An analysis of *intrasemiotic* and *intersemiotic* relations of textual and visual modes in Namibian school science textbooks

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DECLARATION

I, Venasius Mateus, hereby declare that this study entitled *'An analysis of intrasemiotic and intersemiotic relations of textual and visual modes in Namibian school science textbooks'* is my own original work and has not been previously submitted in any form for assessment or for a degree in any other higher education institution. All ideas, quotations and other materials used in this study derived from the work by other people have been acknowledged using complete references according to Rhodes University Education Department Guidelines.

Signature: Date: 25 March 2021

DEDICATION

This thesis is dedicated to the following people:

My dearest grandmother, Martha "Gwashipangela" Nkongo

And

My lovely daughters

Grace Ndinelaolangeliwa, Elizabeth Laudika and Isabel Etuna

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ABSTRACT

Although science education in Namibia receives much attention, learners' performance is low in subjects such as Physical Sciences. The topic of Forces is among the topics in Physical Sciences where learners perform poorly. The provision of basic education in Namibia faces many challenges. One of these is that many teachers are not fully qualified for teaching the subjects they currently teach. Another (possibly related) challenge is that the majority of teachers in Namibian schools rely heavily on school textbooks when planning their lessons. In addition, learners use school textbooks as learning aids. The textbooks are developed and published in the private sector and based on the national curriculum statements. Quality of education has been amongst the major goals of education in Namibia. For quality assurance purposes, school science textbooks have to undergo a formal evaluation process.

School textbooks, especially science textbooks, are multimodal. This means that they are designed with various modes, such as the textual and visual, often used in expressing scientific meanings. Literature reveals the textual and visual as individual modes having their own affordances, however, when integrated in school science textbooks contribute to strengthened meanings. No study published was found in Namibia or elsewhere that focused on analysing the *intrasemiotic* and *intersemiotic* sense relations of the textual and visual modes in Namibian school Physical Sciences textbooks. This study therefore aimed at contributing to filling this knowledge gap. The research is a qualitative case study and employed the interpretive paradigm. The selected Physical Sciences textbooks that constitute the data in this study were explored in depth via document analysis. Related textual and visual modes in the Physical Sciences textbooks were analysed in order to help answer the research questions of the study. Systemic Functional Linguistics was employed as the theoretical underpinning for this study. In this study, the sense relations were explored in terms of the sense relation themes which were coded and developed from common features of scientific discourse. The results reveal that scientific knowledge within the textual mode in the topic of Forces is communicated mostly through synonymy and repetition while within the visual mode it is mostly through antonymy, collocation, and synonymy. This contributed to meaning potential in the topic of Forces for the three Physical Sciences textbooks. The results further indicated that the overall cohesion within the textual and visual modes in the topic of Forces is achieved since repetition, which is the most direct form of lexical cohesion together with synonymy, collocation, and antonymy which are aspects of cohesion, occurred most frequently within these modes. This result further indicates that meaning potential in the topic of Forces in the three Physical Sciences textbooks were strengthened. While some sense relations occurred most frequently within individual modes, they were less frequent in other modes and vice versa. This indicates that different modes have different affordances. Finally, it was found that combining the textual and visual modes in the topic of Forces contributes to *intersemiotic* complementarity being achieved through the sense relations of collocation, hyponymy, and meronymy.

Keywords:

forces, semiotic modes, multimodal school science textbooks, *intersemiotic* complementarity, Systemic Functional Linguistics

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

AR:	Arrows
JSC:	Junior Secondary Certificate
JSP:	Junior Secondary Phase
LTSM:	Learning and Teaching Support Materials
MoE:	Ministry of Education
MoEAC:	Ministry of Education, Arts and Culture
M-SYM:	Mathematical Symbols
NCBE:	National Curriculum for Basic Education
NDP5:	5th National Development Plan
NIED:	National Institute for Educational Development
NV:	Numerical Values
ORF:	Official Recontextualising Field
SATs:	Standardised Achievement Tests
SFL:	Systemic Functional Linguistics
SF-MDA:	Systemic-functional multimodal discourse approach
S-V:	Singular Visuals
SYM-L:	Symbolic Letters
PRF:	Pedagogic Recontextualising Field
PR-V:	Paired Visuals
TC-W:	Technical Words
V:	Visuals
VMEs:	Visual Message Elements
W:	Words

CHAPTER ONE: INTRODUCTION

1.1 Introducing the Foci and Outline of the Study

The aim of this study was to understand how the textual and visual modes for the topic of Forces in three Namibian Grade 8 Physical Sciences textbooks were related in terms of *intersemiotic* complementarity. The thesis is divided into six chapters. The first chapter is an introduction to the study and presents the background where the researcher unpacks the National Curriculum for Basic Education (NCBE) – the core document guiding basic education in Namibia at the classroom level. A discussion of the main topic mechanics is also presented. The researcher further explains the multimodal nature of science discourse and, in particular, school science textbooks as aspects of science education. The language of science and the importance of apprenticing learners into it, is also discussed.

In addition, the criteria used to evaluate textbooks both locally and internationally are highlighted. The statement of the problem, research goal, research questions, as well as the significance of the study, are also provided. Chapter Two presents a literature review on the topic of Forces, Bernstein's pedagogic device, school science textbooks, and the multimodal discourse of school science textbooks. Chapter Three includes a description of the study's theoretical perspective – Systemic Functional Linguistics (SFL) and its extension, Systemic-Functional Multimodal Discourse Analysis (SF-MDA). Chapter Four discusses the research design of the study, including consideration of trustworthiness and research ethics. Chapter Five includes the presentation and discussion of data and the findings for this study. Lastly, Chapter Six gives the summary of findings, and the recommendations and conclusions drawn from this study. The limitations of the study are also presented.

1.2 Background of the Study

1.2.1 Namibia's National Curriculum for Basic Education

The NCBE is an official national policy document that guides teaching, learning, and assessment for basic education in Namibia (Namibia. Ministry of Education, Arts & Culture [MoEAC], 2016a). The document also provides direction for planning, organising, and implementing teaching and learning. As reflected in the current Namibian NCBE, the phases of basic education are as follows: “Junior Primary (Pre-primary and Grades 1-3), Senior Primary (Grades 4-7), Junior Secondary (Grades 8-9), and Senior Secondary (Grades 10-12)” (Namibia. MoEAC, 2016a, p. 15). This official policy document further indicates the key learning areas where essential knowledge can be found and developed. A key learning area is defined as a field of knowledge and skills which is part of the foundation needed to function well in a knowledge-based society (Namibia. MoEAC, 2016a). The key learning areas indicated in the NCBE are: “Languages, Mathematics, Natural Sciences, Social Sciences, Technology, Commerce, Arts and Physical Education” (Namibia. MoEAC, 2016a, p. 11). Each learning area comprises different subjects.

The NCBE points out that the natural sciences are one of the main drivers of the transformation of society and the world (Namibia. MoEAC, 2016a). This transformation can happen through the understanding of the nature of scientific knowledge, and the ability to apply scientific thinking and skills which is indispensable in the world today (Namibia. MoEAC, 2016a). It is further maintained that the natural sciences learning area contributes to the foundation of a knowledge-based society by empowering learners with scientific knowledge. As stipulated in the NCBE, scientific knowledge is communicated to learners through subjects at different phases, and these are: Environmental Learning (Pre-Primary), Environmental Studies (Grades 1-3), Natural Sciences and Health Education (Grades 4-7), Elementary Agriculture (Grades 5-7), Life Sciences (Grades 8-9), Agricultural Sciences (Grades 8-12), Biology (Grades 10-12), Physics (Grades 10-12), Chemistry (Grades 10-12) and Physical Sciences (Grades 8-9). Physical Sciences is the focus subject of this study and will now be further expanded on.

The subject of Physical Sciences is an integral part of Namibia’s NCBE. The subject places strong emphasis on the learners’ understanding of the physical and biological world around them at the local, regional, and international levels (Namibia. MoEAC, 2015a). It includes how societies use natural resources to satisfy their needs, and how the environment may be changed in ecologically sustainable ways. Teaching the content of Physical Sciences, as with other subjects, requires guidance from a subject syllabus (Namibia. MoEAC, 2016a). “A syllabus is a course description for a subject within the curriculum” (Namibia. Ministry of Education [MoE], 2008b, p. 4). A syllabus for Physical Sciences describes the intended learning and assessment in the Junior Secondary Phase (JSP). This syllabus is a single document that is composed of learning content for both Grades 8 and 9 (Namibia. MoEAC, 2015a). The summary of learning content for Grade 8 – 9 Physical Sciences is divided into five main topics:

Scientific Processes and Experimental Techniques, Matter and Materials, Environmental Chemistry, Mechanics, and Electricity and Magnetism (Namibia. MoEAC, 2015a). Each main topic is then divided into topics which are further divided into sub-topics. The main topic mechanics will now be discussed in further detail.

1.2.2 The main topic mechanics in Physical Sciences

Mechanics is one of the significant main topics in Physical Sciences (Namibia. MoEAC, 2015a). It is stated that under this topic, one of the expectations is that learners communicate their physical observations and conclusions using scientific language to explain the source, nature, and transmission of forces and energy in day-to-day living (Namibia. MoEAC, 2015a). It is likely that this expectation is not being fully achieved, based on the evidence of poor performance recorded in this topic. It is revealed by Namibia's national examiners' reports for previous years that learners have difficulties in understanding the topic mechanics (Namibia. MoE, 2014a; MoEAC, 2015-2016b).

Under the main topic mechanics is the topic of Forces which comprises of five sub-topics: "The nature and effects of forces, Weight and mass, Work, Energy, and Friction" (Namibia. MoEAC, 2015a, p. 20). The junior secondary certificate (JSC) national examiners' reports of 2014a specifically revealed that learners had difficulties understanding the concepts of forces, while that of 2015 and 2016 revealed that the energy concept was problematic to learners (Namibia. MoE, 2014a; MoEAC, 2015-2016b). The previously called Ministry of Education (MoE) has now been named the Ministry of Education, Arts and Culture (MoEAC). In this study, the acronyms MoEAC and MoE both represent the ministry that focuses on education in Namibia.

The concepts weight and friction were also found to be a challenge to learners, as the JSC examiners' reports of 2012 and 2016 respectively highlighted (Namibia. MoEAC, 2012 & 2016b). Concepts such as forces, energy, weight, and friction are of central importance to the understanding of science (Kaltakci & Oktay, 2011; Kurnaz & Eksi, 2015; Nordine, Krajcik & Fortus, 2011; Stein, Galili, & Schur, 2015). Understanding these concepts is therefore required of students since they facilitate further understanding of the biological, chemical, physical, and technological world (Neumann, Viering, Boone, & Fischer, 2003). This emphasises why problematic learner performance in the topic of Forces is challenging. The sub-topic of Forces will be discussed in more detail in Chapter Two.

1.2.3 Aspects of school textbooks

In this section, the researcher discusses the significance of school science textbooks. A detailed discussion of the Namibian process of developing school textbooks, including those of Physical Sciences, is also presented. School science textbooks are designed with various semiotic modes, such as the textual and visual (Ogan-Bekiroglu, 2007; Slough & McTigue, 2013). The researcher also presents in this section a discussion of the multimodality of school science textbooks. Scholars such as Fang (2004) revealed the perspective of science as a language. The chapter goes on to consider the features of scientific language which are informational density, abstraction, technicality, and authoritativeness. Furthermore, the three simultaneous meanings of language are also introduced.

1.2.3.1 Significance of school science textbooks

A school science textbook is an important mediating tool that helps learners to make sense of scientific knowledge (Chiappetta & Fillman, 2007; Devetak & Vogrinc 2013). This makes sense considering they are the most accessible resources that science students can use as reference materials (Ogan-Bekiroglu, 2007). School science textbooks guide students with regards to what knowledge they should focus on and include guidelines on how a field of knowledge should be learned (Makgato & Ramaligela, 2012). This is reflected in the style and design of many school science textbooks. For example, Namibia's Grade 8 Physical Sciences textbooks are divided into main topics and sub-topics. The ideas within the main and sub-topics are generally presented in a sequence that can be described as shifting from simpler to more complex concepts. By using a textbook, a student's understanding of the specified objectives within a specific syllabus is made easier (Connor, 2013). The majority of science students' learning is influenced by their use of school science textbooks (McDonald, 2017).

It is then imperative that the type of language used in communicating the content of science textbooks be appropriate in order to effectively facilitate learners understanding of science (Wellington & Osborne, 2001). As suggested by Khine (2013), one of the most important criteria for a good science textbook is the use of appropriate language and consideration of pictorial presentations in the text. The use of scientific language is important for the meaning potential of school science textbooks. It is useful to consider the quality of school science textbooks in terms of their textual and visual contents in the whole process of their development. Quality education is one of the sustainable development goals adopted in

September 2015 at the United Nations and therefore considered a major goal in Namibia's education system (Namibia. MoEAC, 2017a).

School science textbooks are one of the instructional tools used in a school science curriculum (Ogan-Bekiroglu, 2007; Royce, 2002; Young & Nguyen, 2002) and as explained by Mahmood, Iqbal and Saeed (2009) and Peterson (2016), are used for facilitating the proper implementation of that curriculum. Furthermore, these textbooks serve as interpretations of the curriculum objectives to the users, such as teachers and other educational stakeholders. Teachers, for example, can use school science textbooks to facilitate the teaching of scientific knowledge (Lemmer, Edwards, & Rapule, 2008). The relationship between school textbooks and the curriculum is discussed by Bernstein (1990; 1996; 2001) in his model of pedagogic discourse. Bernstein presented three fields of pedagogic discourse: field of production (production of new knowledge), field of recontextualisation (production of curriculum texts, including school textbooks), and field of reproduction (reproduction of new knowledge). The three fields of the pedagogic device are further detailed in Chapter Two.

Some schools in less developed countries, such as Namibia, base the teaching and learning of science very strongly on school science textbooks (Namibia. MoE, 2008a). The dependence on school textbooks contributes to limited access to a wider range of learning and teaching support materials. Mahmood et al. (2009) stressed that school science textbooks are an important part of the teaching process, in addition to their use by learners. It is known that the majority of teachers in Namibia base their lessons on and choose lesson content from what textbooks contain (Namibia. MoE, 2008a). It is also recognised that many teachers in Namibia may not be able to teach effectively without a textbook (Namibia. MoE, 2008a; 2010).

While teachers in developed countries employ school textbooks as supplementary resources due to a greater variety of learning and teaching support materials available to them, in Namibia, school textbooks are often perceived as the sole authority for what is to be taught (Namibia. MoE, 2008a). The dependence on school textbooks by some teachers as a result of them being inadequately trained to teach science subjects has implications for teaching. These teachers may not be capable of transforming the content of these textbooks to make them more relevant to their specific classroom contexts (Jaffer, 2001).

1.2.3.2 School textbook development and evaluation criteria

In many countries in the world such as South Africa and Namibia, school textbooks are written by experts and developed by publishers (Namibia. MoE, 2008a; Stoffels, 2007). The development of school textbooks is usually undertaken following curriculum reforms (Namibia. MoEAC, 2015b; Stoffels, 2007). The process of developing school textbooks is similar across many countries in the world such as South Africa, Kenya, Pakistan, and Namibia. Stoffels (2007) explained that the development of school textbooks involves consultations between various departments of education and members of publishing houses. It is further reported that this consultation involves the provision of details such as the "broad curriculum specification, procedure for selection and endorsement of textbooks, and that each learning area submission should have both a learner and a teacher's guide" (Stoffels, 2007, p. 6).

Namibia's recently introduced Junior Secondary Phase (JSP) for Grades 8 and 9, replaced the previous JSP Grades 8-10 (Namibia. MoEAC, 2015a). Grade 10 was subsequently shifted to the Senior Secondary Phase (SSP), which now includes Grades 10 to 12. The implementation of this new curriculum for Grades 8 and 9 commenced in 2017 and 2018, respectively. The MoEAC is responsible for requesting that qualified and registered publishers develop new textbooks as per the curriculum revisions in Namibia. A qualified publisher is defined as a trading company that is "legally registered and can provide on request a valid certificate of registration and legal operation, as well as a tax certificate" (Namibia. MoEAC, 2015b, p. 4).

Following the most recent curriculum changes, different learning and teaching support materials, including science textbooks, were concurrently developed and evaluated. For all textbooks submitted for evaluation, a maximum of three of the best titles per subject per grade are approved (Namibia. MoEAC, 2019). In Namibia, an approved textbook is "one which has been evaluated by the National Institute for Educational Development (NIED) in accordance with the specialised procedures, methodology, criteria and mark schemes for the revised curriculum" (Namibia. MoEAC, 2015b, p. 4). For Grade 8 Physical Sciences, the learners' textbooks developed and subsequently approved for use in Namibian schools currently are: *Living Physical Sciences Grade 8 Learner's Book* (Jones, Larceda, & Roebert, 2016a), *Platinum Physical Sciences Grade 8 Learner's Book* (Haimbangu, Poulton, & Rehder, 2016) and *Solid Foundations Physical Sciences Grade 8 Learner's Book* (Van Niekerk, 2016). The textbooks will be pseudo-named Textbook A, Textbook B and Textbook C, respectively.

Due to the central role of school textbooks in the provision of education, it is imperative that they provide correct content and instructional support (Lemmer et al., 2008). Furthermore, a well-developed school science textbook has greater potential to help teachers and learners to understand the science curriculum. It is against this background that all school textbooks are subjected to an evaluation process before being endorsed for use by teachers and learners in public or private schools. In Namibia, before school textbooks are included in the Textbook Catalogue of the MoEAC for schools to select from, the developed textbooks are submitted to subject evaluation panels for a formal evaluation. This evaluation is undertaken for the purpose of selecting the most suitable textbooks from the widest possible choices of competing textbooks.

The four main general criteria considered by NIED's subject evaluation panel for selecting and evaluating school textbooks are: conformity to the syllabus, appropriate coverage of the prescribed content, language and editorial quality, the design, presentation, and ease of use of the textbook (Namibian MoEAC, 2015b). Like in South Africa, Kenya, and Pakistan, the criteria used for evaluating and selecting textbooks in Namibia are not subject-specific, but rather general (Mahmood et al., 2009; Makgato & Ramaligela, 2012; Simam, Rotich, & Kemoni, 2012). This is problematic given the fact that subjects such as the sciences can be viewed from the perspective of being languages, as mentioned earlier. The researcher could not find a study that reported specifically on the Namibian national evaluation and selection criteria for the subject of Physical Sciences (which is the focus of this research).

The general criteria used to select and evaluate school textbooks in Pakistan and Kenya are similar to those applied in Namibia (Mahmood et al., 2009; Simam et al., 2012). The similarities are that they focus on whether the textbook covers prescribed content as per the national curriculum statements, and appropriateness of the vocabulary. Considering that school textbook design is important – especially in Namibia where there is a strong dependence on school textbooks as the main teaching and learning resources (Namibia. MoE, 2008a; 2010) – upon having a deeper look at the general evaluation criteria considered by the NIED the researcher found that little emphasis has been directed at textual-visual modes integration. Devetak and Vogrinc (2013), however, stressed that one of the criteria that should be considered in evaluating the quality of school science textbooks is the integration of the textual and visual elements. They further indicated that the combining of the textual and visual modes should be clear to enable readers to make sense of the ideas communicated. Since Namibian school science textbooks due to the multimodal nature of science discourse involve a combination of the textual and visual modes, it is important to have an understanding of how these modes in these textbooks work together to help the learners make sense of science. While the term textual mode usually refers to words or printed text, the term visual mode refers to images (Al-Attar, 2017), and these were used in this study as such.

