0.3)
Electricity and magnetism	119 (11.4%)	1	5(4.2)	31(26.0)	0(0.0)	0(0.0)	17(14.3)	22(18.5)	0(0.0)	4(3.7)
		2	0(0.0)	2(1.7)	3(2.5)	3(2.5)	8(6.7)	5(4.2)	0(0.0)	3(2.5)
		3	0(0.0)	3(2.5)	1(0.8)	0(0.0)	2(1.7)	9(7.6)	0(0.0)	1(0.8)
		4	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Chemical system	62 (6.0%)	1	5(8.1)	5(8.1)	0(0.0)	0(0.0)	3(4.8)	24(38.7)	0(0.0)	4(6.5)
		2	0(0.0)	1(1.6)	0(0.0)	1(1.6)	4(6.5)	5(8.0)	0(0.0)	0(0.0)
		3	1(1.6)	0(0.0)	1(1.6)	0(0.0)	1(1.6)	0(0.0)	**4(6.5)**	2(3.2)
		4	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(1.6)	0(0.0)
Total			**48**	**236**	**51**	**45**	**233**	**318**	**11**	**100**

4.7 KNOWLEDGE AREAS THAT PROMOTE SCIENCE PRACTICES IN THE TEXTBOOKS

Table 4.7 shows how the knowledge areas (Mechanics, Matter and material, Waves, sound and light, Chemical change, Electricity and magnetism, and Chemical system) highlighted in the Physical Sciences national curriculum statement (CAPS) promote the science practices identified in NGSS. Table 4.7 reveals the rate at which science practices were included in each knowledge area of Textbook A that analysed 1444 units. The rate of inclusion of science practices within the knowledge area in Textbook A ranges from 3.2 to 4.5, with highest representation of science practices in Electricity and magnetism and Chemical change. This means that Electricity and magnetism and Chemical change promote science practices more than the other knowledge areas in Textbook A. In addition, the Table 4.7 below indicates the rate of science practices included in each knowledge area of Textbook B that analysed 1485 units. The rate of inclusion of science practices within the knowledge areas ranges from 2.8 to 3.7, with most inclusion in Matter and material, followed by Electricity and magnetism. This shows that the Matter and material, and Electricity and magnetism promote science practices more than the other knowledge areas in Textbook B.

Table 4.7 also illustrates the rate at which science practices were included in each knowledge area for Textbook C that analysed 1042 units. The rate of inclusion of science practices within the knowledge areas ranges from 2.8 to 3.3, with most inclusion in Waves, sound and light, followed by the Chemical change. This means that the knowledge area of Wave, sound and light and Chemical change promote science practices more than the other knowledge areas in Textbook C. Figure 4.2, projected using the rate of inclusion of science practices, demonstrates how the inclusion is addressed within the knowledge areas for the textbooks. The result showed a varied inclusion within the knowledge areas in all the three analysed textbooks; although the representation of science practices within the knowledge areas of Textbook A were most evident. Furthermore, the mean Table 4.8 below shows that Electricity and Magnetism has the highest mean of 3.6, followed by Chemical change with a mean of 3.5. On the contrary, Chemical system has the lowest mean of 3.0. This means that while Electricity and magnetism mostly promotes the inclusion of science practices, there is a similar pattern in the inclusion of science practices within the knowledge areas across the analysed textbooks as shown in Table 4.8 below.

Calculation on Knowledge area inclusion for science practices below

Knowledge area = total number of analysed units for each knowledge area / Number of pages for each knowledge area

Table 4.7: Science practices included in each knowledge area for Textbook A, B and C

T/book	NGSS science practices	Knowledge area					
		Mechanics	**Matter & material**	**Waves, sound & light**	**Chemical change**	**Electricity & magnetism**	**Chemical systems**
A	SP1: Questioning SP2: Modelling SP3: Planning SP4: Analysing SP5: Thinking SP6: Explaining SP7: Argument SP8:Communicating	7 76 6 16 89 77 7 13	15 96 12 5 32 95 8 48	2 8 1 0 4 17 0 3	25 74 30 58 129 190 15 78	5 44 6 11 38 22 5 10	2 11 0 2 5 34 3 10
	Total	**291/80 = 3.6**	**311/88 = 3.5**	**35/9 = 3.9**	**599/134 = 4.5**	**141/31 = 4.5**	**67/21 = 3.2**
B	SP1: Questioning SP2: Modelling SP3: Planning SP4: Analysing SP5: Thinking SP6: Explaining SP7: Argument SP8:Communicating	12 103 3 5 131 62 2 12	14 149 10 1 78 148 2 27	1 11 1 0 11 12 0 1	23 39 20 24 106 146 1 39	7 75 5 20 49 64 1 10	11 13 1 0 6 25 3 3
	Total	**328/116 = 2.8**	**429/115 =3.7**	**37/13 =2.8**	**398/146 = 2.7**	**231/68 = 3.4**	**62/21 = 3.0**
C	SP1: Questioning SP2: Modelling SP3: Planning SP4: Analysing SP5: Thinking SP6: Explaining SP7: Argument SP8: Communicating	5 37 4 11 80 44 2 10	13 5 16 5 31 90 2 34	2 13 1 1 9 13 0 4	17 59 25 24 78 106 2 38	5 36 4 3 27 3 27 36	6 6 1 1 8 29 5 6
	Total	**193/65 =3.0**	**276/88 = 3.1**	**43/13 =3.3**	**349/109 =3.2**	**119/43 = 2.8**	**62/2.8 = 2.8**

Table 4.8: Mean for inclusion of the science practices in each knowledge area in the textbooks

Knowledge areas						
	Mechanics	Matter and material	Waves, sound and light	Chemical change	Electricity and magnetism	Chemical system
Mean	3.1	3.4	3.3	3.5	**3.6**	3.0

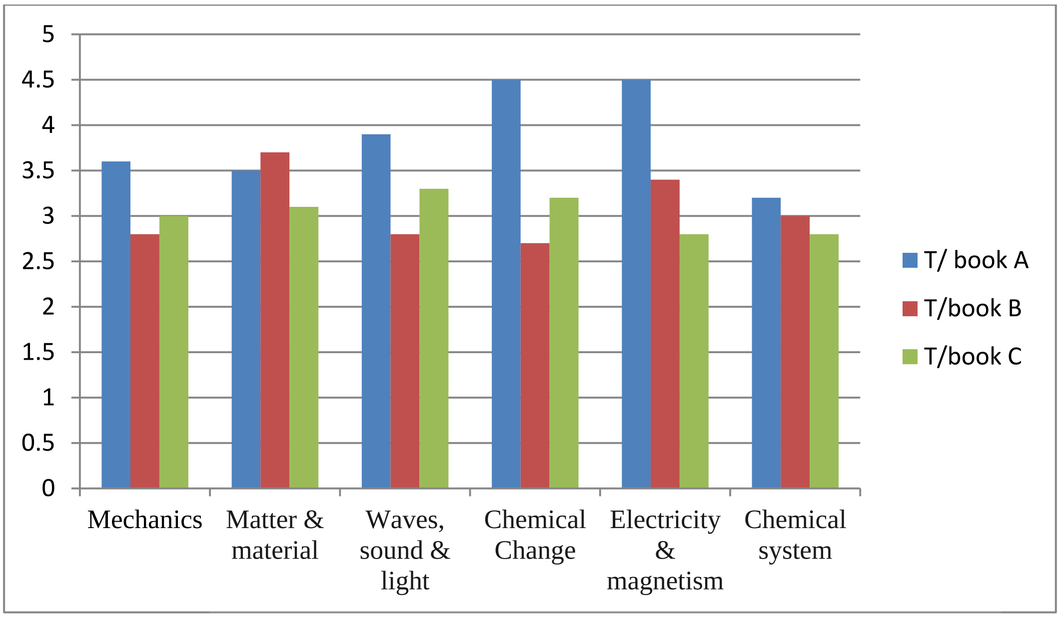

Figure 4.2: Graph of how each knowledge area addressed the science practices in the analysed textbooks

4.8 CONCLUSION

In this chapter the developed rubric that was proved feasible for analysing science textbooks for the inclusion of science practices after a pilot study was discussed. Then the results for the analysis of the three Physical Sciences textbooks were also discussed. The results show that all the eight science practices were represented in each textbook, although the majority were recorded at the lower level of science practices. This means that the textbooks were directed by the teacher and not the learner. The results further revealed that practices of *Constructing explanation, Developing and using models*, and *Using mathematical and computational thinking* were predominant across the three textbooks. On the contrary, practices of *Analysing and interpreting data, Planning and carrying out investigation, Asking questions, and Engaging in Argument from evidence* were least represented. It is therefore important that representation of these science practices shows a similar pattern in the textbooks, as the textbook is considered to be a crucial tool in driving the science education goal.

In comparing the three textbooks, the inclusion of science practices was varied across the textbooks, although the practice of Explaining was similar and predominant in all the textbooks. This is followed by practices of Modelling and Thinking that mostly dominated in Textbook B. On the contrary, least represented practices of Communicating, Analysing and Argument were most included in Textbook A. The practices of Questioning and Planning were also least represented in Textbook C.

Concerning the knowledge area that promotes the inclusion of science practices, the result revealed varied inclusion of science practices within the knowledge areas in each textbook. However, the representation of science practices within the knowledge areas across the analysed textbooks showed a similar pattern, although Electricity and magnetism has the highest mean score while Chemical system has the least mean score.

CHAPTER 5

RESULT DISCUSSION AND RECOMMENDATION

5.1 INTRODUCTION

This study is driven by the fact that the recent focus of science education has shifted to engaging learners in science practices emphasized in the NGSS. As a result, this study considered it worthwhile to explore the extent to which the science practices are depicted in Physical Sciences textbooks. In this regard, both the textbook and teacher are expected to engage learners in the various science practices and assist them in developing a clearer and deep combined knowledge of both scientific concepts and practices simultaneously, as emphasized in the new Science Education *Framework* and NGSS. To achieve the aim of this study, the research process was conducted in two phases. Phase One explained the steps involved in developing the Science Practices Continuum Rubric (SPCR), and Phase Two included an analysis of the three Physical Sciences textbooks for the inclusion of science practices. This is to determine whether the *Next Generation Science Standards* (NGSS) and curriculum emphasis were denoted in the textbooks.

A qualitative approach was employed in this study and the analysis utilised a content analysis research design and purposive sampling. The conceptual and analytical framework for this study is based upon the science practices proposed in the recent US Science Education *K-12 Framework* and *Standards* (NRC. 2012; NGSS Lead States, 2013).

This chapter thus includes discussions on the summary of the finding in both phases one and two involved in this study, followed by recommendation. The limitations of this study and researcher reflection on the study were further highlighted; areas for possible future research and conclusion were also mentioned.

5.2 SUMMARY OF PHASE ONE

The analytical instrument named Science Practices Continuum Rubric (SCPR) developed for this study includes the eight science practices, four levels of each practice and descriptions with examples for each level. The developed rubric made the combination of both science content knowledge and skills clearer compared with the five essential features of IBL used in the previous studies (Aldahmash et al., 2016; Asay & Orgill, 2010).

The developed rubric was found to be feasible for analysing science textbooks for the inclusion of science practices because it was practically used in a pilot study. It was also employed in the actual research by the researcher and expert in the field of scientific inquiry research and textbook analysis who served as co-rater.