1.2.4 Multimodality of science discourse

Science discourses are fundamentally multimodal (Edwards, 2015; Linder, 2013). This means that scientific meanings in school science materials are expressed through semiotic modes, such as the textual and visual modes (Dimopoulos, Koulaidis & Sklaveniti, 2005; Kress & Van Leeuwen, 2002; Wu, 2014). As argued by Jamani (2011), multimodality in science discourses helps to facilitate the understanding of scientific meanings, as the reader interprets the meanings afforded by each of the different semiotic modes. Furthermore, different authors (Fang, 2004; Kress, Ogborn, & Martins, 1998; Wu, 2014) stressed that it allows for developing scientific meanings via interaction between different semiotic modes. A general description of the term semiotics refers to the study of signs for the purpose of making meaning (Harrison, 2003; Jamani, 2011). The term 'mode' is defined by Bezemer and Kress (2008) and Jewitt (2008) as organised sets of socially and culturally shaped semiotic resources such as words and images. A semiotic mode is any visual or verbal representation that is used for the purpose of meaning making (Chuang, 2006, O'Halloran, 2011). Representations, which "are artifacts designed to teach science concepts", can take the form of written texts or diagrams (Tang, Delgado, & Moje, 2014). For the semiotic mode, Al-Attar (2017) expanded on the meaning of this term by stating that it also refers to gestures and other modes having choices for making meaning. Scholars, such as Kress and van Leeuwen (2002) indicated that language, visuals, and sound are the primary semiotic modes. However, Edwards and Robutti (2020) stressed that any means that humans use to express or organise themselves such as any cultural system for making meaning, can be seen as a semiotic mode.

Jaipal (2010) mentioned that the understanding of scientific meanings depends on the reader being able to interpret the integration of different modes. Since the different modes have particular meaning potentials (Jones, 2006; Kress, Charalampos, Jewitt, & Ogborn, 2006), it is important to know how these modes function in scientific discourse due to them differing in terms of their affordances (Culache, 2015; Jones, 2012; Knain, 2015). Singh (2002, p. 2) stressed that meaning potential refers to "the potential knowledge that is available to be transmitted and acquired".

In addition to modes having specific meaning potentials, Jones (2012) emphasised that they allow different kinds of actions. The use of different modes in multimodal texts is a clear indication that meanings occur at different levels, which can be within and across modes (Royce, 2002). The meaning within an individual mode is regarded as *intrasemiotic* meaning (Culache, 2015). Both the visual and verbal modes have their own affordances. Lemke (2002) indicated that while different modes may express different meanings, their combined meanings may result in greater overall meaning. Royce (1999) referred to this relationship as *intersemiotic* complementarity, which is discussed further in Chapter Three of this thesis.

1.2.4.1 School science textbooks as multimodal

For school science textbooks, it is important that the different modes should work together towards communicating and strengthening the books' meaning potential. Slough and McTigue (2013) highlighted that the interaction between the textual and visual modes is in fact an important aspect influencing the quality of science textbooks. Since the visual mode alone cannot make meaning (Stylianidou, 2002), both the textual and visual modes in a school science textbook work together to create a definite meaning (Anthonissen, 2003; Peterson, 2016). As highlighted earlier in this chapter, the use of different modes in science textbooks not only plays a major role in the construction of knowledge, but also contributes to a broader and deeper understanding of meanings in science (Jaipal, 2010). Ogan-Bekiroglu (2007) thus stressed that it is important that school science textbooks are well designed, with information and ideas presented in an organised manner so that students can relate to them meaningfully.

High school science textbooks, like the textbooks used in many other subject areas, are "designed with combinations of the visual and verbal (or written) communication" (Royce, 2002, p. 192). Royce (2002) further asserted that school textbooks' authors and developers place various kinds of visuals, as well as the textual mode, on the pages of textbooks for various meaning-making purposes. Meaning making in science involves an integration of information from different modes to communicate scientific knowledge (Lemke, 1998). The different modes of school science textbooks depend on one another to strengthen meaning.

1.2.4.2 Language in science discourse

Halliday (1993) viewed language as an essential condition of knowing. Language varies in that it is used in different contexts and for different purposes (Fang, Schleppegrell, & Cox, 2006). Fang et al. (2006) highlighted that the textual mode produced for different purposes in different contexts have different features. For example, the language of science differs from the language used in everyday interaction in various ways. One of the distinguishing features, as highlighted by Roth and Lawless (2002) and Fang (2004), is that science is a form of culture that is dominated by technical terms (Gledhill, 2000). Furthermore, it can be argued that the language of science is the feature of science which most clearly separates it from other knowledge forms: "Familiarity with the logical form and structure of the language of science" can help us to distinguish it from other discourses (Hodson, 2009, p. 243).

Other differentiating features of scientific language include characters such as: informational density, technicality, abstraction, and authoritativeness (Fang, 2004; Halliday, 2004). These features are discussed in further detail in Chapter Two of this thesis. Fang (2004, p. 337) also made us aware that "the specialized grammar of scientific language is important in making it possible for scientists to construct an alternative interpretation of the physical world to that provided by the common-sense language of everyday spontaneous speech". In addition, Schleppegrell (2001) mentioned that the specialised language of science facilitates effective presentation of information and development of arguments in science. Success in school science education therefore depends on learners being apprenticed into learning the language of science. It is important that students are oriented to and taught scientific language in order to develop deeper understanding of school science.

According to Halliday (1978), language, including that of science, is used for the purpose of making meaning. Furthermore, Halliday (1978) identified three metafunctions of language: ideational metafunction, interpersonal metafunction, and textual metafunction. Ideational metafunction focuses on the content or knowledge of the world represented in language. The interpersonal metafunction focuses on the relationships constructed by participants through language. Finally, the textual metafunction deals with how texts are structured and composed for a particular register. These metafunctions are discussed further in Chapter Three of this thesis.

1.3 Statement of the Research Problem

As literature has suggested, school science textbooks are designed with combinations of different semiotic modes, such as visual and verbal communication (Edwards, 2015; Royce, 2002). Different scholars have emphasised the importance of integrating different modes in school science textbooks (Anthonissen, 2003; Jaipal, 2010; Slough & McTigue, 2013). The use of different modes in school science textbooks is useful to learners, as this helps them to understand scientific knowledge better (Jaipal, 2010). It is noted that when combined, the visual and verbal modes have the potential to create greater meaning than can be communicated by individual modes (Royce, 1998). It is clearly indicated in literature that insufficient research has been carried out on the nature of *intersemiotic* sense relations in explaining the "features that make multimodal text visually and verbally coherent" (Royce, 2007, p. 63). Having a deeper look at the main general criteria used by the NIED in selecting and evaluating school textbooks, the researcher found that little emphasis was directed at textual-visual mode integration though the two have the potential to make meaning. Furthermore, this gap does not show consideration of the literature which emphasised the importance of this integration and the fact that it strengthens the meaning potential of school textbooks (Slough & McTigue, 2013; Wu, 2014).

The fact that Namibian school textbooks, especially science textbooks (Linder, 2013), are also multimodal allows them to provide insight into how the textual and visual modes function together to help learners make meaning. In all the related literature reviewed for this thesis, no published study was found that analysed the textual and visual modes in terms of *intersemiotic* complementarity in a school science textbook for the Namibian context. This knowledge gap, together with learners' overall poor performance in the topic of Forces, provided a strong rationale for analysing and understanding how the textual and visual modes were related in terms of *intersemiotic* complementarity for the topic of Forces in three Namibian Grade 8 Physical Sciences textbooks.

1.4 Research Goal and Questions

The goal of this study was to understand how the textual and visual modes were related in terms of *intersemiotic* complementarity for the topic of Forces in three Physical Sciences textbooks. In order to achieve this goal, the study addressed the following research questions:

1. What is the nature of the *intrasemiotic* sense relations for the topic of Forces in Physical Sciences textbooks?
    - Within the textual mode
    - Within the visual mode
2. How are the textual and visual modes for the topic of Forces related in terms of *intersemiotic* complementarity?

1.5 Significance of the Study

The findings of this research are not only beneficial to Namibia, as the country where the study was undertaken, but also to other countries as far as the development of quality scientific learning materials is concerned. To clarify the latter point, school science textbooks' authors and publishers will gain insight into how meaning is made when the textual and visual modes are integrated in learning materials, an understanding which can guide them during the process of developing new school science textbooks. The findings of this study are also significant in terms of empirically informing Namibian science textbook publication criteria, endorsement criteria by the NIED's subject evaluation panel, and selection criteria used by teachers in schools. Science teachers can also improve their instructional practices when they understand how meaning is made through both the textual and visual modes. This idea is supported by Knain (2015), who explained that knowing how the textual and visual modes interact in school science textbooks is significant because it has implications for both teaching and research.

1.6 Chapter Summary

In Chapter One, the researcher introduced the foci and background of the study. It was indicated that the study focused on understanding how the textual and visual modes for the topic of Forces in three Namibian Grade 8 Physical Sciences textbooks were related in terms of *intersemiotic* complementarity. The study's background was discussed in terms of an overview of Namibia's education system through key national educational documents, the main topic mechanics in Physical Sciences curriculum under which the topic Forces is a part, and the multimodality of science discourse. Language in science and the significance of school science textbooks was also considered. The problem statement, research goal, and questions, as well as the significance of the study, were detailed. Chapter Two presents a review of literature related to the core concepts of this study.

CHAPTER TWO: REVIEW OF LITERATURE

2.1 Introduction

In this chapter, the researcher firstly discusses the topic of Forces since it is the focal content topic of the study. Secondly, a review of some literature on the pedagogic device offered by Basil Bernstein, one of the most influential theorists on sociology of education, is presented. The place of school science textbooks within the pedagogic device is also discussed. The chapter further includes a discussion on multimodality in school science textbooks and a detailed discussion of semiotic modes and meanings they afford.

2.2 The Topic of Forces in Namibia's Grade 8 Physical Sciences Syllabus

The topic of Forces in the JSP Physical Sciences syllabus for Grade 8 is divided into five sub-topics as mentioned in Chapter One. The sub-topics in the order they appear in the syllabus are: "The nature and effects of Forces"; "Weight and Mass"; "Work"; "Energy"; and "Friction" (Namibia. MoEAC, 2015a, p. 20). The acquisition of knowledge and skills in these sub-topics by learners is important for the reasons stipulated by Namibia's MoEAC (2015a): firstly, it helps them foster an understanding of the interaction of human beings and the environment; and secondly, it helps them to sustain natural resources. Although significant, these sub-topics have proved to be a challenge to the success of the Namibian science education curriculum, as indicated by learners performing poorly in them (Namibia. MoE, 2014a-2015). Each sub-topic will now be examined in more detail.

2.2.1 Sub-topic 1: The nature and effects of forces

The concept of force is at the heart of Newton's laws of motion and is central to the theory of classical mechanics that is taught from lower secondary school to university level (Savinainen, Mäkynen, Nieminen, & Viiri, 2013). As Kurnaz and Eksi (2015) indicated, force is an important physics concept because it facilitates the understanding of other complex topics such as friction. Apart from facilitating the understanding of other concepts, it is important for students to understand this concept as it is relevant to their everyday experiences such as carrying or moving objects around.

In schools, one important type of pictorial representation used in the teaching of forces is a free-body diagram (Savinainen et al., 2013). McTigue and Flowers (2011) defined a diagram as a type of visual mode that usually explains the parts of something. It is further explained that while a photograph looks exactly like a real object, a diagram differs because it lacks the characteristics that contribute to the photographic impression of reality (Jewitt & Oyama, 2001). “A free-body diagram is then a diagrammatic type of representation in which one focuses only on an object of interest and on the forces exerted on it by other objects” (Rosengrant, Van Heuvelen, & Etkina, 2009, p. 3). Free-body diagrams convey much information. This information is described by Savinainen et al. (2013) as follows: firstly, they keep track of all forces and their relative magnitudes; secondly, they allow for a deduction to be made as to whether the object has acceleration or not, as the sum of forces (i.e. net force) is directly related to acceleration via Newton’s second law of motion; thirdly, the direction of acceleration can be deduced as Newton’s second law is a vector quantity; and finally, the state of motion of an object can be changed by altering its acceleration, direction of motion, or both.

Many students have difficulties understanding the concept of force (Savinainen et al., 2013). These difficulties, as Brookes and Etkina (2009) suggested, have a long history in physics and science education research. In fact, there are various reasons behind these difficulties for students. One of the reasons, as indicated by Neumann et al. (2003), is that students in their formal schooling have differing prior knowledge on the concept of force. This pre-knowledge is based on many factors, such as students’ life experiences and everyday language. The differing views of the students on the concept of force may result in misconceptions, and possibly in them performing poorly in the subject Physical Sciences.

2.2.2 Sub-topic 2: Weight and Mass

Weight and mass are two of the most basic and fundamental scientific concepts in school physics (Sarabando, Cravino, & Soares, 2016; Stein et al., 2015). These concepts are important because they play a major role in the understanding of other concepts in various disciplines of Natural Sciences (Gönen, 2008). Stein et al. (2015) claimed that the concept of weight, in particular, is one of the oldest physics concepts known to humans from before formal science was even introduced.

Weight and mass are interrelated concepts. Weight is popularly defined as the force exerted by gravity on a particular object (Stein et al., 2015). Taibu, Schuster, and Rudge (2017) had a slightly different definition of weight. They defined it as a gravitational force on an object due to some other bodies, such as Earth. Stein et al. (2015) argued that relating weight to other concepts such as gravity and gravitational force can cause much confusion among students. Thus, in most high school science textbooks, as stated by Low and Wilson (2017), weight is simply defined as the product of an object's mass and the local gravitational field ($w = mg$). Unlike for the concept weight, the researcher did not find other literature defining the concept mass in more detail. However, a more general definition of mass is that it is the amount of matter in an object (Haimbangu et al., 2016; Jones et al., 2016a; Van Niekerk, 2016).

The weight of an object cannot be determined without first knowing its mass. Similarly, the mass of an object can be determined if its weight is known. Making a clear distinction between the two concepts has proven to be a challenge to many students and teachers. Sarabando, Cravino, and Soares (2014) stated that many students do not have the correct understanding of the concepts weight and mass. The concept of weight is familiar in both everyday life and science. According to Taibu et al. (2017) weight is often confused with mass in everyday discourse. The major cause of this confusion results from the fact that the concept of weight has multiple definitions in scientific and everyday language (Low & Wilson, 2017; Taibu et al., 2017). This is not only problematic to teachers and learners, but also to textbook authors, as they find it challenging to define this concept (Taibu et al., 2017).

2.2.3 Sub-topic 3: Work

Work is defined as the transfer of energy from one system to another (Lancor, 2014). In mechanics, the concept of work is fundamentally explained as the magnitude of force applied multiplied by the distance moved in the same direction of the applied force (Namibia. MoEAC, 2015). The work concept is related to other sub-topics such as energy. Both energy and work concepts have the same unit of measurement which is the joule (J). If work is done on a body, energy is transferred to it (Namibia. MoEAC, 2015). There were very few studies found that focused on the concept work. Nonetheless, some studies (Tang, Tan, & Yeo, 2011) have reported that the concept work is challenging to students. A study by Meltzer (2004) revealed that many students have a weak understanding of the work concept, particularly in the context of mechanics. Meltzer then suggested that the reason for this misconception is that the concept work shares the same unit of measurement as energy.

2.2.4 Sub-topic 4: Energy

Concepts such as energy are of central importance in science and thus in science education. According to Nordine et al. (2011), energy is a fundamental unifying concept in science. Students need to understand energy if they are to understand the biological, chemical, physical, and technological world (Neumann et al., 2003). Furthermore, understanding energy is of paramount importance to secondary school science learners. Constantinou and Papadouris (2012) and Stylianidou (2002) argued that this comprehension creates awareness of topical socio-scientific issues such as energy resources and their distribution and utilisation. It is thus obvious why energy is a key topic in science education for sustainable development, which is an initiative outlined by Tang (2010) on current changes in basic science education.

Namibia's NCBE recognises energy as one of the important topics of the Natural Sciences learning area. The topic of energy appears in the intended curriculum for Natural Sciences subjects from Grade 4 up to Grade 12. As highlighted by Namibia's 5th National Development Plan (NDP5) (Namibia. Government of the Republic of Namibia, 2017), energy is among the country's priorities. NDP5 is aimed at improving the living conditions of all Namibian citizens. One of its key goals is to ensure sustainable development. This is in line with the aims of the NCBE, which are to develop an environmentally sustainable society by providing the scientific knowledge and skills needed to ensure that the environment is respected and sustained (Namibia. MoE, 2010). Energy is thus an "indispensable concept which is driving all economic activities" (Namibia. MoE, 2010, p. 8).

Despite its importance, energy is known to be "one of the most abstract ideas in physics" (Ibáñez & Ramos, 2004, p. 267) and one of the most difficult topics of secondary school science (Stylianidou, 2002). This is problematic to learners, because it may hinder their progress in learning and understanding related topics. It has also been noted that students enter formal schooling with a variety of different energy conceptions stemming from everyday experiences and language, and so have difficulty differentiating between energy and other scientific concepts such as force, power, or temperature (Neumann et al., 2003).

The problem of energy as one of the most challenging topics, as highlighted by Stylianidou (2002) and Neumann et al. (2003), is also the case in Namibia. The results of the Standardised Achievement Tests (SATs) conducted in Namibia revealed that energy is one of the key areas in which learners perform poorly (Namibia. MoE, 2010–2014b). This highlights it as one of the problematic concepts in Namibian school science learning. Namibia's Junior Secondary Certificate national examiners' report of 2017 for the subject Physical Sciences emphasised that "science concepts should be made clear to candidates to avoid confusion" (Namibia. MoEAC, 2017b, p. 247). Ibáñez and Ramos (2004) pointed out that students' first confusion with the concept of energy appears in the main topic mechanics, and Cotignola, Bordogna, Punte, and Cappannini (2002) then suggested that it is in mechanics that energy must be clearly defined and thoroughly understood.

2.2.5 Sub-topic 5: Friction

The concept of friction is important in physics (Kaltakci & Oktay, 2011), and a key element of engineering design (Yuksel et al., 2017). A more recent definition of the concept is offered by Anastasia and Pavlos (2016), who referred to it as a force that opposes the movement of a body. They further explained that friction is always opposite to the relative velocity of one body in relation to the one on which it is in contact. It is important that learners understand this concept for various reasons. One of the reasons given by Kurnaz and Eksi (2015) is that it enables the learning of advanced physics concepts. This physics concept, as with others such as energy, force, and power, is known to be abstract (Ibáñez & Ramos, 2004; Kurnaz & Eksi, 2015). This adds to the challenge facing students especially at secondary level (Anastasia & Pavlos, 2016; Besson, Borghi, De Ambrosis, & Mascheretti, 2007; Besson & Viennot, 2004; Kurnaz & Eksi, 2015).

Many students generally have some misunderstanding of the concept of friction. Besson et al. (2007) indicated that students understand the friction force as an opposition to a movement in one direction, rather than relating it to motion between two solids in contact. Kurnaz and Eksi (2015) had similar findings, revealing that some students misinterpret friction as a reaction force against movement. Other students refer to friction as the same thing as movement (Anastasia & Pavlos, 2016) and this superficial understanding may lead to some students concluding that friction only has one direction. As Anastasia and Pavlos (2016) highlighted, part of this misunderstanding results from many students' failure to recognise friction as a force that can produce motion and have various directions. Besson et al. (2007) thus suggested that secondary school courses give more attention to the topic of friction in order to minimise students' misunderstandings.

In Namibia, the National Curriculum for Basic Education places emphasis on learners' understanding of the effects of friction on objects and how friction depends on the surface of the objects (Namibia. MoEAC, 2016a). As a sub-topic in the syllabus for Physical Sciences for Grades 8 and 9 (Namibia. MoEAC, 2015a), it is also linked to other sub-topics such as static electricity. For example, in static electricity, learners are expected to understand how friction plays a role in the electrical charging of objects.