5.3 SUMMARY OF PHASE TWO

This section discussed the finding on the following:

5.3.1 Summary of the inclusion of science practices in Textbook A, B and C

The results of the textbook analysis for the inclusion of science practices show that all the eight science practices were represented in the three textbooks (A, B and C). The result in Table 4.2 indicates that the all the textbooks promote the practices of *Constructing explanation, Developing and using models, Using mathematical and computational thinking and Obtaining, evaluating and communicating information.* The significance of these representations is that the textbooks provide learners opportunities to improve their competency in these science practices, which is paramount for learners' literacy in science. For instance, understanding science concepts and ideas in order to interpret phenomena and make informed decisions (Duschl et al., 2007); better imagination of a phenomena arouses curiosity and interest in learners (Krajcik & Merritt, 2012); and to develop understanding and competency in a range of mathematical abilities for solving problems and communicating information (Duschl et al., 2007). On the other hand, the result above (Table 4.2) shows the three textbooks do not promote practices of *Analysing and interpreting data*, *Planning and carrying investigation, Asking question,* and *Engaging in argument.* This means that the textbooks engage learners in some science practices such as Explaining, Modelling and Thinking more than the other science practices such as Asking questions, Planning investigation and Argumentation. This result is similar to the findings of a previous study done by Stavros (2016).

In comparing inclusion of science practices across the textbooks, the result (Table 4.3) indicates no pattern in the inclusion. This is because the inclusion of the science practices was similar, especially in *Constructing explanation* practice. The inclusion also displayed most practices of Modelling and Thinking in Textbook B.

It was also revealed that Textbook A showed most inclusion in Analysing, Argument and Communicating practices. The inclusion in Textbook C displayed most practices of Questioning and Planning.

In conclusion, it is evident that not all science practices are being adequately addressed in the textbooks, and hence the findings do not align with the recent US Science Education *Framework* and *Standards* (NRC, 2012; NGSS Lead States, 2013). Hence, there is a need for adequate inclusion of all science practices in order to actualise the goals of the new *Framework* and NGSS using the Physical Sciences textbooks.

5.3 2 Summary of levels of inclusion of science practices in each textbook

The findings from tables 4.4, 4.5 and 4.6 that demonstrated the levels of inclusion practices reveal that the analysed units across the three analysed textbooks showed the inclusion of the eight science practices were mostly at level 1 and 2. In other words, the inclusion of science practices in the textbooks reflected mostly at lower (confirmatory and structured) level, hence the majority of analysed units centred on the teacher-directed learning approach instead of a learner-directed learning approach. This indicates that learners have less autonomy in learning science and are not fully engaged in the science practices. The result shows that the textbooks do not align with the National Science Education Standard for inquiry, as well as the recent US science education *Framework* and *Standards* that proposed that by the end of grade 12 learners should be able to develop and use advance understanding of science knowledge and competence in scientific practices (NRC, 2000; NRC, 2013).

In addition, the finding of this study advocates on the need to rebrand the teaching and learning of school science through inquiry. In other words, the result will help to address the confusion about inquiry in science through science practices (Crawford, 2014; NRC, 2014). Comparing the findings of previous studies that emphasized and used five essential features of inquiry with findings of this study makes the real activities and practices of scientists more explicit in order to improve learning of school science for developing deeper understanding of scientific knowledge and skill in learners.

The review of literature revealed that these results on textbook analysis are similar to previous studies that emphasized on five essential features of inquiry done by Aldahmash et al. (2016), Chabalengula and Mumba (2012) and Lewis (2012).

The conclusion drawn from the level of inclusion of science practices in Textbooks A, B and C is that the inclusion of all the eight science practices appears mostly at lower level. This means the textbooks do not promote the learner-directed active learning approach. Learners are expected to be provided with freedom to fully engage in all science practices in order to master the science practices, for developing deeper understanding of science concepts and ideas, and inquiry abilities to interpret phenomena, solve problems and make decisions related to person and society (Duschl et al., 2007).

5.3.3 Summary of how the inclusion of science practices was addressed within the knowledge areas

The results in Tables 4.7 and 4.8 illustrate how the science practices were addressed within the knowledge areas in the analysed textbooks. The mean result reveals that the inclusion of science practices within the knowledge area of Electricity and magnetism was most represented across the three textbooks, followed by Chemical change and then Matter and material. On the other hand, the knowledge area of Waves, sound and light, followed by Mechanics and Chemical system, were least represented across the textbooks. The mean result indicates that although Electricity and magnetism has the highest mean score, the inclusion of the science practices within the knowledge areas shows a similar pattern across the analysed textbooks. This simply implies that the knowledge area of Electricity and magnetism (Physics) mostly promotes the inclusion of science practices in all the textbooks. The representation of NGSS science practices, therefore, is appropriately addressed within the knowledge areas, but at the lower level. This result shows not much difference to a previous study conducted by Aldahmash et al., (2016).

However, to improve learners' literacy in science in view of sociocultural theory, learners are supposed to fully and actively participate in all the practices of science in their learning of school science. This means that the teacher and textbook should provide the learner the maximum opportunities to engage in authentic science practices just as real scientists (NRC, 2012). This way the textbook offers the guidance to share, critique, construct and acquire scientific knowledge, inquiry skills and meaningful understanding of science concepts which is mainly influenced by the quality of the science instruction (Vygotsky, 1978; Furtak & Penuel, 2019). Hence, this particular theory that underpinned this study can be accomplished through more learner-centred active learning techniques (such as inquiry-based learning and problem-based learning).

5.4 RECOMMENDATIONS

Considering the crucial role of textbooks in driving and teaching and learning in school science, the findings of the study suggest that that the use of these textbooks as an educational tool in achieving curriculum imperatives undermines the advancement of science practices in high school science. This is because there is no appropriate balance in the inclusion of the science practices in the textbooks, as proposed in the recent *Standards* of science learning in order to improve learners' literacy in science. This means that some of the science practices were neglected in the analysed textbooks. However, it is important that the educational stakeholders acknowledge that learners' acquisition of science practices and meaningful science understanding is heavily influenced by the quality of science textbooks and instruction provided by the teacher. In this regard, my suggested recommendation is targeted at the Department of Education (DoE), textbook authors and publishers and, finally, the teachers of school science.

5.4.1 Department of Education

The department of education should employ science education experts, researchers and a group of teachers to review the science (Physical Sciences, Life Sciences and Natural Sciences) curriculum policy document with a focus on integration of science practices. In my review of literature, the inclusion of the science practices in both national curriculum and curricular material could influence the implementation of these practices in science class (Crawford, 2014). I suggest that these science practices be addressed explicitly in the national curriculum policy document, in order to increase effective implementation of the science practices by the teachers in the learning of science. In addition, the department of education should ensure that the science learners' textbooks are modified up to standard (guided and open-ended) by reflecting the inclusion of the eight science practices and providing learners with more learner-directed active activities; as well as a teaching guide that will support explicit teaching of these practices during science instruction.

Teachers' professional development is another important aspect that the Department of Education should address. This is to assist science teachers in achieving the recommended recent Science Education *Framework* and *Standards* in regards to engage the 21st century learners in practices of science, which explicitly addressed the imperative of combining both science content knowledge and inquiry abilities simultaneously in science education. The department of education should sponsor science teachers through short courses, workshops and seminars to boost their competence in facilitating standard practical activities in school science.

On the part of the learners, the Department of Education should further include a compulsory individual or group practical examination, especially in Grade 12 matric, that will require either guided or open-ended science practices. This will help to expose the learners to these aforementioned science practices in their learning of science, with the guidance of an expert science teacher.

5.4.2 Curriculum designers

It is imperative for the curriculum designers to be aware of the recent K-12 *Framework* and NGSS that advocate for learners' engagement in the science practices in their science learning. I suggest that the Department of Education should ensure that the NGSS science practices are explicitly stated in the national curriculum document (CAPS) by the curriculum designers in order to enable the authors, publishers and teachers to properly address the inclusion of the science practices in science textbooks and classrooms.

5.4.3 Textbook authors and publishers

There is a need for the authors and publishers of textbooks to be aware of this recent reform of science practices proposed by the US National Research Council, and if possible to be trained on these practices of science. This is to ensure that the inclusion of these science practices is adequately addressed in the writing of Physical Sciences textbooks. However, I suggest that the science (Physical Sciences, Life Sciences and Natural Sciences) textbooks should be modified to include all the eight science practice adequately. This inclusion should be of a more learner-centred approach than teacher-centred approach, which promotes high knowledge and practices (skills). In other words, the science textbooks should provide learners with more opportunities to develop and use the required science practices, which are critical in a society driven by science and technology.

Table 5.1 Some NGSS science practices with description of what learners do and examples provided by the researcher (adapted from NRC, 2012)

NGSS Science Practices	What Learners Do	Examples
1. Asking questions	a) Ask questions to develop explanation about the natural world. b) Ask questions that can be answered using evidence from investigations or gathered by other.	Activity: a) State an investigation question/ hypothesis for this investigation. b) Eutrophication refers to a natural process where mainly nitrates and phosphate enter the water system that leads to death of organic matter. Based on your understanding about eutrophication, formulate three investigation questions.
2. Planning and carrying out investigations	a) Design investigations that will produce data that can be used to answer scientific questions. This includes aim of the investigation, predictions, and procedure. b) Identify and analyse experimental variables, controls and methods (e.g., how many trials to do. c) Conduct investigations to gather data (observations or measurements) using appropriate tools and methods.	Activity: Design an investigation method using titration to find an unknown quantity. Write up a report including the following: Background research on ethanoic acid .Aim .Apparatus .Method .Variables- control, dependent and independent .Write your observations and result.
3. Analysing and interpretation of data	a) Analyse and interpret data to determine pattern and relationship. b) Represent data in tables and graphs to reveal patterns and relationships. c) Construct the limitations of data analysis such as source of error	Activity: Result a)Record investigation result in a table b)Plot a graph of emf against internal resistance on suitable axis c) Describe the graph. See if you can find any patterns in the graph (e.g is there any relationship between the emf and internal resistance) in the simple circuit.
4. Engaging in argument from evidence	a) Construct and refine arguments based on evidence. b) Critique arguments from peers and other sources by citing relevant evidence and asking scientific questions. c) Compare and critique two arguments based on the quality of evidence and reasoning.	Activity: a) Discussion of the result- compare your results for the emf with the value stated on the each cell. b) Discuss any source of error b) Activity: Class debate to evaluate the impact that the use of fertiliser has on humans and the environment. Learners can be divided into two groups, one group argues in support of inorganic fertilisers and the other in support of organic fertiliser and indigenous methods to fertilise plants.

5.4.4 Science teachers

Considering that teachers have the sole responsibility of translating curriculum policy into classroom practice effectively, it has been revealed that most science teachers do not engage learners in the science practices such as asking questions, planning investigations and argument. A review of literature documented the teachers' constraints in implementing inquiry teaching and learning (Crawford, 2014, Mokiwa & Nkopodi, 2014). To support science teachers in engaging learners in science practices using the science textbook, the four levels of included science practice rubric known as Science Practices Continuum Rubric (SPCR) developed in this study may serve as a guide to the science teachers to shift their teaching approach from more teacher-directed instruction to more learner-directed instruction of inquiry-based teaching.

5.5 LIMITATION AND IMPLICATION

The limitation of this study was that three Physical Sciences textbooks were selected to be analysed for this study. During the course of this study, it was discovered that one of the textbooks was available only as an e-book, which makes it difficult for the raters to code this particular textbook. The unavailability of the hard copy, therefore, delayed the process of data collection; the textbook was eventually replaced after much effort to get hold of the hard copy from the publisher.