2.3 Bernstein's Pedagogic Device

Basil Bernstein was one of the most influential theorists on the sociology of education (Singh, 2002). He was the first British sociologist who introduced the theory of the pedagogic device. Bernstein (1996) described the ordering and disordering principles of the pedagogising of knowledge as the pedagogic device. According to Singh (2002, p. 573), Bernstein suggested that "this device constituted the relay of rules or procedures through which knowledge, such as intellectual and practical, is converted into pedagogic communication". The concept of the pedagogic device is also explained by Singh (2002, p. 572) as a "process by which discipline-specific expert knowledge is converted or pedagogised", i.e. made suitable for the learning process to consider school knowledge.

Bernstein (2001) identified three main fields of the pedagogic device: production, recontextualisation, and reproduction. The pedagogic device model is useful for this study because it provided an explanation of how scientific knowledge is pedagogised and communicated to learners. A school science textbook is an aspect of the recontextualisation field. It is important to note that the production, recontextualisation, and reproduction fields, as stressed by Bernstein (2001), are hierarchically related. The recontextualisation of knowledge cannot take place without its production, and reproduction cannot take place without recontextualisation. The three fields of this device will now be briefly outlined.

Firstly, the field of production is concerned with the production of new knowledge (Bernstein, 1990). Bernstein (1990) asserted that the production of new knowledge is known to take place mainly in institutions of higher education and private organisations involved in educational research and teaching. He also stated that the main focus of these institutions involve processes where new ideas are created selectively or changed. Furthermore, it is within this field where specialised discourses such as science are developed (Bernstein, 1990). Secondly, the recontextualisation field links the field of production with the field of reproduction. Jaffer

(2001) explained that the recontextualising field transforms the educational discourse produced in the field of production to constitute a new discourse that may be reproduced in the field of reproduction.

According to Jaffer (2001), educational discourse transformed in the recontextualising field may undergo further recontextualisation when introduced into local pedagogic practices, such as within classrooms. At the level of the classroom, textbooks are pedagogic texts that “realise the recontextualising principles of the curriculum” (Jaffer, 2001, p. 6). A textbook therefore constitutes an interpreted curriculum for teachers (Jaffer, 2001). The field of recontextualisation involves a country’s department of education and training, curriculum authorities, specialist education journals, and teacher education institutions.

In addition, the field of recontextualisation as Bernstein (1990) indicated, comprises two sub-fields: The Official Recontextualising Field (ORF), and the Pedagogic Recontextualising Field (PRF). The “ORF includes the specialized departments and sub-agencies of the state and local educational authorities together with their research and system of inspectors” (Bernstein, 1990, p. 192). This is similar to Namibia’s National Institute for Educational Development (NIED) – a directorate within the MoEAC that spearheads the design and development of curriculum for schools (Namibia. MoE, 2008a). This sub-field regulates the official pedagogic discourse through, for example, constructing official curriculum documents and educational policy (Jaffer, 2001).

The PRF, on the other hand, consists of textbook publishing houses, professional teacher associations, and other non-governmental educational institutions. The current study was concerned with the production of school science textbooks in terms of how meaning is made by the integration of the textual and visual modes. The field of recontextualisation was significant to this study, as it provided a theoretical context for the place of school textbooks such as those of science, in the bigger picture of knowledge.

Lastly, the field of reproduction has to do with the selective reproduction of educational knowledge (Bernstein, 1990). The reproduction of knowledge usually takes place in primary, secondary, and tertiary schooling institutions. Singh (2002) pointed out that the field of reproduction allows the transformation of pedagogic texts, such as school textbooks, as they are appropriated by teachers and converted into modes of shared classroom knowledge. According to Singh (2002), textbook transformation occurs in two ways. The first one is the conversion of knowledge appropriated from the field of production within the official and pedagogic recontextualising field. The second is the translation of this pedagogised knowledge by teachers/lecturers and students in the recontextualising field of the school or tertiary institution. For example, “in the process of constructing modes of classroom knowledge, teachers may recontextualise discourses from the community or peer groups of students for purposes of social control” (Singh, 2002, p. 577).

2.4 Situating School Science Textbooks Within the Pedagogic Device

Bernstein’s pedagogic device provides ideas on how scientific texts are produced. This happens “through three inter-related rules which are: distributive, recontextualising, and evaluative” (Singh, 2002, p. 573). The three rules are known as hierarchically related because the recontextualising rules are derived from the distributive rules, and the evaluative rules are obtained from the recontextualising rules. Singh (2002) indicated that all three rules serve different functions within the pedagogic device. The distributive rules play roles in regulating the power relationships between groups in society by spreading various forms of knowledge. The recontextualising rules regulate the formation of specific pedagogic discourse. Bernstein (1996) suggested that recontextualising principles are for delocating a discourse, relocating, and refocusing it. Through recontextualisation, a discourse is transferred from the site where it is produced to another site. There, it is then transformed by relating it to other discourses. Finally, “evaluative rules constitute specific pedagogic practices” (Singh, 2002, p. 573).

The process of developing and publishing school science textbooks, such as with Physical Sciences, falls within the Pedagogic Recontextualising Field, a subset of the field of recontextualisation as discussed in Section 2.3. School science textbooks constitute scientific knowledge (Devetak & Vogrinc, 2013). According to Halliday (2004), knowledge, including that of science, is semiotic which means that it is a process of meaning. The process of transforming something into meaning, as Halliday (2004) maintained, is known as understanding. It is important that the designing of school textbooks from the national curriculum be correctly done for learners to make sense of scientific knowledge (Namibia. MoEAC, 2016a).

2.5 The Significance of Science Textbooks within the School Curriculum

School science textbooks are globally considered as important agents of school curriculum implementation. It is reported that relying on school science textbooks for teaching and learning purposes is not only an issue in Namibia, but in other countries as well such as Australia and the United Kingdom (King, 2010; McDonald, 2016). The importance of school science textbooks in general within the education system is recognised by many scholars. Khine (2013), Davila and Talanquer (2010) and Mahmood et al. (2009) mentioned that school science textbooks influence how science teachers facilitate proper implementation of a school curriculum. In science classrooms, Ogan-Bekiroglu (2007) stated that school science textbooks are considered important instructional tools. This makes school science textbooks indispensable as many teachers depend on them for the provision of learning tasks as well as assessment of students (Davila & Talanquer, 2010; Menon & Mukundan, 2010).

It has been pointed out that school science textbooks help interpret science syllabi and make them easier for the learners to better understand specified objectives (Connor, 2013). Some schools in the world, especially those in less developed countries, base the teaching and learning of science strongly on school science textbooks. This is one of the reasons why Mahmood et al. (2009) argued that school science textbooks are an important part of teaching and learning processes. In the classroom, school science textbooks are used as learning tools from which students obtain knowledge (Devetak & Vogrinc, 2013; Ogan-Bekiroglu, 2007). It is known that these textbooks significantly influence students' learning (McDonald, 2017). This means that they guide what knowledge should be learned and how it should be learned (Makgato & Ramaligela, 2012). Learners also use school science textbooks as reference books (Menon & Mukundan, 2010). For example, learners use them as resources when it comes to completing school activities such as homework (McDonald, 2016).

School textbooks in general are part of Namibia's schooling because they are designed from the curriculum documents (Namibia. MoEAC, 2016a). In Namibia, the majority of science teachers and learners have access to a limited range of learning and teaching support materials (LTSM). As a result, they rely more on school science textbooks as the main source of knowledge (Namibia. MoEAC, 2016a). School science textbooks have a considerable influence on teachers' pedagogical practices (Makgato & Ramaligela, 2012). This is true in

Namibia because the majority of teachers, irrespective of the subject they teach, base their lessons on and choose lesson content from textbooks (Namibia. MoE, 2008a).

Many science teachers in Namibia may not be able to teach effectively without a science textbook (Namibia. MoE, 2008a; 2010). This has implications for teaching, especially because some teachers in Namibia, like in many other developing countries, are inadequately trained to teach science subjects. This concurred with McDonald's (2016) reasons that one of the factors that lead to reliance on school science textbooks is either because science is taught by teachers with specialisations outside that of science, or who are inexperienced. The availability of school science textbooks in Namibian schools has been a challenge since the country's independence. Learners in many schools share the few available endorsed science textbooks, a situation that makes their learning even more challenging.

2.6 Multimodal Discourse Analysis

Various authors have different but related understandings of the term multimodality. A common definition identified is that it refers to the integration of language with other semiotic modes such as visuals, to represent scientific reasoning and findings (Edwards, 2015; Jones, 2006; Kress, Charalampos, Jewitt, & Ogborn, 2006; Marissa, O'Halloran, & Judd, 2011). Thus, multimodality refers to the phenomenon of texts integrating diverse semiotic modes (Siefkes, 2015; Wu, 2014). Culache (2015) had a similar explanation of multimodality – that it aims to offer an improved understanding of how semiotic modes work together to convey a unitary meaning. One of the reasons provided by Chiew (2004) is that semiotic modes, such as the visual and verbal elements, are not the same and are different meaning-making systems.

The fundamental principle of multimodal discourse analysis is that discourse includes more than just language (Jones, 2012) since it involves non-verbal modes of communication such as visuals, music, dance, and art. There are several reasons for the paradigmatic shift away from the study of language alone to studies involving the integration of language together with other non-language resources. O'Halloran (2011) provided two reasons. The first is that discourse analysts who aimed to understand the broader perspective of human discourse practices found it necessary to explain the meaning that comes from different semiotic modes which are found in different media. The second reason is that "technologies to develop new methodological approaches for MDA, such as multimodal annotation tools, have become available and affordable" (O'Halloran, 2011, p. 3). A third reason is provided by Jones (2012), who stressed that focusing on language alone at the expense of these other modes might result into reduced understanding and meaning potential of science learning materials. This is in relation to ideational metafunction, which according to Weiss and Archer (2014) involves semiotic modes such as the visual and verbal modes which act as resources for constructing representations of the world.

Multimodal discourse analysts see discourse as involving multiple modes which often work together to convey meaning (Jones, 2012). It is understood that in multimodal texts, modes support each other to convey the message (Febrianti, 2013). Hence, language alone misses much of how texts create meaning (Machin, 2009). Jones (2012) pointed out that multimodal discourse analysis generally has two foci. The first focus is on texts such as magazines, comic books, web pages, films, and works of art. The second focus is directed at social interaction, which Jones also referred to as multimodal interaction analysis. The first focus of multimodal discourse analysis features various studies aimed at understanding how different modes integrate to make strengthened meaning as discussed in earlier sections (Febrianti, 2013; Jones, 2006; Royce, 1998; Wu, 2014). The current study also fell into this category, as it focused on analysing the textual and visual modes' *intersemiotic* complementarity, with school science textbooks as the objects of analysis.

A great deal of work has been done to analyse how meaning is made through verbal language (Halliday, 1993; Wellington & Osborne, 2001), with studies in more recent years extending to studying visual languages and what meanings they project (Dimopoulos, Koulaidis, & Sklaveniti, 2003). Kress and Van Leeuwen (1996) were among the first scholars to extend the idea that meaning within a multimodal text cannot be made through the textual mode alone. Thus, Van Leeuwen (2006) recognised that visuals, such as images, constitute a semiotic mode in their own right. Kress and Van Leeuwen (1996) found that the visual modes are not dependent on the textual mode but have their own grammar and way of structuring and organising meaning.

Following Kress and Van Leeuwen (1996) and other studies (Martinec, 1998; O'Toole, 1994), "multimodal research rapidly expanded from the mid-2000s onwards, as systemic linguists and other language researchers became increasingly interested in exploring the integration of language with other semiotic modes in multimodal texts" (O'Halloran, 2011, p. 5). A multimodal text is defined as a text whose meanings can be made through more than one semiotic mode (Kress & Van Leeuwen, 2006).

Some other studies which aimed at analysing how meaning is made through semiotic modes were conducted in South Africa. One of these studies is by Lycoudi (2017) which was carried out to analyse the presentations of the topic electrostatics in approved South African Physical Sciences textbooks. A similar study was conducted and aimed at assessing some of the differences in the structuring of knowledge that exist between a high school and a university biology curriculum (Kelly-Laubscher & Luckett, 2016). Of all these studies none focused on analysing *intrasemiotic* and *intersemiotic* complementarity of the textual and visual modes, which the current study has an interest in. The term semiotic mode highlighted in this and other paragraphs is significant to this study and is now discussed further in detail.

2.7 Semiotic Modes

The term semiotics is defined in different ways by various authors. Harrison (2003, p. 47) generally described it as "the study of signs", while Van Niekerk and Jenkinson (2011) explained that it concerns everything that can be taken as a sign. A more detailed definition of semiotics is that it is the study of meaning-making through signs (Harrison, 2003; Jamani, 2011; Wellington & Osborne, 2001). Martin and Ringham (2000, p. 2) asserted that "semiotics covers all disciplines and signifying systems as well as social practices and signifying procedures". Van Niekerk and Jenkinson (2011) defined a sign as everything that can be taken as significantly substituting for something else. A study of semiotics by Pierce (1999) reported that meaning of a sign arises in its interpretation.

The field of semiotics aims to characterise the different kinds of signs that compose different semiotic resources (Machin, 2016). The mental interpretations of a person include the emotions, ideas, and feelings that the sign evokes for a person at that time (Pierce, 1999). Therefore, for a sign to exist, there must be meaning manifested through some form of expression or representation (the sign). Harrison (2003) complemented Pierce's ideas by stating that some signs exist within semiotic systems. For example, the green light in a traffic signal is a sign meaning 'go' within the semiotic system of traffic control. Also, the colour red in terms of temperature of water is a sign meaning 'hot', while the colour blue is a sign meaning 'cold' (Harrison, 2003).

According to Jamani (2011), the textual and visual modes are used to construe meanings in science discourse. The discourse of science is a knowledge system of signed information (Danesi, 2007) and is communicated through various forms such as concepts, theories, symbols, laws (e.g. f = ma), models (e.g. force fields), methods, and processes (McComas, 2008). It is during the creation of this knowledge system that many technical terms, such as 'motion', were derived from the nominalisation of everyday words, such as 'moved' (Jamani, 2011). The term nominalisation which is discussed further in Section 2.7.2 was defined by Halliday (1998) as the remodelling of grammar from verbs or adjectives into nouns. Jewitt and Kress (2003) and Jamani (2011) both argued that the discourse of science is more than a knowledge system represented in the textual mode, because scientific meanings can be expressed through a variety of semiotic modalities including gestures and visuals.

Jamani (2011) made it clear that a reader's understanding of scientific meanings depends on their being able to interpret the different semiotic modalities should they attempt to analyse how they interact with each other in communicating meaning of the content. It is important to consider this because, as Lemke (2002) suggested, each semiotic modality expresses a slightly different meaning. There is meaning that the textual mode can individually afford that the visual mode alone cannot and vice versa (Marissa et al., 2011). For example, the textual mode is symbolic while visual modes resemble the objects they depict (Machin, 2016). To further explain this, Machin (2016) argued that the visual modes can depict and symbolise in a way that the code of textual mode cannot. The reason given for this is because a photograph has no code (Machin, 2016). However, these different meanings can complement each other and add to the overall meaning of the content (Lemke, 2002; Royce, 2002). School science textbooks, which were the focus in this study, also include various semiotic modes which are aimed at contributing to their meaning potential. The next section discusses in more detail the multimodal discourse of school science textbooks.

2.8 General Description and Multimodal Discourse of School Science Textbooks

School science textbooks are significant to science education because they are mostly the only source of scientific knowledge in science classrooms (Penney, Norris, Phillips, & Clark, 2003). They are known to be unique in terms of their structure and how their content is organised. This structure and organisation of scientific texts as highlighted by Penney et al. (2003) influence the readers' comprehension. It has been noted that major ideas and key concepts within different chapters or topics in these textbooks are commonly organised in a similar way (Bryce, 2013). The chapters/topics usually begin with key vocabulary words which are subsequently explained within the main paragraphs of the textual mode. These vocabulary words often appear highlighted through bolding or italics within the school science textbooks (Bryce, 2013; Fang, 2004). To enhance comprehension, scientific texts are further designed with various structures such as, outlining the objectives, chapter reviews, and questions and exercises for learners self-testing (Penney et al., 2003).

The discourse of science in modern days, as emphasised by various authors (Lee, 2010; Maier, Kampf, & Kastberg, 2007; Royce, 1999), considers different semiotic modes both aimed at adding to meaning potential of scientific texts. It is the multimodal character of scientific texts that helps learners make meaning as they read through them (Linder, 2013). The textual mode in school science textbooks is often combined with the visual mode. In terms of the visual mode, a textbook with more images may be easier to engage with than one having fewer images. One reason for this argument could be that images show concrete examples. When it comes to the textual mode, Hsu and Yang (2007) cautioned that school science textbooks often contain unique terminologies that differ from everyday language. Students may thus find it challenging to work with a textbook that includes more abstract terminologies. It is thus important that great emphasis is placed on how the textual and visual modes in school science textbooks are integrated to produce a combined meaning. The textual and visual modes, which are the most relevant semiotic modes for the purpose of this study, are now discussed in further detail.

2.8.1 The textual mode as semiotic mode

Halliday (1978) emphasised that the most important feature of language that makes it relevant to its readers is meaning. This meaning, according to Jones (2012) and Flowerdew and Mahlberg (2009), is realised as a result of the relationships or connections between words or sentences in a text. There are various definitions of the term text. Halliday (1978) and Witte (1992) unpacked the word text as an organised set of symbols that is meaningful in a particular situation and includes both the spoken and written language. The word *symbol* is generally explained by Jamani (2011) as a form of conventional practice, such as letters representing abbreviations of concepts. Halliday and Hasan (1985) defined a text as any particular instance of language and/or visual mode in use that has coherence and coded meanings. Then, in social and metafunctional terms, text is understood either as a single mode or multiple modes (Royce, 2007). In this study, the term text is used to refer to written words only.

The foundation for meaning is choice (Halliday, 1978). For this study, this meant that the consideration of the language used in school science textbooks by authors is meaningful, especially to learners as the main readers. In his theory of SFL, Halliday (1978) viewed language as a meaning making tool intimately involved in negotiating, constructing, organising, and in how people perceive and interpret the world around them. Fang (2004) supported this definition by stating that language is seen as a principal resource for making meaning. It is important that a relationship should exist between words or sentences (referred to as lexical items) in a text for meaning to be made. Jones (2012) pointed out that the connection that exists between a collection of words in a text is considered important for its meaning.

This form of connection was significant to this study as it could provide insights on the textual mode in school science textbooks in terms of meaning arising from it. Nurjannah (2018) explained that a lexical item or unit refers to words or phrases forming the textual mode. Jones (2012) further suggested that the main part of a text that makes it relevant is the relationships or connections between words or sentences. He then introduced three relationships between words or sentences: (a) the relationship between words, sentences, or other elements inside the text (cohesion); (b) the relationship between the text and the person reading it or using it (coherence); and (c) the relationship between the text and other texts (intertextuality). Halliday and Hasan (1985) stated that coherence exists in a text when the meaning relations are realised by words and phrases that allow sentences to be understood as a connected discourse.

Taking the concept of cohesion further, Halliday and Hasan (1976, p. 4) indicated that "the concept of cohesion is a semantic one", and that it refers to relations of meaning that occur within a text and that interpret it as a text. They further clarified that cohesion does not concern the meaning of the text but deals with how the text is constructed for that meaning to be made. A slightly different but very related definition of cohesion is given by Ahmed (2013) who explained it as the characteristics of unity forming up a text. In this study, cohesion refers to the relation of meanings that occur within and across the textual and visual modes of a text. Ahmed (2013) and He (2014) stated that there are two types of cohesion, and they are:

grammatical cohesion and lexical cohesion. Figure 2.1 is used to illustrate the systems of cohesion.