The implication for this study is that the Physical Sciences textbooks are required to provide the learners with opportunities to develop and use high science content knowledge and science practices, in order to develop understanding of nature of science, improve the learners' literacy in science and prepare them for the workforce as well to make informed decisions. The findings also provided insight into the strengths and weaknesses of the textbooks used in high school science in promoting science practices.

5.6 FUTURE RESEARCH

I suggest further research be conducted with a focus on exploring South African teachers' understanding in implementing science as practices on the basis of eight science practices emphasized in NGSS. Further research should be done on the teachers' use of science textbooks in promoting learners' engagement in science practices, as identified in the recent US science education *Framework*, in a South African classroom context.

5.7 CONCLUSION

The intention of the study was to explore the extent to which the Physical Sciences textbooks reflect the science practices as identified in recent United States science education K-12 *Framework* and NGSS (NRC, 2012; NGSS Lead States, 2013). This study thus focuses on the analysis of three Physical Sciences textbooks popularly used by teachers in planning for teaching. The study targeted analysing the units included in textbooks based on eight science practices.

The findings indicated that these analysed textbooks represented all the eight practices, although the majority of the inclusion centred on a teacher-directed approach, which presents learning of science as more of knowledge transmission of facts and fails to engage learners fully in all the science practices (Aldahmash et al., 2016; Dunne et al., 2013). Consequently, the textbooks do not provide learners with sufficient opportunities to develop high-order scientific thinking and reasoning emphasized in the Next Generation Science Standards (NGSS). In addition, the findings also show that the levels of science practices present in the analysed textbooks do not aligned with the previous *National Science Education Standards* (NRC, 1996; 2000) and new science learning *Framework* and *Standards* (NRC, 2012, NGSS Lead States, 2013). The low inclusion of the science practices in the textbooks may be attributed to these practices not being explicitly stated in the national curriculum policy document (CAPS) and a lack of awareness by the textbook authors of the recent NGSS science practices.

Considering the significance of textbooks in determining in large measure what is taught and learned in the classroom (Niaz & Maza, 2011), this is especially true within the South African education landscape where science teachers' lack of readiness in implementing an inquiry-based approach and new reform goals has resulted in teachers being heavily dependent on the school science textbook in advancing curriculum aims (Malcolm & Alant, 2004; Ramnarain & Chanetsa, 2017).

Lastly, this study suggests that further research be conducted to explore science teachers' understanding in implementing an inquiry-based learning approach based on the identified eight science practices and the use of the textbook in promoting these science practices in classroom. For example, how do South African teachers use textbooks in facilitating learners' engagement in science practices in their teaching? How does the teachers' understanding influence the implementation learners' engagement in science practices?

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APPENDICES

APPENDIX 1

FACULTY OF EDUCATION

10/17/2018

PO Box 13271
Vona Valley
Midrand
1686
Reference number: 201243061

APPROVAL OF PROPOSAL – MRS AE NDUMANYA (201243061)

Dear Mrs AE Ndumanya

You first registered for the qualification M. Ed in Mathematical and Science Education (M5MSEQ) in 2017 as a part time student. Your proposal served for notification at the Faculty Higher Degrees committee meeting on the 14th of August 2018.

Proposed title: An analysis of grade 12 Physical Science textbooks for inclusion of 'practice' of inquiry-based learning
Supervisor: Prof U Ramnarain
Co-Supervisor: Prof H-Kai Wu (National Taiwan Normal University)

Should your title change prior to the final submission of the minor dissertation, be advised that a change of title must serve at the Faculty Higher Degrees Committee.

Regards

Ms B Tshidumo
Faculty Officer: Higher Degrees
belindat@uj.ac.za

APPENDIX 2

SCORING SHEET SHOWING DATA COLLECTED FROM TEXTBOOK A

- **Mechanics (1)**

Unit	Topic	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
1	Momentum & Impulse	1 2 3 4	5 0 0 0	25 3 0 0	0 5 0 0	0 3 4 0	14 15 3 0	15 10 7 0	0 3 0 0	0 6 1 0
2	Vertical projectile motion	1 2 3 4	0 0 0 0	5 0 3 0	0 0 0 0	5 1 2 0	5 5 0 0	5 4 1 0	0 0 0 0	0 1 0 0
	Total		**5**	**36**	**5**	**15**	**42**	**42**	**3**	**8**

- **Mechanics (2)**

	Unit	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
1	Work	1 2 3 4	0 0 0 0	12 8 0 0	0 0 0 0	0 0 0 0	11 13 0 0	8 4 1 0	0 0 0 0	1 0 0 0
2	Force and Power	1 2 3 4	1 0 1 0	10 7 3 0	0 1 0 0	0 0 1 0	7 16 0 0	11 7 4 0	0 1 3 0	1 0 3 0
	Total		**2**	**40**	**1**	**1**	**47**	**35**	**4**	**5**

- **Matter and Material (1)**

Units	Topic	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
1	Organic molecular structure	1 2 3 4	2 0 0 0	13 6 1 0	0 2 0 0	0 0 0 0	1 0 0 0	10 5 1 0	0 1 0 0	4 2 0 0
2	Organic compounds and their functional group	1 2 3 4	2 0 0 0	9 6 5 0	0 1 0 0	0 0 0 0	1 0 0 0	11 2 2 0	0 1 2 0	4 7 0 0
3	Physical properties of organic compound	1 2 3 4	2 0 2 0	20 4 1 0	1 2 1 0	0 1 1 0	10 6 0 0	21 6 1 0	0 0 0 0	2 6 4 0
4	Polymer and polymerization	1 2 3 4	6 0 0 0	17 5 1 0	1 1 1 1	0 1 0 0	1 0 0 0	14 5 2 0	0 2 0 0	4 6 1 0
	Total		**14**	**88**	**11**	**3**	**19**	**80**	**6**	**40**

- **Matter and materials (2)**

	Unit	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
	Reflection, absorption and transmission	1 2 3 4	1 0 0 0	8 0 0 0	0 1 0 0	0 0 2 0	7 6 0 0	11 3 1 0	0 0 2 0	6 0 2 0
	Total		**1**	**8**	**1**	**2**	**13**	**15**	**2**	**8**

- **Waves, sound and light**

	Unit	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
1	Doppler effect	1 2 3 4	2 0 0 0	8 0 0 0	0 1 0 0	0 0 0 0	2 2 0 0	10 4 3 0	0 0 0 0	2 0 1 0
	Total		**2**	**8**	**1**	**0**	**4**	**17**	**0**	**3**

- **Chemical change (1)**

	Units	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
1	Rate of reaction	1 2 3 4	5 0 3 0	25 7 1 0	0 6 6 0	9 4 7 2	5 5 3 0	23 16 8 0	0 2 0 0	1 11 4 0
2	Chemical equilibrium	1 2 3 4	1 0 1 0	3 0 0 0	1 0 1 0	20 8 0 0	16 7 2 0	34 16 4 0	0 0 0 0	9 12 1 1
3	Acids and bases	1 2 3 4	3 0 1 1	12 0 0 0	1 5 1 1	0 1 0 1	23 31 0 1	30 3 3 1	0 5 0 1	11 8 2 1
	Total		**15**	**48**	**22**	**52**	**93**	**138**	**8**	**61**

- **Chemical change (2)**

	Unit	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
1	Electrolysis and electrolytic cell	1 2 3 4	5 0 0 0	14 5 0 0	0 5 0 0	1 3 0 0	0 14 0 0	17 6 6 0	0 5 0 0	2 10 0 0
2	Galvanic cell and standard electrode potential	1 2 3 4	4 0 1 0	3 4 0 0	0 2 1 0	0 2 0 0	7 15 0 0	14 7 2 0	0 2 0 0	1 3 1 0
	Total		**10**	**26**	**8**	**6**	**36**	**52**	**7**	**17**

- **Electricity and magnetism**

	Unit	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
1	Current electricity	1 2 3 4	3 0 0 0	10 8 1 0	0 4 1 0	1 1 3 0	7 18 3 0	4 1 1 0	0 2 2 0	2 3 1 0
2	Electrical machines	1 2 3 4	2 0 0 0	19 4 2 0	0 1 0 0	4 1 1 0	2 8 0 0	15 0 1 0	0 1 0 0	3 1 0 0
	Total		**5**	**44**	**6**	**11**	**38**	**22**	**5**	**10**

- **Chemical system**

	Unit	**Level**	**Questioning**	**Modelling**	**Planning**	**Analysing**	**Thinking**	**Explaining**	**Argument**	**Communicating**
1	Plants and nutrients, and Fertilizer	1 2 3 4	2 0 0 0	8 3 0 0	0 0 0 0	0 2 0 0	2 3 0 0	26 7 1 0	0 0 3 0	2 7 1 0
	Total		**2**	**11**	**0**	**2**	**5**	**34**	**3**	**10**

APPENDIX 3

SCORING SHEET SHOWING DATA COLLECTED FROM TEXTBOOK B

- **Mechanics (1)**

Units		**Level**	**Questioning**	**Modelling**	**Planning**	**Analysing**	**Thinking**	**Explaining**	**Argument**	**Communicating.**
1	Momentum and impulse	1	5	16	0	0	14	12	0	1
		2	0	13	1	0	28	12	0	1
		3	1	1	1	1	0	1	0	1
		4	0	0	0	0	0	0	0	0
2	Vertical projectile motion in one dimension	1	2	4	0	2	4	3	0	1
		2	0	2	0	0	8	4	2	0
		3	0	0	0	0	0	1	0	1
		4	0	0	0	0	0	0	0	0
Total			**8**	**36**	**2**	**3**	**54**	**33**	**2**	**5**

- **Matter and materials (1)**

Units	**Topic**	**Level**	**Questioning**	**Modelling**	**Planning**	**Analysing**	**Thinking**	**Explaining**	**Argument**	**Communicating.**
3	Organic molecular Structures	1	3	18	0	0	0	31	0	6
		2	0	11	1	0	0	2	0	2
		3	0	6	0	0	0	0	0	1
		4	0	0	0	0	0	0	0	0
	Structure and physical property relationship and Application of organic chemistry	1	2	15	0	0	9	13	0	1
		2	0	6	1	0	7	9	0	2
		3	0	1	0	0	0	1	0	0
		4	0	0	0	0	0	0	0	0
	Types of reactions of organic compounds, and Plastics and polymer	1	5	36	0	0	17	23	0	4
		2	0	13	5	0	13	5	2	3
		3	0	0	0	0	0	0	0	5
		4	0	1	0	0	0	0	0	0
	Total		**10**	**107**	**7**	**0**	**46**	**85**	**0**	**24**

- **Mechanics (2)**

Units	**Topic**	**Level**	**Questioning**	**Modelling**	**Planning**	**Analysing**	**Thinking**	**Explaining**	**Argument**	**Communicating**
4	Work and Work energy theorem	1 2 3 4	0 0 0 0	20 11 6 0	0 0 0 0	0 0 0 0	14 14 0 0	9 7 0 0	0 0 0 0	0 0 0 0
	Conservation of energy, and Power	1 2 3 4	2 0 0 0	11 8 2 0	0 1 0 0	0 2 0 0	13 36 0 0	6 5 2 0	0 0 0 0	4 3 0 0
	Total		**2**	**58**	**1**	**2**	**77**	**29**	**0**	**7**

- **Waves, sound and light**

Units	**Topic**	**Level**	**Questioning**	**Modelling**	**Planning**	**Analysing**	**Thinking**	**Explaining**	**Argument**	**Communicating**
5	Doppler effect	1 2 3 4	1 0 0 0	10 0 1 0	1 0 0 0	0 0 0 0	5 6 0 0	6 3 3 0	0 0 0 0	0 1 0 0
	Total		**1**	**11**	**1**	**0**	**11**	**12**	**0**	**1**