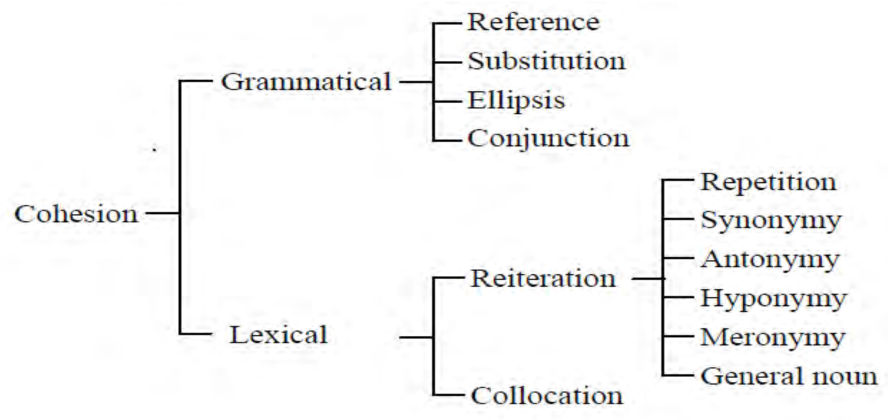


Figure 2.1: Examples of types and subtypes of cohesion (Biskri, 2012; He, 2014)

Grammatical cohesion involves cohesive devices such as reference, substitution, and ellipsis. On the other hand, lexical cohesion deals with words and phrases. Lexical cohesion is achieved when words and phrases which are closely related in meaning occur together in a text (He, 2014). This simultaneous occurrence of the words and phrases in a text helps in making the different parts of a text semantically related. Halliday and Hasan (1976) stated that lexical cohesion has two categories, reiteration and collocation.

"Reiteration is a form of lexical cohesion which involves the repetition of lexical items" (Sari, 2012, p. 14). This form of lexical cohesion also includes the use of synonymy, antonymy, hyponymy and meronymy. Collocation is concerned with expectancy relations between words that are usually used together (Renkema, 2004; Webster, 2009). This study used repetition, synonymy, antonymy, hyponymy, meronymy, and collocation as the meaning similarities and differences that exist within the textual and visual modes. These meaning similarities and differences are known as sense relations. Alyousef and Alnasser (2015) noted that these sense relations help in achieving lexical cohesion within a text. The sense relations were explored in this study through finding out how the textual and visual modes in the topic of Forces in three

Namibian Grade 8 Physical Sciences textbooks related in terms of *intersemiotic* complementarity. A more detailed discussion of these sense relations appears in Chapter Three.

There are various ways in which the textual mode used in school science textbooks makes meaning. Halliday and Martin (1993) stated that some of these involve the use of terms and nominalisation. These and other "features of the language of science" (Halliday, 2004, p. 122), such as informational density, abstraction, and authoritativeness mentioned earlier in Section 2.8.1, will now be further detailed. Informational density is one of the distinguishing features of scientific writing (Fang, 2004). The informational density of a text can be measured by an index called lexical density. Fang (2004) clarified that lexical density can be calculated in two ways: (a) as the number of content words per non-embedded clause; or (b) as the percentage of content words over total running words. Content-carrying words include nouns, the main part of the verb, adjectives, and some adverbs; while non-content-carrying words include prepositions, conjunctions, auxiliary verbs, some adverbs, determiners, and pronouns.

Abstraction is another feature of scientific writing. Unlike the common-sense language used for construing day to day life experiences, "scientific language theorises concrete life experiences into abstract entities" (Fang, 2004, p. 339). These conceptual entities as Fang (2004) indicated can eventually be further explored and critiqued. Such theorising involves turning processes (as expressed by verbs and adjectives) into participants (as expressed by nouns). A type of abstraction is nominalisation (Fang, 2004). Fang (2004) stated that nominalisation (introduced earlier in Section 2.7) involves more than remodelling of grammar and is a process of re-meaning. For example, when a verb, adjective or phrase is written as a nominal group, much of the meaning is lost and the word becomes ambiguous.

A nominal group is explained as a grammatical resource used to transforming lexical items into denser form (Halliday & Matthiessen, 2004). Christie (2001, p. 66) mentioned that nominalised phrases "abstract away from immediate, lived experiences, to build instead truths, abstractions, generalizations, and arguments", so that they can further participate in the process. Fang (2004) gave an example of the nominalised phrase, *the destruction of Brazilian rainforest,* which might be interpreted as: "People cut down trees in Brazilian rainforest", "Trees in Brazilian rainforest are cut down (by logging companies)", or "Brazilian rainforest is destroyed (by people or natural disasters)" (Fang, 2004, p. 340). Both informational density and nominalisation features can be realised through another feature called technicality (Fang, 2004).

Technicality refers to the use of "terms or expressions with a specialised field and meaning" (Hsu & Yang, 2007, p. 639). The concept of technicality arose from earlier research into how different school subjects, such as history, geography, and later science, create their field-specific meanings (Wignell, Martin, & Eggins, 1993). In the context of science, technicality is necessary in order to realise the specialised contents of science (Fang, 2004). Technicality in science is characterised by technical vocabulary which involves a shift from the common-sense world of the everyday to the uncommon-sense world of science (Fang, 2004; Halliday, 2004; Jones, 2006). Technical vocabulary refers to "terms or expressions with a specialized field-specific meaning such as magma and asthma which are more associated with Geo-science and Natural Sciences respectively" (Wignell et al., 1993, p. 144). These words as clarified by Penney et al. (2003) have precise meaning that differ from those of the same words when used in everyday language of communication. Fang (2004, p. 341) stated that "words or phrases of technical vocabulary allow scientists to construct classes/categories and establish taxonomic relationship among entities in the natural world". Thus, students learn scientific language better when they have an understanding of science vocabulary words (Ceglie & Olivares, 2012).

Additionally, Fang (2004, p. 341) mentioned that "technical terms can be non-vernacular adjectives that describe physical objects/phenomena (e.g. multicellular), or verbs that describe unique activities or processes of science, such as evaporate or condense". A technical term can often be easily identified in a science textbook because it is sometimes highlighted within sentences or paragraphs through typographical resources such as a different colour, bold face, or italics (Fang, 2004; Jones, 2006). These features of the textual mode, as indicated by Van Niekerk and Jenkinson (2011), are ways of conveying the relative importance of parts of a message. Technicality has implications on science education. Ceglie and Olivares (2012) and Harmon, Hedrick and Wood (2005) indicated that vocabulary load in school science textbooks poses a great challenge to secondary school learners as they are required to use scientific terminologies in explaining concepts.

Furthermore, it is stressed that learners who have difficulties in understanding meanings of technical vocabulary often struggle with comprehension of science texts (Fang, 2004). Having this lack of understanding also means learners lack the grammatical resources needed to effectively communicate scientific ideas and knowledge. According to Harmon et al. (2005), some learners seek solutions to the demands of school science textbooks by resorting to memorising scientific terms and facts, instead of deeply understanding them. Students involved in this way of learning may develop a wrong perception about science, that it is related to facts only. Fang (2004) stressed that it is important that learners are well apprenticed in technical vocabulary in science in order to overcome challenges in constructing scientific knowledge and communicating scientific information effectively in their own writings.

An additional feature of scientific writing is its authoritativeness. In science, information is typically presented accurately and objectively, as well as in an assertive tone (Schleppegrell, 2001). In order to do so, the author must distance themself from the text by refraining from using (a) first person references (e.g. I am writing); (b) references to their mental processes (e.g. I think, I suppose); (c) discourse fillers for monitoring information flow (e.g. you know); (d) direct quotes (e.g. it says, "I am tired."); and (e) vagueness and hedges (e.g. sort of, stuff like that) (Chafe, 1982). Fang (2004, p. 342) pointed out that "in scientific writing, authoritativeness is typically conveyed through the use of technical terms rather than through common-sense vocabulary (e.g. asthma); declarative, imperative, or interrogative sentences (e.g. Severe asthma attacks may require emergency medical care)". This feature of scientific language is also communicated through passive rather than active voice (Fang, 2004). Together, these grammatical resources enable "the realization of an assertive author who present him/herself as a knowledgeable expert providing [accurate and] objective information" (Schleppegrell, 2001, p. 444). Because of its authoritativeness, scientific language is distinct from the more informal and engaging language of everyday, ordinary life.

2.8.2 The visual mode as semiotic mode

It is well recognised that visual modes are an important part of science education. This importance is defined by the roles that visual modes play in scientific texts. Firstly, Royce (1999) reminded us that visual modes are never used as fillers to fill up spaces on the page but play a significant role in helping learners to learn better. Secondly, visual modes help scientists in communicating science concepts better (Kress et al., 1998). It is known that science discourse is characterised by many abstract concepts which necessitate the use of visual modes to assist learners in understanding them (Kapıcı & Savaşcı-Açıkalın, 2015). Thirdly, Liu and Treagust (2013) believed that visual modes can help limit the ambiguity of textual explanations of scientific concepts, thus their inclusion in school science textbooks can help to clarify confusing concepts and establish a visual foundation for field-related topics such as energy and force. This is one of the reasons why the quality of textbooks has become an issue for serious consideration, especially the Physical Sciences textbooks containing numerous visuals embedded in the print (Hsu & Yang, 2007).

Furthermore, visual modes in school science textbooks are not just randomly used for the purpose of illustration or as subsidiary elements of the verbal elements of the text, but serve as significant modes helping to express the main ideas being communicated (Pintó & Ametller, 2002). There are certain meanings we wish to convey in science that cannot possibly be put across in words alone. This is evidenced by the messages and meanings that are conveyed by visuals, charts, and graphs which can never be replaced by the textual mode (Wellington & Osborne, 2001). Due to this situation, "the latter part of the twentieth and the early part of the twenty-first centuries has seen a significant shift in the prominence of visual modes in school science textbooks" (Unsworth, 2006, p. 1167).

In addition, visual modes in school science textbooks, as explained by Korfiatis, Stamou, and Paraskevopoulos (2004), illustrate what is written in the text and are usually more easily remembered than the text itself. This explanation concurred with Carvalho, Tracana, Skujiene, and Turcinaviciene (2011), who maintained that visual modes are powerful tools in the teaching and learning environment. From this background, it can be understood that a textbook's content presented with more visual modes can help readers to make sense of meaning within the textual mode. Harrison (2003) suggested that a useful guide for analysing visual modes is visual social semiotics. This is a new field of study that views visual modes as existing to convey specific kinds of meanings (Jewitt & Oyama, 2001). The visual social semiotics is linked to Halliday's (1978) SFL theory which was the theoretical perspective for this research. In the next paragraph this connection is clarified.

Starting with the term semiotics, introduced earlier in Chapter One, this concept was initially derived from the word sign (Halliday & Hasan, 1985). A sign is a visual element – such as text, paintings, photographs, sculptures, and animations (Nakakuwa, 2019). Visual elements are not the results of isolated or creative activities but are themselves social processes. This suggests that their meanings are negotiated between the producers and viewers, reflecting their individual contexts (Harrison, 2003). The link between visual social semiotics and SFL therefore, is that both see language that is not only confined to text but also includes the visual mode as a social semiotic system. Furthermore, visual social semiotics follows SFL in recognising the three simultaneous meanings (Jewitt & Oyama, 2001) which were already introduced in Chapter One. Based on this developed field of study, Harrison (2003) identified three categories of the visual mode that will feature in the research design section. These are (not in order of identification): *icons*, *indexes*, and *symbols*, as exemplified in Table 2.1. A detailed explanation of these categories is presented after the table.

Table 2.1: Categories of the visual modes in visual social semiotics

Categories of the visual mode	**Examples**
Icons	Paintings, maps, photographs, diagrams, models
Indexes	Arrows
Symbols	Words, such as *rose*

The first category of the visual mode identified is *icons*. A visual mode is iconic if it bears a similarity or resemblance to what we already know or conceive about an object or person (Harrison, 2003). The evolution of language as reflected by Darian (2001) started with pictures and is evident from cave paintings with their iconic meanings existing before alphabets and other textual modes (Dondis, 1973). Historically, people used paintings to understand the world around them (Dondis, 1973). The iconic nature of the textual mode came down to us today in Chinese and Arabic, as well as in languages that use the Roman alphabets (Darian, 2001; Van Niekerk & Jenkinson, 2011). It has been stated that letters are often replaced by pictures of objects that resemble the letters so that they (pictures and letters) have the same meaning (Van Niekerk & Jenkinson, 2011). An example given is that of a typical baby type of picture, such as play blocks, that can be used as *icons* to visualise alphabetical letters.

These iconic alphabets as pointed out by Darian (2001) as well as Van Niekerk and Jenkinson (2011), represent an additional semiotic system that is integrated in the writing process. It is also stated in literature which concerns the use of *icons* in science education that school science textbooks contain more diagrams and photographs than paintings, maps, and models (Guo, Wright & McTigue, 2018). For the current study, not all examples of *icons* as illustrated in Table 2.1 were relevant for analysis purposes. The researcher chose to focus on photographs and diagrams because the design features of visual modes in the three Physical Sciences textbooks included these.

Pozzer and Roth (2003) explained photographs as *icons*, and identified four kinds of photographs: decorative, illustrative, explanatory, and complementary. Illustrative photographs include a caption that names or describes what the reader will see in the photograph (Pozzer & Roth, 2003). Contrary to what is stated in the previous sentence, captions on illustrative photographs are not usually used for the purpose of providing additional information to the main text. Such photograph-caption ensembles constitute a visual resource for the reader in the sense that a concrete specimen of a class or concept is depicted. The visual information possibly provided does not alter the understanding of the subject matter; that is, the photograph does not show the phenomenon treated in the text but provides a visual illustration that was only referred to in the text as an example. Complementary photographs are associated with captions that add new information about the subject matter treated in the main text (Pozzer & Roth, 2003). This information is not only new and never mentioned before in the main text, but is also important and helps readers to further understand the concept that is being emphasised in the main text.

Explanatory photographs include photographs with captions that provide an explanation of what is represented in the photographs (Pozzer & Roth, 2003). The captions do not only name the object or phenomenon in the photograph, but also add information about this object or phenomenon. The index presented in the main text and replicated in the caption allows the reader to connect figure and text. Decorative photographs are photographs not referred to in the main text at all, often not including a caption, and usually appearing at the beginning of a unit, chapter, or section of text (Pozzer & Roth, 2003). Jones (2006) emphasised that the visual modes which contribute little to ideational meaning of multimodal texts are decorative.

The second category of the visual modes is *indexes*. A visual mode is of the index type if it is recognisable, not because of any similarity to an object or person but because we understand the relationship between the visual mode and the concept for which it stands. Examples of *indexes* are arrows. Heiser and Tversky (2006) mentioned that arrows belong to a class of privileged diagrammatic elements, along with lines, boxes, crosses, and circles. They are used in diagrams and within scientific texts to express many relations such as, movement, connection, sequence and forces (Heiser & Tversky, 2006). It is further explained that for diagrams of compound systems, “arrows can be used to indicate temporal sequence (the order of the operation of the components) to accomplish the overall goal of the system” (Heiser & Tversky, 2006, p. 582). Figure 2.2 shows an example of a diagram of complex system with arrows used in signifying temporal sequence.

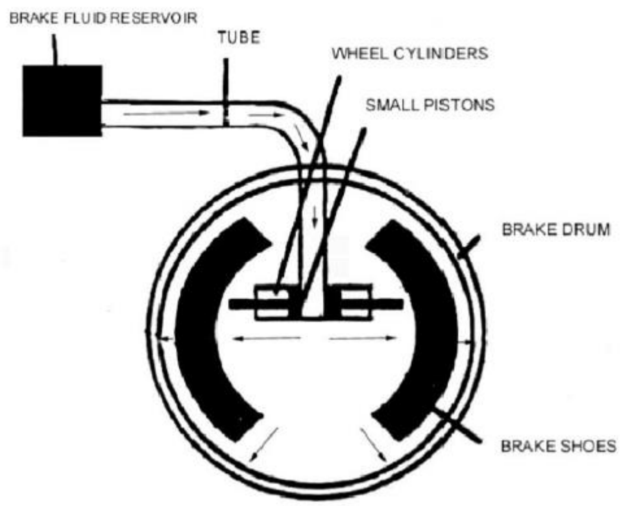


Figure 2.2: A diagram showing arrows used in signifying temporal sequence (Heiser & Tversky, 2006)

In the figure, the arrows indicate that from the brake fluid reservoir, brake fluid enters and travels sideways and down the tube. Heiser and Tversky (2006) also indicated that in the case of maps, arrows are used to determine directions of roads.

Indexes can be abstract, and therefore are thus often labelled with the textual mode to explain them. Jones (2006) elaborated that abstract visual modes are those which differ from familiar representations of events, participants, and places in the concrete world. The levels of abstraction of the visual modes may differ depending on their physical appearances. For example, Pozzer and Roth (2003) identified that the level of abstraction of a visual mode depends on the amount of contextual detail that they carry in their background. Pappas (2006) defined labels as isolated words or phrases, which are frequently connected to the pictorial representation through an arrow or line to the relevant component.

The third category of the visual modes are the *symbols*. A visual mode is a symbol when it has no visual or conceptual connection to an object or person. People know the meaning of a visual mode only because of convention, which means that it is something people have learned. A *word* for example, is a *symbol* because it does not resemble what it stands for, nor does it have any indexical relationship to what it signifies. For example, the word *rose*, does not look like a rose or have any visual relationship to the concept of a rose. Jamani (2011) had similar and different ideas to that of Harrison when it comes to the meaning of *symbols*. He offered a general description that *symbols* stand for some conventional practice, such as words, sentences, and alphabetical letters representing constants in mathematics. For example, in an algebraic expression $2x + 4y$, the letters x and y are perceived as *symbols*. Jamani (2011) further stated that in science discourse, *symbols* represent a knowledge system of society, and provided other examples of *symbols* such as, terms, equations, and formulae. Since the examples of *symbols* provided in this paragraph are more fitting with the textual mode discussed earlier in Section 2.7.2, they were used to help do the coding in that mode.

Studies around visual modes (Royce, 2002) have been undertaken worldwide for the purpose of analysing them in school science learning materials. Some of these studies identified as similar to the current study will now be discussed. The study by Dimopoulos et al. (2003) aimed at analysing the pedagogic functions of visual images included in primary and lower secondary level science textbooks, and Daily Press articles about science and technology. The findings of their study revealed that most visual modes used in science textbooks are realistic and analytical. Realistic visual modes are defined as those that represent reality according to human optical perception (Dimopoulos et al., 2003). Both photographs and drawings belong to this category of visual modes. Analytical visual modes, on the other hand, focus on the relationship between the objects of representation in terms of a part-whole structure (Dimopoulos et al., 2003).

It is further explained that the parts of the whole may be labelled, or it may be left up to the viewer to label them. Also, as a whole, an analytical visual mode is described as the most elementary option, and its meaning has a close similarity to the linguistic terms “this is” or “this consists of” (Dimopoulos et al., 2003, p. 196). The inclusion of more realistic and analytical visual modes in school science textbooks as argued by Dimopoulos et al. (2003) is useful for the reasons mentioned next. Firstly, these visual modes will promote a particular emphasis on the physical appearance of things. Secondly, they will portray scientific knowledge as not being fully divorced from everyday knowledge. It is again reported in Dimopoulos et al.'s (2003) study that visual representations are frequently employed in school science textbooks as a means of exposing learners to the structures and the physical appearances of various entities.