- **Chemical change (1)**

Units	**Topics**	**Level**	**Questioning**	**Modelling**	**Planning**	**Analysing**	**Thinking**	**Explaining**	**Argument**	**Communication.**
6	Rate and extent of reaction	1 2 3 4	6 0 0 0	4 0 0 0	0 5 0 1	9 2 3 0	1 5 0 0	8 13 2 0	0 0 0 0	3 3 2 0
7	Chemical equilibrium and factor affecting equilibrium	1 2 3 4	3 1 0 0	3 1 0 0	1 2 1 0	3 2 0 0	14 13 0 0	25 10 0 0	0 1 0 0	4 3 1 0
8	Acids and bases, and Application of acids and bases.	1 2 3 4	3 0 0 0	6 0 0 0	0 2 3 0	1 0 0 0	23 13 0 0	35 5 0 0	0 0 0 0	10 4 1 0
	Total		**13**	**14**	**15**	**20**	**69**	**98**	**1**	**32**

- **Electricity and magnetism**

Units	Topic	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating.
9	Electric circuits	1 2 3 4	3 0 0 0	17 11 1 0	3 0 0 0	0 2 1 0	9 18 0 0	6 8 5 0	0 0 0 0	2 3 0 0
10	Electrodynamics	1 2 3 4	3 0 1 0	30 8 8 0	0 2 0 0	10 7 0 0	10 11 1 0	26 11 8 0	0 1 0 0	4 0 1 0
	Total		**7**	**75**	**5**	**20**	**49**	**64**	**0**	**10**

- **Matter and materials (2)**

Units	Topics	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating.
11	Photoelectric effect	1 2 3 4	3 0 0 0	27 0 0 0	0 2 1 0	0 1 0 0	9 13 0 0	25 14 6 0	0 0 0 0	1 2 0 0
	Atomic emission and absorption	1 2 3 4	1 0 0 0	16 5 0 0	0 0 0 0	0 0 0 0	3 7 0 0	10 6 3 0	0 0 0 0	1 0 0 0
	Total		**4**	**48**	**3**	**1**	**32**	**64**	**0**	**3**

- **Chemical change (2)**

Units	Topics	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
12	Galvanic and electrolytic cells	1 2 3 4	9 0 0 0	14 2 0 0	0 5 0 0	1 3 0 0	11 8 0 0	23 3 0 0	0 0 0 0	1 4 1 0
	Relation of current and potential to rate equilibrium, and Writing of equation	1 2 3 4	1 0 0 0	2 2 1 0	0 0 0 0	0 0 0 0	5 6 1 0	7 3 1 0	0 0 0 0	0 0 0 0
	Oxidation number and application of electrolytic processe	1 2 3 4	0 0 0 0	2 2 0 0	0 0 0 0	0 0 0 0	3 3 0 0	9 0 2 0	0 0 0 0	1 0 0 0

	s									
	Total		**10**	**25**	**5**	**4**	**37**	**48**	**0**	**7**

- **Chemical systems**

Units	**Topics**	**Level**	**Questioning**	**Modelling**	**Planning**	**Analysing**	**Thinking**	**Explaining**	**Argument**	**Communicating.**
13	Elements in fertilisers , and Industrial manufacture of fertilizer	1 2 3 4	8 0 0 0	7 2 0 0	0 0 0 0	0 0 0 0	4 2 0 0	16 2 0 0	0 0 0 0	0 0 0 0
	Impact of the use of inorganic fertilizer	1 2 3 4	3 0 0 0	3 0 1 0	0 0 1 0	0 0 0 0	0 0 0 0	5 1 1 0	0 2 1 0	0 1 2 0
	Total		**11**	**13**	**1**	**0**	**6**	**25**	**3**	**3**

APPENDIX 4

SCORING SHEET SHOWING DATA COLLECTED FROM TEXTBOOK C

- **MECHANICS 1**

Units	**Topic**	**Level**	**Questioning**	**Modelling**	**Planning**	**Analysing**	**Thinking**	**Explaining**	**Argument**	**Communicating**
1	Momentum and impulse	1 2 3 4	3 0 0 0	9 3 1 1	0 2 0 0	0 1 0 0	22 10 0 0	13 4 4 0	0 2 0 0	3 1 2 0
2	Vertical projectile motion in one dimension	1 2 3 4	1 0 0 0	8 2 0 0	0 1 0 0	6 2 1 0	18 4 1 0	6 2 1 0	0 0 0 0	0 2 0 0
Total			**4**	**24**	**3**	**10**	**55**	**30**	**2**	**8**

- **MATTER AND MATERIALS**

Units	**Topics**	**Level**	**Questioning**	**Modelling**	**Planning**	**Analysing**	**Thinking**	**Explaining**	**Argument**	**Communicating**
1	Organic molecular structure	1 2 3 4	8 0 0 0	21 2 0 0	0 7 1 0	0 1 0 0	2 2 0 0	20 2 0 0	0 0 0 0	8 2 2 0
2 & 3	IUPAC naming and Structure-physical property	1 2 3 4	0 0 0 0	11 3 1 0	0 0 0 0	0 0 0 0	0 0 0 0	10 1 1 0	0 0 0 0	5 0 0 0
4 & 5	Application of organic chemistry and Addition, elimination & substitution	1 2 3 4	1 0 0 0	14 4 0 0	0 1 0 0	0 0 0 0	10 5 0 0	15 1 2 0	0 0 0 0	2 1 0 0
6	Plastics and polymer	1 2 3 4	2 0 1 0	15 4 1 0	0 4 1 0	0 0 1 0	0 0 1 0	21 1 0 0	0 0 1 0	4 0 5 0
Total			**12**	**76**	**14**	**2**	**20**	**74**	**1**	**29**