A study undertaken in Greece by Koulaidis and Dimopoulos (2006) focused on examining how certain meanings related to the nature of school science are produced by how the textual and visual modes interact in Greek primary science textbooks. Koulaidis and Dimopoulos (2006) recognised that the textual and visual modes are very important resources for meaning making in primary school science textbooks. As part of their data reduction process, they limited their analysis to only parts of the science textbooks that aimed at delivering scientific knowledge. By doing this, their analysis excluded all those parts aimed at students' assessment, such as questions, activities, and solved exemplary problems.

One of the findings of their study was consistent with that of Dimopoulos et al. (2003) who revealed that the majority of visual modes used in primary and lower secondary levels science textbooks are realistic and analytical. Another finding of Koulaidis and Dimopoulos' (2006) study revealed that the interaction of the textual and visual modes contributed little to meaning potential of Greek primary science textbooks, because the majority of the visual modes included in the textbooks were not explicitly labelled, and some were not linked with their corresponding textual mode through indexical references.

The textual mode and a diagram can interact in various ways. According to Slough, McTigue, Kim and Jennings (2010), the textual mode can provide information about the diagram itself, such as labelling its components. Also, a diagram can present wholly new information that reinforces the information within the textual mode. Slough et al. (2010) argued that indexical references are critical because they help to connect the textual mode with the visual mode. For example, a textual mode may reference a visual mode using statements such as "see figure 1" (Slough et al., 2010, p. 312). Slough et al. (2010) further indicated that cues in the verbal text that reference the information in the visual mode guide the reader on how to integrate the textual mode and the visual mode. It is also noted that diagrams are frequently used to supplement the textual mode, especially in teaching complex systems (Heiser & Tversky, 2006). Heiser and Tversky (2006) emphasised that the combination of the textual mode and labelled visual modes help improve performance on problem solving.

2.9 Chapter Summary

Chapter Two began with a discussion of the topic of Forces, which comprises the key concepts of forces, weight and mass, work, energy, and friction. Bernstein's pedagogic device and an explanation of the recontextualisation field where school textbooks are located in the pedagogic device were also discussed. The chapter then highlighted the significance of school science textbooks in science education. A detailed explanation was presented on the process of developing school textbooks in general and those of science textbooks in Namibia. Linder (2013) placed emphasis on the multimodality of these textbooks and various authors have stressed the importance of school textbooks in teaching and learning of scientific knowledge. An extension of meanings afforded by the textual and visual modes as individual semiotic resources were discussed. Chapter Three will now present the theoretical framework of the study.

CHAPTER THREE: THEORETICAL FRAMEWORK

3.1 Introduction

In this chapter, the researcher presents the theoretical perspective informing the study – Systemic Functional Linguistics (SFL). Eisenhart (1991, p. 205) defined a theoretical framework as "a structure that guides research by relying on a formal theory, constructed by using an established, coherent explanation of certain phenomena and relationships". Jansen and Vithal (1997) as well as Hofstee (2006) described theory as a well-developed, logical, and coherent explanation for an event. Bertram and Christiansen (2015) highlighted that the importance of theory lies in it providing a possible model or explanation for how and why things happen.

Researchers use theory for different purposes. Bertram and Christiansen (2015) found that some researchers approach their study with a specific theory held clearly in mind and aim to determine whether the theory is true or false. They also revealed that other researchers may use theory as a way of broadly framing their study. This perspective entails researchers having no intention to prove or disprove a theory but operationalising the principles of the particular theory to broadly inform their research. In addition, it was found that researchers use "certain ideas from the theory to help them make sense of the data" (Bertram & Christiansen, 2015, p. 118). In this study, SFL was employed for the purpose of theoretically framing the research. Systemic Functional Linguistics theory will now be discussed with emphasis on the aspects of importance to this study.

3.2 Systemic Functional Linguistic Theory

The theoretical orientation of this study drew from SFL theory devised by Halliday (1978). Systemic Functional Linguistics theory is an extension of the work by an influential linguist, J.R. Firth in the 1950s, whose major interest was in the cultural backgrounds of language users (Taiwo, 2006). In addition, he developed an approach to phonology known as *prosodic phonology*, which enables phonological features to be shared over successive phonemes rather than each phoneme having its own unique features (Almurashi, 2016). Halliday's SFL is then concerned with how people use language in social settings to attain specific targets (O'Donnell, 2011). Systemic Functional Linguistics theory was developed by Michael Halliday during the

1960s in the UK and then in Australia (Almurashi, 2016). The theory is based on “an elaborate model in which language, life, the universe and everything can be viewed in communicative terms” (Halliday & Martin, 1993, p. 23).

Halliday (1978) made four central claims about language. The first claim was that language is functional in terms of what it can do or what can be done with it. The second claim was that language is semantic, which refers to its relationship to meaning making. The third claim stipulated language as contextual, in that meanings exchanged both influence and are influenced by their social and cultural situations. The fourth claim viewed language as semiotic in that it is a process of meaning (Halliday, 2004). The fourth claim, which is related to semiotic modes, will now be discussed.

3.2.1 Language as a social semiotic system

Systemic Functional Linguistics theory considers language to be a social semiotic system. Halliday took the notion of system from J.R. Firth – one of his teachers (Almurashi, 2016). For Firth, “system refers to a set of choices” (O’Donnell, 2010. p. 4). According to Halliday and Matthiessen (2004), the term systemic means that the grammar consists of system networks that comprise the pattern of choices through which meaning is communicated. Because of the concern of SFL with the use/application of language, great importance is placed on the function of language (such as what exactly it is being used for), in contrast to its structures (grammar) – the manner in which it is composed (Matthiessen & Halliday, 1997).

Halliday in fact insisted that the central concern of linguistics should be the study of language and its function in meaning-making (Halliday, 1985). Echoing the ideas of Halliday and elaborating on the functional view of language, Fang (2004, p. 336) mentioned that scholars have shown language to be an “open-ended yet interlocking system of options” in which users make choices regarding the words and grammar used, based on their personal needs as well as the particular social context. Halliday (1993, in Fang, 2004, p. 336) took this point further by arguing that “language is simultaneously a part of reality, a shaper of reality, and a metaphor for reality”. This argument challenges the traditional formal view of language which focuses on grammatical rules.

The perspective of SFL recognises the relationship between language and context, and it maintains that language itself is a tool for construing meaning (Halliday, 1978; Halliday &

Martin, 1993). Halliday (1978) proposed that the meaning-making functions of language are grouped into three main categories called metafunctions (introduced in Chapter One). These are the ideational metafunction, interpersonal metafunction, and textual metafunction. Although the three metafunctions are related and act simultaneously (Halliday (1978), they relate to different meanings. Furthermore, Jones (2012) stressed that the three metafunctions play a role in the way a text promotes a particular ideology. Each of the metafunctions will now be considered.

The interpersonal metafunction is concerned with "the social, expressive and conative functions of language, with expressing the speaker's angle, his attitudes and judgments" (Halliday & Hasan, 1976, pp. 26-27). This metafunction has to do with power relations between the text producer and the reader (Halliday & Martin, 1981). Furthermore, Royce (2007) stated that this meaning of language responds to the tenor or social relations of the participants involved in the text. In some written discourse such as recount text, if the writer and reader are not personally known to each other the writer may use a neutral tenor which is formal, as opposed to them expressing personal feelings and emotion (Cakrawati, 2008). Recount is one text that is learned both in junior secondary and senior secondary school levels, its purpose being to tell what happened or to retell with the aim of informing.

The textual metafunction involves "the organisation of the informational content of a subject on the page in various ways and in accordance with accepted compositional or layout conventions" (Royce, 2002, p. 193). Bilal (2012) expanded on this explanation by stating that the textual metafunction also involves the flow of information in a text. Ahmed (2013) explained that the textual metafunction contains the resources for creating coherent and relevant text. The textual metafunction has two components: the structural part, that focuses on issues like the organisation of the clause as a message and the non-structural part, which is concerned with cohesion systems (Ahmed, 2013; He, 2014). For the non-structural component, Taiwo (2006) clarified that it deals with how the lexical items in a text are linked to produce a cohesive whole. Since the textual metafunction is associated with cohesion, this type of meaning is of some relevance to this study in terms of the textual and visual modes affording particular meanings.

The ideational metafunction involves "the expression of content, with the function that language has of being about something" (Halliday & Hasan, 1976, p. 26). Lee (2010) elaborated that this metafunction deals with informational content on a certain subject matter and speaks mostly to the represented content (in this study, science). Bilal (2012, p. 726) added that ideational metafunction is the "function of language representing the natural world in the broadest sense, including our own consciousness". This study was not aimed at analysing issues of power relations between language producers and users and so the study did not consider interpersonal meanings when exploring the *intrasemiotic* and *intersemiotic* sense relations of the textual and visual modes. Since the aim of this study was facilitated by Royce's (1999) idea of *intersemiotic* complementarity of the visual and verbal modes as realised through ideational meanings, ideational metafunction was considered most relevant and will now be further discussed.

The ideational metafunction is seen as the function of language (verbal) and visuals representing the 'goings-on' in the world (Kress & Van Leeuwen, 1996; Royce, 1999). Royce (2007) then added to the conception of ideational metafunction by stating that it is meaning in the sense of content. He also pointed out that visuals are representations of reality, experience, and information, and therefore can also realise ideational meanings. In addition, Jones (2006, p. 140) argued that "intersemiosis of ideational domain of meaning concerns the content and the field of discourse, and how this is construed across semiotic resources".

Martin and Rose (2007) averred that ideational metafunction has two types or sets of meaning known as discourse systems. These are the conjunction and ideation discourse systems. The conjunction discourse system focuses on how activities are interconnected and can be described as logical ideational meanings. The ideation discourse system, which was relevant to this study, is concerned with the construal of experience and has two components: the *taxonomic relations* – chains of relations between words, and *nuclear relations* – the relationships between the words within a clause (Martin & Rose, 2007). "*Taxonomic relations* include the sense relations of repetition, synonymy, hyponymy, meronymy and antonymy", while *nuclear relations* deals with collocations (Ahmed, 2013, 19). These sense relations are discussed in further detail later in this chapter.

Unsworth (2006, p. 62) extended our understanding of ideational metafunction by adding the concept of ideational complementarity. He defined ideational complementarity as the situation in "multimodal texts where what is represented in the textual mode and visual mode may be different but complementary, and contributes to an overall meaning that is greater than meanings conveyed by the separate modes". Ideational complementarity appears as two types: augmentation and divergence (Unsworth, 2006). Augmentation refers to instances when each of the modes provides meanings additional to and consistent with those stated in the other mode (Unsworth, 2006). Divergence is when the contents of the textual and visual modes have opposite meanings.

Systemic Functional Linguistics theory as originally presented focused primarily on spoken language and the associated written text (Halliday, 1978). However, it has been emphasised in recent years that this alphabetical language is only one semiotic system among other varieties of meaning-making modes in any context (Halliday, 1985; Unsworth, 2006). Thus, Royce and Bowcher (2007) argued that SFL theory need not be limited to language alone as there are other ways by which meaning can be realised. This is supported by Unsworth (2006, p. 57), who mentioned that the assumption of SFL is all forms of semiotic modes "are related to the meaning-making functions they serve within social context".

Previous studies such as by Kress and Van Leeuwen (1996) as well as Lemke (1998) extended the application of SFL to interpret the grammar of other semiotic modes apart from language. Kress and Van Leeuwen (1996) and Van Leeuwen (1999) for example, have applied SFL theory to study semiotic modes such as the visual mode and music, respectively. They (Kress & Van Leeuwen, 1996) extended Halliday's idea of the three metafunctions by demonstrating that the visual mode, too, can fulfil all three of these simultaneous meanings. As the interest in exploring how different semiotic modes interact in multimodal texts grows, an approach called systemic-functional multimodal discourse analysis (SF-MDA) resulted from SFL theory (Febrianti, 2013; O'Halloran, 2008; O'Toole, 1994). Systemic-functional multimodal discourse analysis will now be considered in more detail.

3.2.2 Systemic-functional multimodal discourse analysis

O'Halloran (2011) described SF-MDA as an approach within SFL that is employed in research that aims to study language in combination with other resources such as the visual mode, scientific symbolism, gesture, action, music, and sound. Systemic-functional multimodal discourse analysis draws on Halliday and Hasan's (1976) and Halliday and Matthiessen's (2004) framework for the analysis of cohesion. It was first developed by O'Toole (1994) in his work *The Language of Displayed Art*, in which he used SFL to analyse art forms such as paintings, sculptures, and architecture. O'Halloran (2008; 2011) and Bhatia, Flowerdew, and

Jones (2008) elaborated that SF-MDA is a fairly new and fast-developing approach in the field of multimodal discourse.

O'Halloran (2011) employed SF-MDA to examine multimodal discourses at a micro-textual level, which evolved into the analysis of mathematical symbols and the visual mode. This form of analysis aims at applying practical methods to analysing and understanding meanings in written, printed, and electronic texts, and other kinds of multimodal texts that use a combination of semiotic modes (O'Halloran, 2008). Royce's (1999) study, which is foundational to this thesis, was also informed by SFL. Systemic-functional multimodal discourse analysis was relevant in this study because it involved analysis of *intrasemiotic* sense relations within modes and how these were related in terms of *intersemiotic* complementarity in the topic of Forces in Physical Sciences textbooks. A detailed discussion of SF-MDA approach for studies involving the analysis of multiple modes will now be presented.

3.2.3 *Intersemiotic* complementarity in terms of sense relations

Intersemiotic complementarity is an approach to multimodal discourse analysis developed by Royce (1998). Royce derived this framework from Halliday's metafunctional view of communication as outlined by SFL. Royce (2007) further elaborated that *intersemiotic* complementarity refers to instances where semiotic modes complement each other towards communicating meaning or ideas that cannot adequately be communicated by a single mode. It is used for exploring meaning making across different semiotic modes in multimodal texts in terms of Halliday's ideational, interpersonal, and textual metafunctions (Liu & O'Halloran, 2009). Royce (2007) indicated that *intersemiotic* complementarity is realised through various linguistic and visual means. Jones (2006) undertook a study related to that of Royce (1999), in which he presented a metafunctional account of multimodal meaning making in university science textbooks and electronic learning materials. The findings of his study revealed that a combination of visual and verbal meanings through intersemiotic mechanisms can strengthen overall meaning.

Recent studies involving the analysis of intersemiosis in multimodal texts were undertaken by Febrianti (2013) and Wu (2014). Both scholars used SFL to frame their studies. Febrianti (2013) analysed how the multimodality of the visual and verbal elements in Indonesian print advertisements expressed meanings through *intersemiotic* complementarity. One of his key findings was in agreement with the result from the study by Jones (2006), that "meanings from the textual mode in print advertisements strengthen meanings from the visual mode, and vice versa" (Febrianti, 2013, p. 310). Wu (2014) analysed image-text relations of picture books using the concepts of elaboration, extension, enhancement, and projection. Elaboration, which he described as a relationship of similarity across semiotic modes, relates to synonymy which was highlighted in Royce's (1998) and Febrianti's (2013) studies. Jones (2006, p. 146) explained further that "elaborating relations for example, some parts of the main text, caption, or label, may expand an aspect of the visual mode or vice versa, by restating or representing the same information in a different semiotic mode".

Van Leeuwen (2005) and Liu (2015) described extension as relations where meaning in one mode extends or changes meaning within the other mode. Instances of extension occur when each of the textual and visual modes provide meaning additional to and consistent with those provided by each individual mode (Unsworth, 2006). Enhancement, also known as conjunction relations, refers to one mode providing meanings which expand another spatially, temporally, or causally. Jones (2006) criticised the analysis of enhancing relations under ideational meaning, on the grounds that it is difficult to reason about relations of cause, time, and purpose between the textual and visual modes. Finally, Unsworth (2006) and Liu (2015) explained that projection occurs where a verb in the textual mode quotes what a character says, and the textual quotation is realised by the visual rather than the textual mode.

Royce's (1998) study, although conducted much earlier than more recent studies on *intersemiotic* complementarity, was found to be most relevant to the current study. His study focused on analysing the co-occurrence of the visual and verbal modes in a multimodal text of *The Economist* magazine in terms of the sense relations (mentioned earlier in Section 2.8.1 of Chapter Two). "An *intersemiotic* complementarity framework of the visual and verbal modes was formulated to help in understanding how the two modes semantically complement each other to produce a single textual phenomenon" (Royce, 1998, p. 26). Drawing from SFL, Royce (1998) outlined three features that may lead to this *intersemiotic* complementarity being achieved.

Firstly, *ideational* meanings in both the visual and verbal mode have to be related lexicosemantically through *intersemiotic* sense relations. Lexical relates to words and phrases as highlighted earlier in Section 2.8.1 of Chapter Two, while semantics refers to the associated meaning (Fillmore, 2003; Halliday, 1978). Secondly, the interpersonal meaning in both modes should be related, and thirdly, the textual meanings should be integrated. In order to understand how the visual and verbal modes work together in a multimodal text, Royce developed the framework shown in Figure 3.1 to analyse the *intersemiotic* complementarity between the visual message elements (VMEs) and printed text.

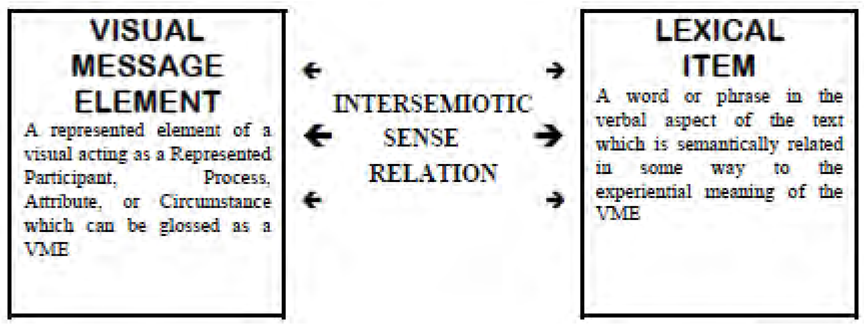


Figure 3.1: A framework for analysing visual and verbal *intersemiotic* complementarity (Royce, 1999)

Royce's framework is believed to be a model for meaning systems, with visual and verbal modes in the left and right column, respectively. In the middle of the two columns are the *intersemiotic* sense relations, which describe the nature of the relationship between the visual and verbal modes. This framework was employed as the foundation of the study being reported on in this thesis, specifically for analysis of intersemiotic sense relations between the textual and visual modes in the Grade 8 Physical Sciences textbooks. From his framework, Royce (1999) explained VMEs as visual features which carry meaning and stated that these meanings are potentially realised by a variety of visual techniques at the disposal of the visual designers.

Royce (1999) analysed the visual and verbal *intersemiotic* complementarity by starting with the VMEs and evaluating the verbal aspect of the text for related lexical items. A series of lexical inventories was then formulated. An explanation of these inventories in terms of their meaning relationship to the VMEs was provided based on the *intersemiotic* sense relations of repetition, synonymy, antonymy, hyponymy, meronymy, and collocation. These sense relations informed the actual coding of data in the current study as described in the research design chapter of this thesis. Each of the sense relations will now be discussed in more detail.

3.2.3.1 Repetition

Repetition is described by Halliday and Matthiessen (2004) as the most direct form of lexical cohesion and was explained earlier in section 2.8.1 of Chapter Two. Repetition of key words in a text helps in achieving cohesion (Danglli & Abajaz, 2014). Ahmed (2013) stated that repetition occurs when a lexical item is simply repeated. A study by Zhong (2013) reported that repetition takes one of two possible forms: lexical repetition and paraphrase. Both types have simple and complex forms. Zhong (2013) explained the distinction between the two categories. Simple lexical repetition relates to lexical items that are exactly repeated while complex lexical repetition refers to words or phrases which are partly repeated, for example, a word expressing singular and plural. Simple paraphrase typically covers synonymy (different words with the same meaning), while complex paraphrase includes antonymy (words with opposite meanings). In the study reported in this thesis, the researcher did not include the simple/complex paraphrase type of repetition as these are already covered separately through the individual sense relations of synonymy and antonymy.