- **MECHANICS 2**

Units	Topics	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
1-4	Work, energy and power	1 2 3 4	1 0 0 0	8 3 2 0	0 1 0 0	0 1 0 0	25 0 0 0	12 1 1 0	0 0 0 0	0 2 0 0
	Total		**1**	**13**	**1**	**1**	**25**	**14**	**0**	**2**

- **WAVES, SOUND AND LIGHT**

Units	Topics	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
1-3	The Doppler effect	1 2 3 4	2 0 0 0	13 0 0 0	1 0 0 0	1 0 0 0	7 2 0 0	12 1 0 0	0 0 0 0	3 1 0 0
	Total		**2**	**13**	**1**	**1**	**9**	**13**	**0**	**4**

- **CHEMICAL CHANGE 1**

Units	Topics	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
1	The rate and extent of reaction	1 2 3 4	4 0 0 0	14 8 1 0	0 6 1 0	7 6 3 0	5 6 0 0	17 5 1 0	0 0 0 0	4 6 3 0
2	Chemical equilibrium	1 2 3 4	3 0 0 0	7 0 1 0	0 2 0 0	5 0 0 0	10 7 0 0	15 11 1 0	0 0 0 0	0 0 1 0
3	Acid and base	1 2 3 4	2 0 0 0	8 0 2 0	2 8 1 0	0 0 0 0	18 7 1 0	24 1 1 0	0 0 0 0	5 7 0 0
	Total		**9**	**41**	**20**	**21**	**54**	**76**	**0**	**12**

- **ELECTRICITY AND MAGNETISM**

Units	Topics	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
1	Electric circuits	1 2 3 4	3 0 0 0	10 2 0 0	0 3 1 0	0 3 0 0	11 7 2 0	9 1 4 0	0 0 0 0	1 3 0 0
2	Electrodynamics	1 2 3 4	2 0 0 0	21 0 3 0	0 0 0 0	0 0 0 0	6 1 0 0	13 4 5 0	0 0 0 0	3 0 1 0
	Total		**6**	**36**	**4**	**3**	**27**	**36**	**0**	**8**

- **MATTER AND MATERIALS 2**

Units	Topics	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
2	Optical phenomena and properties of material	1 2 3 4	1 0 0 0	10 0 0 0	1 1 0 0	2 1 0 0	7 4 0 0	13 3 0 0	0 1 0 0	4 1 0 0
	Total		**1**	**10**	**2**	**3**	**11**	**16**	**1**	**5**

- **CHEMICAL CHANGE 2**

Units	Topics	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
4	Electrochemical reaction	1 2 3 4	6 0 1 1	14 1 3 0	0 3 1 1	0 3 0 0	12 12 0 0	24 2 4 0	0 0 2 0	4 3 2 2
	Total		**8**	**18**	**5**	**3**	**24**	**30**	**2**	**11**

- **CHEMICAL SYSTEMS**

Units	Topics	Level	Questioning	Modelling	Planning	Analysing	Thinking	Explaining	Argument	Communicating
1	Chemical Industry	1 2 3 4	5 0 1 0	5 1 0 0	0 0 1 0	0 1 0 0	3 4 1 0	24 5 0 0	0 0 4 1	4 0 2 0
	Total		**6**	**6**	**1**	**1**	**8**	**29**	**5**	**6**

APPENDIX 5

Acceleration due to gravity

New word

simultaneous: at the same time

Galileo Galilei (1564–1642) investigated the motion of falling bodies. He observed that if you drop objects of different masses at the same time from the same height, they hit the ground together. This means that the acceleration due to gravity (*g*) of objects is the same and is independent of their mass. This is provided that frictional forces are zero.

Investigate this further in the following investigation:

Experiment 1 Investigate the motion of a falling object

In this recommended informal experiment you will:

- record the motion of a falling body
- draw graphs of position vs. time and velocity vs. time
- determine the acceleration due to gravity *g*.

MATERIALS

- ticker timer apparatus or data logging apparatus
- stand or platform
- metal mass piece (approximately 100 g)
- metre rule
- graph paper
- calculator

Figure 1 Apparatus for Experiment 1.

METHOD

Step 1 Attach the mass piece to a ticker tape.

Step 2 Set up the ticker timer apparatus to record the motion of the falling mass piece.

Step 3 Set up the tape so it passes through the ticker timer freely. The effect of friction is very small with a falling mass piece of 100 g.

Step 4 Release the mass piece and switch on the timer apparatus simultaneously.

Step 5 The completed tape should look like the one in Figure 2.

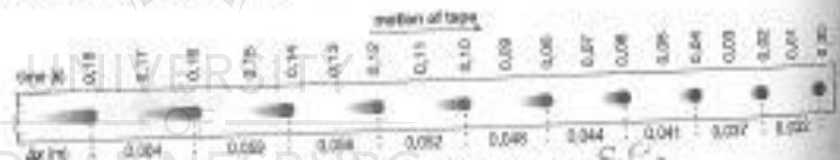

Figure 2 Data on a ticker tape. The ticker timer has a period of 0,02 s.

Step 6 Draw a graph of position vs. time of the results.

Step 7 Draw a graph of velocity vs. time. To do so:

- Measure the length of each interval (Δy).
- Calculate the average velocity, $v = \left(\frac{\Delta y}{\Delta t}\right)$ of the mass piece during each interval. The average that you calculate is the same as the instantaneous velocity at the middle of the interval.

Step 8 Use the *v* vs. *t* graph to determine the acceleration due to gravity.

QUESTIONS

1 For this experiment identify the:

1.1 independent variable

1.2 dependent variable

1.3 control variable(s).

2 Describe the shape of the position vs. time graph.

3 Velocity vs. time graph:

Extract of analysed page in one of the Physical Sciences textbooks analysed