Royce (1999) explained that in multimodal discourse that involves the textual and visual modes, repetition considers the occurrence of a lexical item that expresses the same meaning represented in the visual. Royce (1999) explored repetition in analysing visual and verbal *intersemiotic* complementarity in a multimodal text within a magazine. Although Royce's study focused on a magazine, his findings were useful to the current study. The findings of his study helped the researcher understand how meaning in a multimodal text is made as a result of integrating the verbal and visual modes through the sense relations.

Repetition is useful in communication for various reasons. For example, Zhong (2013) highlighted that it is used for emphasis and clarity in a text. Chung and Nation (2003) mentioned that repetition also provides a clue that a word may need to be remembered. They explained that technical vocabulary typically occurs much more frequently in a specialised text than ones in general usage. Furthermore, Naser and Almoisheer (2018) indicated that writing which contains a high frequency of lexical repetition contributes to achieving the overall cohesion within the text more effectively than writing containing a lower frequency of repetition. It is important to note as Naser and Almoisheer (2018) suggested, that the overall meaning of a text may become clearer when there is greater lexical repetition of key words. In Physical Sciences textbooks, one example of repetition that is useful in facilitating scientific knowledge is the lexical item, opposite in direction, that is used together with a corresponding visual mode, showing two arrows facing opposite directions (Van Niekerk, 2016). The diagram in Figure 3.2 taken from Textbook C illustrates this example.

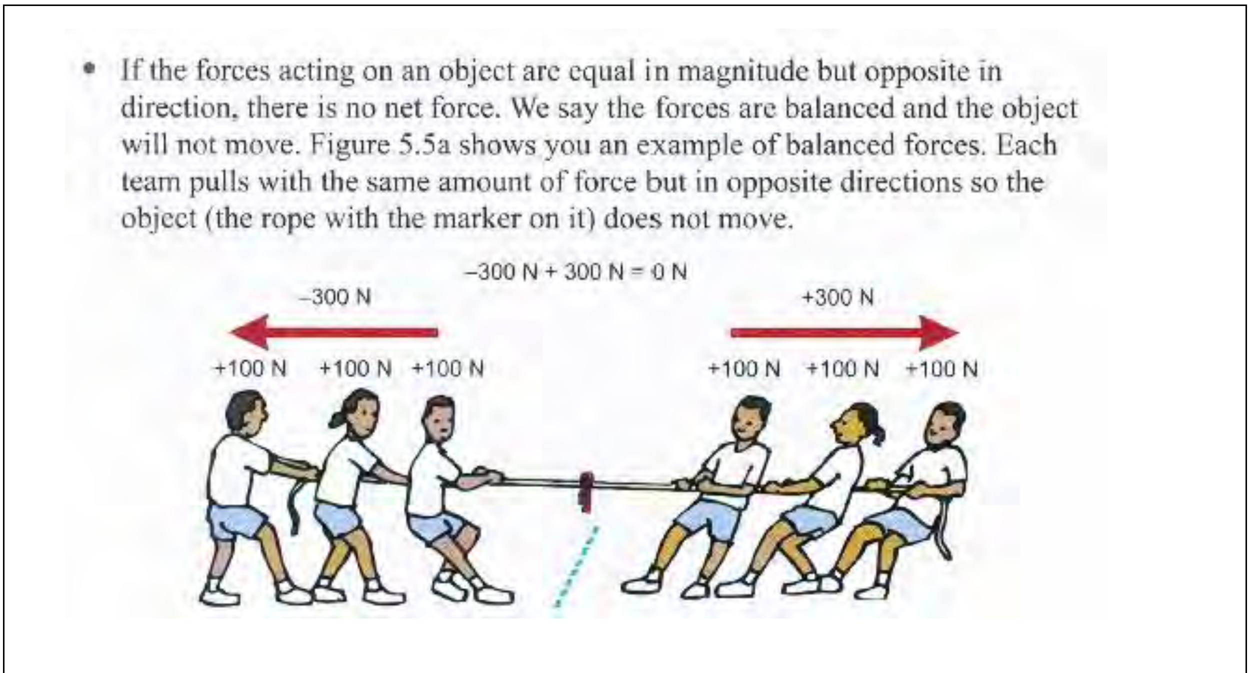


Figure 3.2: A diagram from Textbook C illustrating *intersemiotic* repetition (Van Niekerk, H. [2016]. *Solid Foundations Physical Science Grade 8 Learner's Book*. Windhoek: Namibia Publishing House [Pty] Ltd. pp. 90-109. Reprinted by permission of Namibia Publishing House [Pty] Ltd.)

3.2.3.2 Synonymy

There are various definitions for synonymy in the literature. A synonym is a term having the same or nearly the same meaning as another word. Examples of synonyms are pal and friend, and jump and leap (Norlindh, 2012). Various scholars have a common understanding of synonymy, defining it as the experiential meaning of two lexical items that are similar, and may often be used interchangeably (Ahmed, 2013; Royce, 1999). Bahaziq (2016) defined synonymy as words that have almost the same meanings, such as attractive and beautiful. Another example of words with synonymous relations is the word bank that has synonyms such as banking, and depository financial institution (Norlindh, 2012). Some lexical items can be quite different but can still be semantically related (Rodríguez & Egenhofer, 2003). For example, the words clinic and hospital have only a few alphabetic characters in common, making their word similarity very low; however, their semantic similarity is fairly high since both refer to buildings where patients are provided with medical care.

Synonymy is also related to equivalence (Marco, 1999). Castro (2015) explained that lexical items are considered equivalents if they have the same meaning, for example, damage and destroy. Another example of lexical items that have a synonymous relationship provided by Royce (1999) are scaled and stepped up. When the relation between items is equivalent, it does not mean they are semantically identical but that under certain conditions, they have the same use, function, or value (Marco, 1999). This is one way in which synonymy differs from repetition which is more closely related to equivalence. Therefore, the equivalence between two lexical items lies in their overlapping communicative potential in certain contexts. An example of two statements that contain elements of equivalence is presented next:

A: So, you *want* to *meet* Harry?

B: Yes, and I am *dying* to *see* Bill too.

'Dying to see' is equivalent to 'want to meet', because both have the same discourse value (Marco, 1999). Another example provided by Stock (2010) is that abbreviations (e.g. TV/television), inverted word order (the sweet night air/the night air sweet), and shortened versions (The Met/The Metropolitan Opera) are synonymous as well. Synonymy is also sometimes confused with antonymy. The two sense relations differ in that synonymy represents words whose semantic similarities do not primarily contrast with each other (Arppe, 2008). In addition, Murphy (2003) suggested that synonymy is usually characterised as a symmetric relation. A symmetric relation occurs when the meaning relations of two words is the same for both a direct and an inverse comparison (Stock, 2010). This means that the semantic relation between the lexical items couch and sofa is not distinguishable from the semantic relation between sofa and couch (Murphy, 2003). Thus, we can say couch and sofa are synonyms of each other and can be used interchangeably.

In multimodal discourse, synonymy refers to meanings of the visual and verbal modes that are similar (Royce, 1999). The term *intersemiotic* synonymy was applied in Royce's (1999) study to analyse visual and verbal *intersemiotic* complementarity within *The Economist* magazine. Royce (1999) further argued that meanings of two lexical items need to be the same or almost the same in order to be regarded as synonymous. As Royce and other scholars used synonymy to refer to lexical items with similar meanings, in this study the researcher employed synonymy for the same purpose as in Royce's (1999) study. This means that words or phrases and corresponding visual modes which are not repetitions of each other but have the same or similar meaning, were regarded as synonymous. In Physical Sciences textbooks, synonymy could be considered in facilitating learning. For example, when the textual element "applying a force" is used together with the corresponding visual showing an "arrow" within a hand pointing towards an object (Van Niekerk, 2016, p.100). The diagram in Figure 3.3 from Textbook C illustrates this example.

Figure 3.3: A diagram from Textbook C illustrating *intersemiotic* synonymy (Van Niekerk, H. [2016]. *Solid Foundations Physical Science Grade 8 Learner's Book*. Windhoek: Namibia Publishing House [Pty] Ltd. pp. 90-109. Reprinted by permission of Namibia Publishing House [Pty] Ltd.)

Synonymy plays various roles in a text. Danglli and Abajaz (2014) suggested that lexical synonymy is used by writers to increase the cohesion within a piece of writing. They further claimed that knowledge of synonymy helps readers improve their writing vocabulary. For example, synonymy can be used instead of repeating the same word many times (Danglli & Abajaz, 2014). The act of repeatedly using one word in a text is known as monotony (Tuttle, 2009) and while this has the advantages of repetition pointed out earlier in this chapter, it may not add value when the repetition is not achieving any purpose. Synonymy if not used properly, however, may negatively affect the meaning of a text. Danglli and Abajaz (2014) cautioned that when a word is replaced with a synonym, attention should be paid to the closely related synonyms with the speaker/writer not just randomly choosing any word from a group of synonymous words. It is thus important that synonyms are considered in terms of their appropriateness for the context they intend to be used in.

3.2.3.3 Antonymy

Antonymy is another example of a sense relation. It occurs when the experiential meaning of two lexical items is essentially one of opposition (Ahmed, 2013; Royce, 1999). Two words are believed to be antonymous if they are mutually exclusive (Stock, 2010). For example, the relations between the words love and hate, genius and insanity, and dead and alive are all antonymous. There are two kinds of antonymic pairs as categorised by Murphy (2003). These are: canonical and non-canonical antonyms. Canonical antonyms are common pairs that "automatically follow one another in free word association tasks" (Murphy, 2003, p. 10). Some examples of antonymy seem to have special status, in that their relationships are well known in culture, and are seemingly stable. Antonymy pairs such as hot and cold, big and little, good and bad, and happy and sad are considered canonical.

Non-canonical antonymy as defined by Murphy (2003) refers to pairs that are not common and are therefore context dependent. Examples include, distant and near, big and little and warm and cool. While canonical pairs are considered as the direct antonyms, non-canonical pairs are linked to indirect antonyms (Pastena & Lenci, 2016). In Royce's (1999) study on *intersemiotic* complementarity of visual and verbal modes, *intersemiotic* antonymy was explored in expressing opposite meanings achieved through the integration of visual and verbal modes. Royce (1999) stated the example of a line graph in the *Mountains* text representing increasing losses, that was used together with the word, profit. This visual mode (line graph representing increasing losses) was intersemiotically related through antonymy to the lexical item profit.

In Physical Sciences textbooks, the use of antonymy could be beneficial to the acquisition of scientific knowledge. Some concepts in these textbooks require the use of words with opposite meanings. For example, the subtopic 'The nature and effects of forces' in Grade 8 Physical Sciences textbooks, could involve the use of words with opposite meanings such as downward force and upward force, or attract and repel (Haimbangu et al., 2016; Jones et al., 2016a) to indicate the direction of forces and electrostatic forces, respectively. Other examples of antonymy in Physical Sciences textbooks might be observed when dealing with pressure and surface area. Although the two words are not antonyms, their relationship is one of inverse proportionality. An increase in the surface area causes a decrease in pressure (Haimbangu, Poulton, & Rehder, 2017). Apart from being useful in acquiring scientific knowledge, the use of antonymy in Physical Sciences textbooks could also possibly be the causes of misconceptions. Kacovsky (2015) gave an example of the misconception between the words heat and cold, which many students may refer to as antonyms. According to Murphy (2003), heat is not the antonym of cold, but the best word to be the antonym of cold is hot. Furthermore, Nakakuwa (2018, p. 82) highlighted that "generally, there are few opposite words or meanings in science that can contribute to the construction of knowledge compared to other disciplines, such as the languages which covers a wide range of binary contrast pairs which express the opposite of each other". In other disciplines, such as the languages, antonymy covers a wide range of binary contrast pairs which express the opposite of each other (Kostić, 2017).

3.2.3.4 Hyponymy

Hyponymy involves a classification of the cohesive relations between a general class and its sub-classes, or between a sub-class and its general class (Ahmed, 2013). It is also indicated that hyponymy is the most common-sense relation used in ontology and involves the hyponymic relation *type of* (Gil-Berrozpe & Faber, 2016; Rodríguez & Egenhofer, 2003). Murphy (2003) mentioned that hyponymy relations are hierarchical and non-symmetrical. "Hierarchical relations are used to distinguish between hyponymic relations (set of generic-specific relations) and meronymic relations (set of part-whole relations)" (Gil-Berrozpe & Faber, 2016, p. 9). Rodríguez and Egenhofer (2003) stated that hierarchical relations involve the subordinate terms which inherit all the characteristics from their superordinate terms. For example, a cat which is a subordinate of a mammal, has the characteristics (such as mammary glands) that defines it as a type of a mammal, the superordinate. The relationship signs: 'less than' (<) and 'greater than' (>) are considered in hyponymy examples, to indicate whether it is a subordinate-superordinate relation or superordinate-subordinate relation (Murphy, 2003). For example, the relation of hyponymy between cat and mammal can be represented as follows: cat<mammal (cat is a hyponym of mammal) or mammal>cat (mammal is the hypernym of cat).

A non-symmetric relation on the other hand occurs when the semantic relations of two words are not the same for both a direct and an inverse comparison (Stock, 2010). This means that the relationship between the lexical pairs is distinguishable. For example, cat is a hyponym of mammal, and mammal is the hypernym of cat. In this example of hyponymy, cat and mammal can be distinguished in that a cat is an example/type of a mammal, but a mammal is not an example/type of cat (Murphy, 2003). In addition, Rodríguez and Egenhofer (2003) argued that although the general organisation of words is determined by their semantic interrelations, this information alone may not be enough to distinguish one class from another. For example, while hospital building and apartment building have the common superordinate class, building, this information falls short when trying to differentiate a hospital from an apartment building. This is because the hyponymy does not indicate the important difference in terms of the functions of the words (i.e. a hospital is a building where medical care is given, and an apartment is a type of building that is used for residential purposes). As indicated by Rodríguez and Egenhofer (2003), functions are aimed at providing details of what is done to or with a lexical item. They provide the example of the function of a college, as being to educate.

In analysing visual-verbal *intersemiotic* complementarity, Royce (1999) explored *intersemiotic* hyponymy to classify the cohesive relations between a general class in visual message and its sub-classes in verbal mode, and vice versa. Royce (1999) gave an example of a visual element displaying a large round object, labelled *Lloyd's problems* and interpreted as a visual metaphor for Lloyd's current problems. He indicated that the visual element of *Lloyd's problems*, is intersemiotically related through hyponymy to the verbal elements such as, losses and negligence. The words losses and negligence serve as types of problems.

One example of hyponymy in Physical Sciences textbooks that could be used to enhance learning is when the lexical items, e.g. renewable sources of energy and a visual mode showing a geothermal power station are used (Haimbangu et al., 2016). The general class in this example are the lexical items renewable sources of energy, and the sub-class is a visual mode showing a geothermal power station. The diagram in Figure 3.4 from Textbook B illustrates this example.

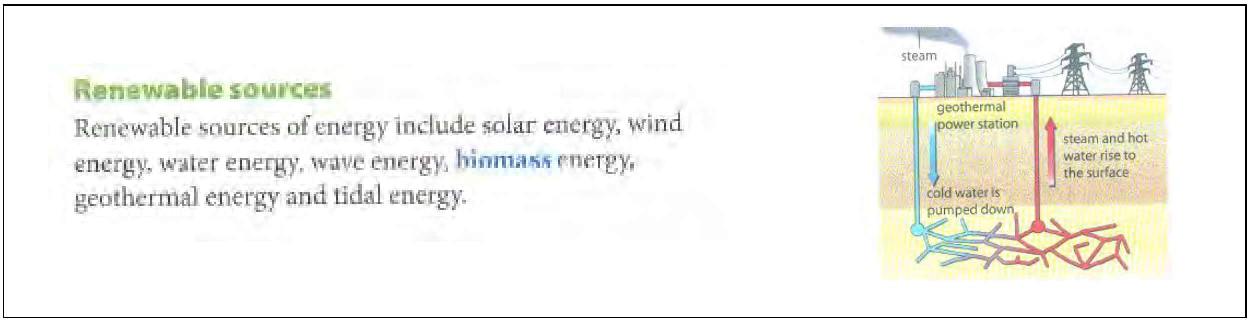


Figure 3.4: A diagram from Textbook B illustrating hyponymy (*Platinum Physical Science Grade 8 Learner's Book*, M Haimbangu, A Poulton & B Rehder [1st ed.] 2016. Reprinted by permission of Pearson Education Namibia [Pty] Ltd.)

Hyponymy plays a crucial role in the acquisition of scientific knowledge. This sense relation is linked to classification learning which according to Nosofsky, Sanders, and McDaniel (2018) is a fundamental component of science education. Furthermore, Nosofsky et al. (2018) indicated that classification learning helps readers of scientific texts developing category-learning. In Physical Sciences textbooks, learning hyponyms could be enhanced by studying the different forms of energy such as gravitational energy, potential energy, kinetic energy, and heat energy (Haimbangu et al., 2016). Another benefit of hyponymy highlighted by Peng (2016) is that it contributes to the ability of learners to memorise terminology efficiently, both in short-term and long-term memory.

3.2.3.5 Meronymy

The relation of meronymy is established when a lexical item, referring to a complete whole known as a holonym, is accompanied by the constituent parts of the whole (meronym) (Ahmed, 2013; Kuzmenka, 2015; Royce, 1999). When two or more lexical items are constituent parts of some whole object, this relation is referred to as co-meronymy. As with hyponymy relations, meronymy involves superordinate class versus subordinate class and vice versa (Murphy, 2003). Murphy (2003) considered the relationship signs: 'greater than' (>) and 'less than' (<) in meronymy examples to indicate whether they are instances of superordinate-subordinate or subordinate-superordinate relations. For example, stanza is a part of poem, and poem is the whole made of stanzas. These relations of meronymy can be represented as follows: stanza<poem (stanza is a meronym of poem) or poem>stanza (poem is the holonym of stanza).

Similar to hyponymy, the relationship between lexical pairs for meronymy is hierarchical and non-symmetrical, indicating a distinguishable relationship between the lexical pairs (Murphy, 2003).

Meronymy is also explored in studies that aim at analysing the interaction between the visual and verbal modes. Royce (1999) considered *intersemiotic* meronymy as another sense relation that contributes to *intersemiotic* ideational complementarity of the visual and verbal modes in multimodal texts. Royce (2002) presented a schematic diagram showing an energy-efficient house, labelled as the meronym 'energy-efficient house'. The superordinate class, energy-efficient house, relates through *intersemiotic* meronymy to the lexical subordinate class: solar panels.

No literature could be found which directly mentioned the importance or benefits of meronymy to learning science or other discourses. However, considering it in scientific texts could be useful since science involves looking at objects or systems in relation to their constituent parts. The human body, global cycles such as the water cycle, electrical circuits, and chemical equations are some of the more obvious examples of this. In Physical Sciences textbooks, meronymy could be used to facilitate learning when a diagram of a nuclear power station illustrating the constituent parts is presented. The parts of a nuclear power station as shown in the diagram in Figure 3.5 are: control rods, steam generator, reactor vessel, turbine and condenser.

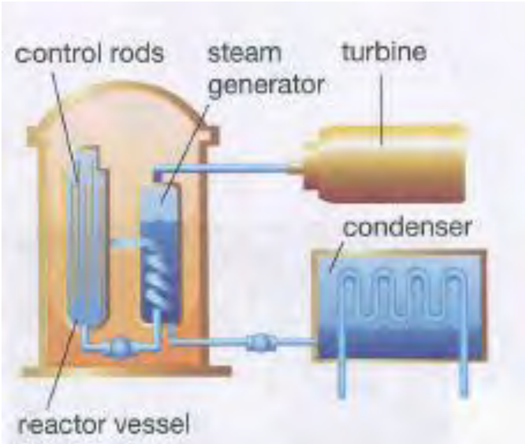


Figure 3.5: A diagram from Textbook A illustrating meronymy (Reproduced by permission of Oxford University Press Southern Africa [Pty] Ltd. From *Physical Science Grade 8 Learner's Book* by R C Jones, M A Roebert, C L Larceda_© Oxford University Press Southern Africa 2016)

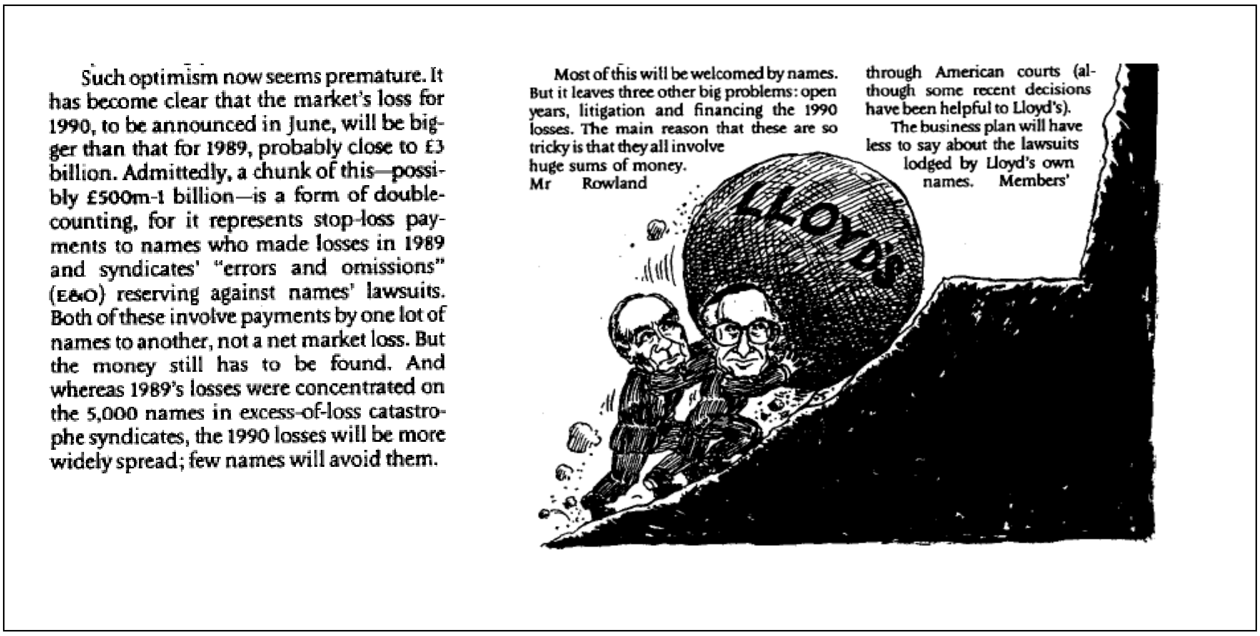
3.2.3.6 Collocation

The word collocation was first used as a technical term in the late 1950s (Xiao & McEnery, 2006). This term is now used widely in different ways, and often with different meanings (Biskri, 2012). A definition by Firth (1968, p. 181) averred that "collocations of a word refer to statements of the habitual or customary associations of that word". Greenbaum (1974, p. 82) defined collocation "as the frequent co-occurrence of two lexical items in language". Halliday and Hasan (1985) stated that collocation is an aspect of lexical cohesion which embraces the relationship between lexical items that regularly co-occur (as discussed in Chapter One). Therefore, it is evident that collocation has to do with certain words tending to occur together (Jones, 2012).

According to Xiao and McEnery (2006), Greenbaum's definition of collocation does not inform how frequent the co-occurrence of two lexical items should be for their relation to be considered collocation. "Researchers adopting the frequency-based approach to collocations have differing views as to what numeric value or range constitutes collocations" (Menon & Mukundan, 2012, p. 151). Moon (1998) considered co-occurrence of all frequencies as collocations, while Stubbs (1995) only accepted frequent co-occurrences. For many linguists, collocations are related to a range of commonly "recognised multi-word phrases in language including catchphrases, clichés, fixed expressions, formulae, free and bound collocations, idioms, lexical phrases, turns-of phrase, and so on" (Gledhill, 2000, p. 11).

Recent studies indicated that collocation is a result of the co-occurrence of lexical items, which are in some way typically associated with each other in similar fields or subject areas (Danglli & Abazaj, 2014; Zhong, 2013). The lexical relations for collocation do not necessarily enter into the semantic relations of repetition, synonymy, antonymy, hyponymy, or meronymy. The tendency of certain words to co-occur, as Hadi and Jabir (2011) highlighted, has to do with their propositional meanings; for example, cheque is likely to co-occur with bank, pay, money, and write. While associated, the relation is not covered by the other sense relations. There are two types of collocations: lexical and grammatical (Akpinar & Bardakçi, 2015; Menon & Mukundan, 2012). Collocations in which two lexical elements co-occur are lexical collocations, such as any combination of associated nouns, verbs, adjectives, and adverbs (Menon & Mukundan, 2012). However, collocations in which a lexical and a grammatical element such as a preposition, infinitive, or a clause, co-occur, are grammatical collocations (Akpinar & Bardakçi, 2015); for example, grammatical collocations can take the form: noun + preposition (e.g. admiration for) while lexical collocations take the form verb + noun (e.g. compose music).

An exploration of collocation relations is also considered in studies involving multimodal discourse. Royce (1999) considered collocation relations in analysing the visual and verbal elements in a multimodal text. In the current study, collocation was considered in analysing how the textual and visual modes in the topic of Forces related in terms of *intersemiotic* complementarity. The picture in Figure 3.6 appeared in Royce's study and was used to explain the *intersemiotic* collocation of the visual and verbal elements in a multimodal text of *The Economist* magazine. Royce (1999) saw *intersemiotic* collocation as significant in that any reference to a financial institution such as Lloyd's, invariably brings to mind related associated words such as bankruptcy, losses, and money. Royce further claimed in his study that the visual features are semantically related to verbal aspects of the article via collocation. He gave an example that the verbal element *chunk* forms an *intersemiotic* collocation with the visually represented *boulder*. The picture in Figure 3.6 illustrates this relation.



Such optimism now seems premature. It has become clear that the market's loss for 1990, to be announced in June, will be bigger than that for 1989, probably close to £3 billion. Admittedly, a chunk of this—possibly £500m-1 billion—is a form of double-counting, for it represents stop-loss payments to names who made losses in 1989 and syndicates' "errors and omissions" (E&O) reserving against names' lawsuits. Both of these involve payments by one lot of names to another, not a net market loss. But the money still has to be found. And whereas 1989's losses were concentrated on the 5,000 names in excess-of-loss catastrophe syndicates, the 1990 losses will be more widely spread; few names will avoid them.

Most of this will be welcomed by names. But it leaves three other big problems: open years, litigation and financing the 1990 losses. The main reason that these are so tricky is that they all involve huge sums of money. Mr Rowland

through American courts (although some recent decisions have been helpful to Lloyd's). The business plan will have less to say about the lawsuits lodged by Lloyd's own names. Members'

Figure 3.6: An example of a magazine picture illustrating collocation (Royce, 1998)

There are various benefits associated with learning collocations in the textual mode. Kalogeropoulou (2017) claimed that the frequent co-occurrences of specific lexical items contribute to essential meaning relations which allow readers to make predictions when words are missing. For example, when the word *bite* is used, the reader can possibly associate it with the word *teeth*. Other examples of collocate words are *lick* and *tongue*, *bark* and *dog*. This type of relation between words contributes to coherence of the textual mode (Hadi & Jabir, 2011). Other scholars such as Menon and Mukundan (2012) argued that collocation allows us to think and communicate more quickly and efficiently. Collocation is also believed to help learners in recognising word patterns which is useful for language acquisition (Menon & Mukundan, 2012). Furthermore, Biskri (2012) indicated that when readers of texts engage with collocations, it helps them learn meanings of phrases. Myers (1991) claimed that learning the language of science entails learning collocations and idioms, as well as which word or phrase counts as a technical term.

3.3 Chapter Summary

In this chapter, the researcher discussed the theoretical framework used to inform this study. SFL views language as a social semiotic tool and recognises the role all semiotic modes (including the visual mode) play in the process of making meaning (Halliday, 1978; Kress & Van Leeuwen, 2002; Van Leeuwen, 1996). The three metafunctions of language: ideational, interpersonal, and textual were also discussed. SF-MDA, which is an extended approach to SFL, was also explained. As highlighted by O'Halloran (2008), SF-MDA aims at applying practical methods to analysing and understanding meanings in written, printed and electronic text, and other kinds of multimodal texts. In addition, Royce's (1999) idea of *intersemiotic* complementarity resulting from the integration of the visual and verbal modes in multimodal text was discussed. Royce (1998, p. 103) claimed that *intersemiotic* ideational meaning is achieved when the visual and verbal modes are "lexico-semantically related through *intersemiotic* sense relations of repetition, synonymy, antonymy, hyponymy, meronymy, and collocation". These sense relations featured in the research design are presented and discussed in Chapter Four.

CHAPTER FOUR: RESEARCH DESIGN

4.1 Introduction

This section is an introduction to Chapter Four. In designing a study on the production of knowledge, researchers often start by identifying a research question before developing the research design. Research design involves planning how the researcher will systematically collect and analyse data that is needed to answer the research questions (Bertram & Christiansen, 2015). This strategy, as Nieuwenhuis (2007, p. 70) indicated, is formulated from the "underlying philosophical assumptions to specifying the selection of participants or respondents, and subsequent data collection and analysis techniques to be undertaken". These and other components of research design are detailed in various sections of this chapter. Section 4.2 presents the research paradigm. The research method of this study which was qualitative case study is discussed in section 4.3. Sections 4.4 and 4.5 provide a discussion of the research site, object of analysis and sampling, and the reduction of data.

Section 4.6 focuses on document analysis as the qualitative method used and the approaches to data analysis are discussed in Section 4.7. Sections 4.8 and 4.9 present a discussion of how data was coded, and a description of analytical tools employed in the study. Section 4.10 includes a discussion of how the analytical tools for this study were piloted. In section 4.11, the researcher presents further details on the data analysis procedure. The researcher then ends the chapter by discussing the trustworthiness and ethical considerations relevant to the study in Sections 4.12 and 4.13, respectively.

The goal of this study was to understand how the textual and visual modes were related in terms of *intersemiotic* complementarity for the topic of Forces in three Namibian Grade 8 Physical Sciences textbooks. In order to achieve this goal, the study explored the following research questions:

1. What is the nature of the *intrasemiotic* sense relations for the topic of Forces in Physical Sciences textbooks?

    - Within the textual mode
    - Within the visual mode

2. How are the textual and visual modes for the topic of Forces related in terms of *intersemiotic* complementarity?

4.2 Research Paradigm

Researchers have different beliefs about ways of conducting research. "These beliefs are guided by some standard principles, which are referred to as paradigms" (Agunbiade, 2015, p. 41). The term paradigm is complex and is explained in different ways depending on the context. Hancock (2007) asserted that "a paradigm, as defined by theorists and philosophers of science, refers to a set of basic beliefs or a worldview that precedes any questions of empirical investigation" (p. 64). Nieuwenhuis (2007, p. 47) provided a more detailed definition that involve paradigms being "sets of assumptions or beliefs about fundamental aspects of reality that give rise to a particular worldview". He further explained that a paradigm addresses fundamental assumptions taken on faith, such as beliefs in the nature of reality (ontology), the relationship between knower and known (epistemology), and assumptions about methodologies (Nieuwenhuis, 2007, p. 47). Feilzer (2010) added that a paradigm is prescriptive and relates to particular research methods while excluding others.

Three key paradigms stipulated by Bertram and Christiansen (2015) are postpositivism, interpretivism, and the critical paradigm. The interpretive paradigm is most compatible with qualitative case study (Feilzer, 2010). "Interpretivism usually seeks to understand a particular context, with a core belief that reality is socially constructed" (Thanh & Thanh, 2015, p. 25). In addition, the interpretive paradigm aims at a deep analysis and understanding of how meaning of particular actions is undertaken in the social world (Bertram & Christiansen, 2015). Interpretivists believe that there is no existence of a single objective reality; this is because the social world is not understood via physical-law-like rules (Carcary, 2009). Therefore, multiple realities, internal and external, are considered. Internal reality is subjective and unique to an individual, while external reality occurs in the physical world (Carcary, 2009). The interpretive paradigm was employed in the current study which aimed at understanding how the textual and visual modes were related in terms of *intersemiotic* complementarity for the topic of Forces in three Namibian Grade 8 Physical Sciences textbooks.

4.3 Research Method

This research involved a qualitative approach. Qualitative research is concerned with understanding the process and the social and cultural contexts that underlie various behavioural patterns (Creswell, 1994; Nieuwenhuis, 2007). Furthermore, this approach is mostly concerned with exploring the *why* questions of research. Qualitative research focuses on understanding a central phenomenon, the process explored, or the perspectives and world views of people or objects involved (Creswell, 2008; Merriam, 1998). Scholars have also highlighted that qualitative research typically studies people or systems by interacting with and observing the participants or objects in their natural environments and focusing on their meanings and interpretations (Holloway & Wheeler, 1996). In addition, it has been noted that qualitative approaches often generate rich data "necessary for interpretivists to fully understand contexts" (Thanh & Thanh, 2015, p. 25).

Since the current study focused on understanding a particular case, it is considered a case study. Bertram and Christiansen (2015) defined a case study as a systematic and in-depth study of one particular case in its context. They further highlighted that a case study is used to help the researcher gain a more comprehensive understanding of a phenomenon. From the perspective of interpretivism, a case study aims at understanding how information relates and interacts in a specific situation for possible meaning-making (Nieuwenhuis, 2007). A case study is used extensively in qualitative research to answer how and why questions. In this study, the case is the government-endorsed Namibian Grade 8 Physical Sciences textbooks.

4.4 Research Site, Objects of Analysis, and Sampling

The study was carried out in Namibia. The objects of analysis were Namibian Grade 8 Physical Sciences textbooks. The sample for the study were three Grade 8 Physical Sciences textbooks endorsed by the Namibian government at the time of this study being conducted. Endorsing school textbooks involves them undergoing government approval based on defined criteria, as discussed in Chapter One, before being used in public schools. Purposive sampling, according to Bertram and Christiansen (2015, p. 60), is used by researchers to "make specific choices about which people, groups or objects to include in the sample". The three Physical Sciences learners' textbooks for Grade 8 were selected purposively because of the defining characteristic of being endorsed by the government following a formal evaluation process conducted by NIED's subject evaluation panel. The sampling was also purposive in terms of the focus on

Grade 8, because the implementation of Namibia's revised curriculum for Grade 8 started in 2017 when this study began (Namibia. MoEAC, 2015a). In addition, the study focused only on the topic of Forces. The purposive selection of this topic (and thus sections of the textbooks) resulted from its significance in Physical Sciences, coupled with the poor performance of learners in it (Namibia. MoE, 2014a-2015) as outlined in Chapter One.

4.5 Data Reduction

Data reduction "is the process of selecting, focusing, simplifying, abstracting, and transforming the data" to make sense of it (Bertram & Christiansen, 2015, p. 116). When the coding of data was done in this study, a lot of information came out, but only the features of relevance to answering the research questions were analysed. Other information was left out because they were not relevant to the focus of the study and not necessarily for answering the research questions. Firstly, only the textual and visual modes related to the main text were analysed and the textual and visual content in assessment components were excluded from analysis. This included data within activities, practical investigations and experiments, topic tasks, and self-assessment boxes. One of the reasons supporting the choice of focusing only on the main text was because they are aimed at developing scientific knowledge as opposed to testing mastery of this knowledge (Koulaidis & Dimopoulos, 2006).

Furthermore, it was likely that much of the *intrasemiotic* and *intersemiotic* sense relations of the textual and visual modes would occur in the main text, which focuses more on content rather than assessment. It is intended that the Namibian curricula, including that of science, should have learning as its focus rather than assessment (Namibia. MoEAC, 2015a). It was further noted that textbook assessment activities are normally included as a supplement to the main text for the purpose of supporting or enhancing learning, rather than being the core aspect. In addition, analysis of *intrasemiotic* sense relations within the textual mode for the topic of Forces only focused on the technical terms highlighted, and common to all three or any two of the three Physical Sciences textbooks.

4.6 Document Analysis

The selected Physical Sciences textbooks that constituted the data in this study were explored in-depth via document analysis. This method of analysing data is defined as "a systematic procedure for reviewing or evaluating documents – both printed and electronic material".

(Bowen, 2009, p. 27). In the document analysis method, existing documents themselves are the source of data and is different from other methods of collecting data such as interviews, which requires data to be elicited (Pennington, 2017). The use of existing documents such as textbooks as sources of data means that there is no creation of new data, since it already existed in such documents prior to the research in which they are being used as data sources (Bertram & Christiansen, 2015).

In this study, the researcher used document analysis as a stand-alone method of analysis. Bowen (2009, p. 29) explained that "whereas document analysis has served mostly as a complement to other research methods, it has also been used as a stand - alone method". It is further highlighted that "some specialised forms of qualitative research rely solely on the analysis of documents" (Bowen, 2009, p. 29). Numerous qualitative studies that have employed document analysis as a single method of analysis have been carried out around the globe. A recent example is a qualitative case study carried out with the purpose of gaining an understanding of the challenges and opportunities that faced the state systems of community colleges in USA (Salinas & Friedel, 2016). In that case study, document analysis was used to identify the most frequently listed themes provided by the state system directors of community colleges.

Another qualitative case study in which document analysis was utilised aimed at exploring how "bookstore contracts within the state university system of Florida define affordability" and what measures are being taken to enforce it (Raible & deNoyelles, 2015, p. 7). The study investigated issues such as textbook affordability and digital resources and the researchers analysed the bookstore contracts by engaging in thematic analysis (Raible & deNoyelles, 2015). Bowen (2009) explained thematic analysis as a form of recognising patterns within the data.

4.7 Approach to Data Analysis

Data analysis is a process of reducing data, and involves organising, sifting, sorting, and reviewing a large amount of data in order to make sense of it (Bertram & Christiansen, 2015; Cohen, Manion, & Morrison, 2011; Kawulich, 2004). "Qualitative data analysis is usually based on an interpretative philosophy that is aimed at examining meaningful and symbolic content of qualitative data" (Nieuwenhuis, 2007, p. 99). It has been further noted that qualitative analysis is an interactive process in which data processing, analysis, and reporting are considered as closely linked. Researchers thus often find it necessary to go back to the original field notes or to the objects of analysis to re-analyse data and verify the analysis (Nieuwenhuis, 2007). In this study, data within the topic of Forces in the three approved Grade 8 Physical Sciences textbooks were analysed and re-analysed both deductively and inductively. The two data analysis approaches will now be detailed.

4.7.1 Deductive approach

The deductive approach to data analysis involves an advance formulation of categories of information required from the data (Bertram & Christiansen, 2015). This approach is used by researchers to test the implications of existing theories or explanatory models about the topic under study against the analysed data (Graneheim, Lindgren, & Lundman, 2017). The researcher moves from "a more abstract and general level, to a more concrete and specific one" (Graneheim et al., 2017, p. 30). The researcher has taken a deductive approach in developing codes for the textual and visual modes and was guided by the literature on design features of scientific language and the visual mode in science discourse.

As discussed already in Chapter Two, the literature revealed three categories of the visual mode in visual social semiotics: *icons*, *indexes*, and *symbols*. In addition, Fang (2004) mentioned that one of the features of scientific language is technicality. It is on the basis of these categories of the visual mode and feature of scientific language that the researcher developed the codes as detailed in Section 4.8. The codes for the textual mode were developed from the categories: *symbols* and *indexes*, and the scientific language feature, technicality. For the visual mode, the codes were developed from the categories, *icons* and *indexes*. Nieuwenhuis (2007) cautioned that a deductive approach can create blind and blank spots, impacting negatively on the trustworthiness of a study by allowing certain preconceptions and biases to cloud the data analysis. It thus makes sense that a combined inductive-deductive approach would reduce these problems.

4.7.2 Inductive approach

An inductive approach to data analysis is primarily a form of pattern recognition in data where themes or concepts are derived from the readings and interpretation of raw data without the restraints imposed by theory (Cohen et al., 2011). In this data analysis approach, researchers focus on similarities and differences within data which are described in categories on various levels of abstraction and interpretation (Graneheim et al., 2017). Unlike the deductive approach, inductive coding of data entails a "move from the concrete and specific to the abstract and general" (Graneheim et al., 2017, p. 30). In the current study, an inductive approach was applied using the researcher's own understanding in re-developing the categories of the textual and visual modes, and scientific language features suggested by literature. In developing the codes for the textual and visual modes, the researcher searched for patterns in the data and associated the literature with the details obtained from the thick description of data in the three Physical Sciences textbooks. This resulted in more specific codes (themes) for the textual and visual modes developed which helped in analysing the data in order to answer the research questions of the study.

4.8 The Coding of Data

Coding is defined by Nieuwenhuis (2007, p. 105) "as marking the segments of data with *symbols*, descriptive words, or unique identifying names". The term code refers to "names or symbols" used in place of a group of similar words or ideas that the researcher has noticed in their data set (Mackey & Gass, 2012, p. 222). While coding in quantitative research is more numerical, qualitative researchers use coding by analysing raw data to recognise patterns and organising them into themes that assist in interpreting the data (Kawulich, 2004; Mackey & Gass, 2012).

There are different approaches to the coding process and Kawulich (2004) suggested three: theory driven coding, research driven coding, and data driven coding. The theory driven coding involves the elements of the codes derived from the theory, while research driven coding deals with elements obtained from previous studies conducted (Kawulich, 2004). The two approaches to coding are related to the deductive coding method. Alternatively, it was explained that data driven coding involves inductive formulation of codes based on the data analysed in the study undertaken.

In the current study, both approaches to coding were useful and worked together towards exploring the *intrasemiotic* sense relations within modes and how these are related in terms of *intersemiotic* complementarity for the topic of Forces in Namibian Physical Sciences textbooks. The research driven coding approach informed the coding of data by considering the categories of visual mode (*icons*, *indexes*, and *symbols*) used in science discourse (Harrison, 2003; Jamani, 2011) and the features of scientific language already discussed in Chapter Two.

The researcher used the data driven coding approach in the coding of data by focusing on the design features of the textual and visual modes.

The theory driven coding approach was used in the coding of data by relating the categories and design features of the visual and textual modes to the sense relations derived from Halliday and Hasan's (1985) approach to examining cohesion within written texts. This led to the formulation of themes (discussed in more detail later in this section), which were used for analysis of *intrasemiotic* sense relations within the textual and visual modes. The analysis of how the textual and visual modes for the topic of Forces were related in terms of *intersemiotic* complementarity did not involve the themes formulated for this study. It was carried out using a similar analytical tool to the one used in analysing visual and verbal *intersemiotic* complementarity in *The Economist* magazine (Royce, 1999). The analytical tool that was used in this study is discussed in Section 4.9 of this chapter.

The information that related to words, concepts, and other textual elements were coded as words (W). Information relating to letters, mathematical operations, and numerical values were coded as symbolic letters (SYM-L), mathematical symbols (M-SYM), and numerical values (NV) respectively. In addition, the information relating to the use of arrows was coded as arrows (AR). The diagram in Figure 4.1 contains examples of information that was coded as symbolic letters, mathematical symbols, numerical values, and arrows.

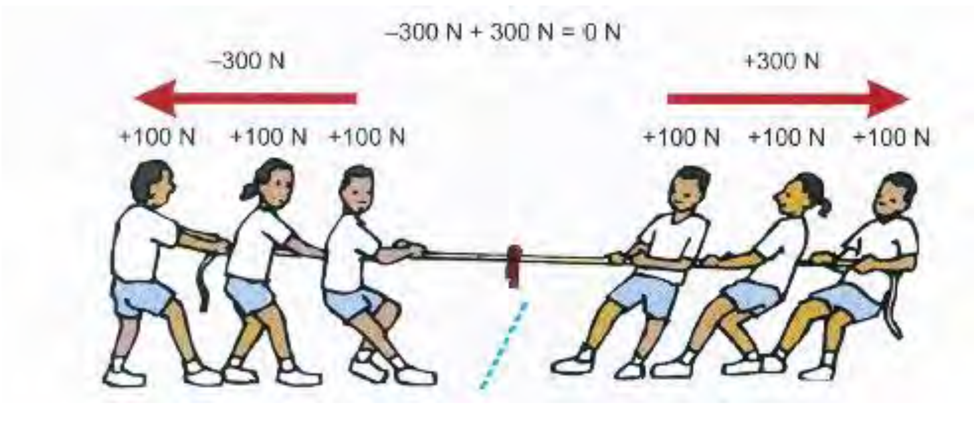


Figure 4.1: An example of a diagram from Textbook C illustrating letters, operations, numerals, and arrows (Van Niekerk, H. [2016]. *Solid Foundations Physical Science Grade 8 Learner's Book*. Windhoek: Namibia Publishing House [Pty] Ltd. pp. 90-109. Reprinted by permission of Namibia Publishing House [Pty] Ltd.)

The words referred to as keywords in the Physical Sciences textbooks and that appear in bold font, highlighted in colour, or written in italics were coded as technical words (TC-W) (Haimbangu et al., 2016; van Niekerk, 2016). An extract from Textbook C in Figure 4.2 contains examples of words which are referred to as keywords in the three Physical Sciences textbooks.

Kinds of force

In the example in Figure 5.1, different kinds of force were involved in causing the effects shown in the figure.

- The apple started moving when Amanda kicked it out of the way. It changed direction when it came into contact with Theo's foot. The apple stopped moving when it hit the rock. These are all effects of **contact forces**. A contact force is a force that is applied when one object touches another.
- Apples had fallen to the ground because of the force of **gravity**. Gravity pulled the apple downwards (Figure 5.2a). Gravity is a force that acts at a distance. There was no contact between the object on which the force was applied (the apple) and the source of the force (the Earth). Gravity is, therefore, a **non-contact force**. You will learn more about gravity later in this topic.

Other examples of non-contact forces include magnetic force and electrostatic force.

- Magnetic force is the **attraction** or **repulsion** between the poles of two magnets (see Figure 5.2b).
- Electrostatic force results when an object with an electrostatic charge attracts or repels other objects with a charge.

Key words

contact force: a force that is applied when one object touches another

gravity: a non-contact force that attracts objects to the centre of a body with a large mass, such as a planet

non-contact force: a force exerted on one object by another, without contact between the objects

attraction: a force that pulls two objects together

repulsion: a force that pushes two objects apart

Figure 4.2: An extract from a Textbook C showing keywords (Van Niekerk, H. [2016]. ***Solid Foundations Physical Science Grade 8 Learner's Book*****. Windhoek: Namibia Publishing House [Pty] Ltd. pp. 90-109. Reprinted by permission of Namibia Publishing House [Pty] Ltd.)**

Also, coding of data was undertaken on the diagrams and photographs appearing in the topic of Forces. The diagrams and photographs were coded as visuals (V). Some diagrams and photographs in the topic of Forces for the three Physical Sciences textbooks were paired. The paired diagrams and photographs were coded as paired visuals (PR-V). The positioning of visual modes next to each other on the page in a textbook, signals that they are related in terms of conveying meaning. This is supported by Boucheix, Lowe, Ainsworth, Bétrancourt, and de Vries (2012) who stated that the visual modes in school science textbooks which are related should be used together rather than independently. The visual mode in Figure 4.3 illustrates examples of diagrams that appear paired in a Physical Sciences textbook.

Figure 4.3: Example of paired diagrams from Textbook B (*Platinum Physical Science Grade 8 Learner's Book*, M Haimbangu, A Poulton & B Rehder [1st ed.] 2016. Reprinted by permission of Pearson Education Namibia [Pty] Ltd.)

Other diagrams and photographs in the topic of Forces for the three Physical Sciences textbooks appear as singular. These diagrams and photographs were coded as singular visuals (S-V). Having a visual mode presented as singular on the page of a textbook enables the reader to focus their attention only on the meaning relationships between the textual mode and that visual mode, unlike when there are two or more visual modes on the page. Having many photographs or diagrams on a textbook page is sometimes regarded as a problem as readers are faced with the challenge of further making sense of the meaning relations between those visual modes (Darian, 2001). The visual mode in Figure 4.4 obtained from one of the three Physical Sciences textbooks illustrates an example of a photograph that appears as singular.

Figure 4.4: An example of a photograph from Textbook B that appeared as singular (*Platinum Physical Science Grade 8 Learner's Book*, M Haimbangu, A Poulton & B Rehder [1st ed.] 2016. Reprinted by permission of Pearson Education Namibia [Pty] Ltd.)

Following the coding of data in the topic of Forces for the three Physical Sciences textbooks, the researcher formulated these sense relation themes: technical words, symbolic letters, numerical values, mathematical symbols, arrows, and paired and singular visuals (see Appendix B). Technical words dealt with technical terms that appeared highlighted in bold font or colour, or written in italics, as well as those not highlighted. Symbolic letters related to information about abbreviations of technical terms such as N for newton, Kg for kilograms, CO_2 for carbon dioxide, F for force. Numerical values dealt with information about numbers, e.g. 50kg, 500N, 10N/kg. Mathematical symbols covered information about mathematical operations. Arrows related to information about the use of arrows within the textual and visual modes. The paired and singular visuals dealt with diagrams and photographs that appear paired and as singular respectively in the three Physical Sciences textbooks.

4.9 Analytical Tools

Analytical tools allow qualitative researchers to analyse the sources of data in research, such as documents (Leech & Onwuegbuzie, 2011). When developing analytical tools for a qualitative study, Leech and Onwuegbuzie (2011) suggested that it is important to consider their design. Jones and Diment (2010) explained that it should be made clear why and how the analytical tools will be employed in research, so that they are able to generate data which can respond to the research questions. The analytical tools used to analyse data in this study were developed after the coding of data was undertaken. The researcher developed three analytical tools for this study. Each analytical tool responded to one of the three research questions.

The first and second analytical tools were used for analysis of *intrasemiotic* sense relations within the textual and visual modes (see Appendices C). Each of the two analytical tools included themes specifically developed to analyse the *intrasemiotic* sense relations within individual modes. The third analytical tool was used in analysing *intersemiotic* sense relations between the textual and visual modes (see Appendix E). This analytical tool differed from the first two, as it was specifically designed to analyse how the textual and visual modes within the topic of Forces of the three Physical Sciences textbooks related in terms of *intersemiotic* complementarity. The analytical tool was adapted from Royce's (1999) analytical framework (as already discussed in Chapter Three) that he used in analysing visual and verbal *intersemiotic* complementarity in *The Economist* magazine. The researcher focused on meaning expressed between the textual mode and their corresponding visual mode in terms of the sense relations.

4.10 Piloting of Analytical Tools

Piloting is an important mechanism in qualitative research processes. Polit, Beck, and Hungler (2001) defined a pilot study as a small-scale version that is normally undertaken before the actual study is carried out. According to Bertram and Christensen (2015), pilot testing must be done before an instrument is used in research. One of the reasons why piloting is done in research is to help the researcher obtain a more reliable analytical tool for use in the study (Agunbiade, 2015). In addition, Cohen et al. (2011) indicated that pilot testing increases the reliability, validity, and practicability of the study. For the reasons stated in this paragraph, the analytical tools that provided guidance for actual data analysis in this study were tested on one of the three approved Grade 8 Physical Sciences textbooks. The purpose of testing these analytical tools was to verify whether they would provide the data required to answer the research questions. After the analytical tools were tested, their contents were modified. The analytical tool used for analysis of *intrasemiotic* sense relations within the textual mode for the topic of Forces previously focused on technical terms. However, after the piloting, the researcher modified the analytical tool by including some common features of science discourse such as letters, symbols, and operations. These common features of language are not characteristics to science discourse since they do occur in other discourses such as mathematics. That does not mean they are any less important to science discourse, and thus are part of what science education inducts learners into.

Literature highlights that epistemological access to scientific knowledge considers creating opportunities of apprenticing learners into the discourse of science (Ellery, 2011). This argument contributed to the decision of exploring the sense relations in terms of these science discourse features because they contribute to the density of meaning in science discourse (O'Halloran, 2011). This means that the sense relations for these features are especially important towards epistemological access to science discourse, hence, the focus of this thesis being on sense relations to these science discourse features. In addition, the analytical tool was further refined by including the sense relation themes, technical words and symbolic letters that were formulated following the coding of data.

The analytical tool used for analysis of *intrasemiotic* sense relations within the visual mode was refined by including the sense relation themes, paired visuals and singular visuals also formulated after the coding of data. The modified analytical tool involved descriptions of the visual modes and how they were related in terms of the sense relations. This analytical tool before it was tested did not include the changes described. However, the changes were found to be necessary as they contributed to answering research question two of the study. Another analytical tool employed in analysing how the textual and visual modes for the topic of Forces were related in terms of *intersemiotic* complementarity did not require refinement since the results it generated during piloting enabled the answering of research question three of the study.

4.11 Data Analysis Procedure

In this section, the researcher discusses how data for this study was analysed. The analysis of data in the selected Physical Sciences textbooks for this study was carried out in the topic of Forces and was undertaken in three phases. The flow diagram in Figure 4.5 illustrates the three phases of data analyses.

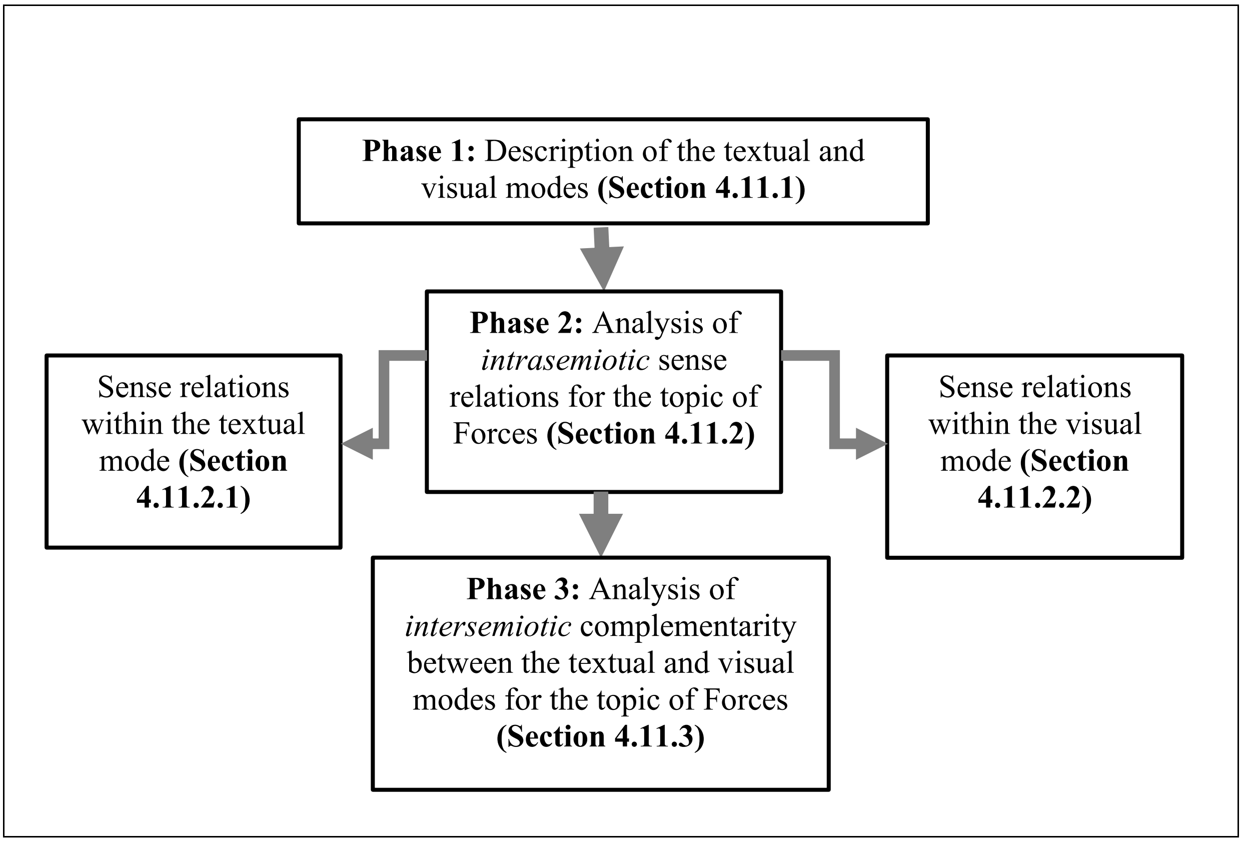


Figure 4.5: Flow diagram illustrating data analysis

4.11.1 Phase 1: Description of the textual and visual modes

Phase One aimed at providing a description of the textual and visual modes (Appendix A) for Forces in the three textbooks. Qualitative researchers explain description of data as a way of creating contextualised information of an event to increase credibility and transferability of the research findings (Creswell, 2012). This detailed description of data, as Stake (2010) suggested, is achieved when the information has some form of connection to the theory or is linked to scientific knowledge.

In Holliday's (2007) view, description of data is closely related to analysis and this positions it as a form of a pre-analysis. The description in this study was carried out in order for the researcher to obtain an understanding of the common features of science discourse within the textual and visual modes in the topic of Forces for the three Physical Sciences textbooks. The description of data was undertaken on the main parts that fell under the topic of Forces. The reason for doing this was to provide a more complete account of the document data in order to arrive at a better understanding of the data without imposing theory onto the data (allowing the data to speak for itself).

4.11.2 Phase 2: Analysis of *intrasemiotic* sense relations for the topic of Forces

Analysis of *intrasemiotic* sense relations for the topic of Forces within the textual and visual modes was undertaken in two ways: within and across all three Physical Sciences textbooks. The reasons for analysing data first within the textbooks and later across, was that the study aimed at providing an understanding of how the textual and visual modes were related in terms of *intersemiotic* complementarity for the topic of Forces across all Physical Sciences textbooks. It was therefore necessary for analysis to be done first within individual textbooks.

The researcher carried out the analysis by firstly calculating the percentage of the occurrence of each sense relation out of the total number of occurrences of all sense relations. This percentage frequency was calculated for the sense relation themes, within the textual and visual modes. Secondly, the percentage frequencies for the sense relations per sense relation theme in each mode were added together for all three Physical Sciences textbooks and the total was divided by three to find the average. For example, the percentage frequency for repetition in all three Physical Sciences textbooks were added together to give a total percentage, which was then divided by three to get an average percentage. The aim of calculating the average percentage was to provide a general idea of the occurrence of sense relations across the three

Physical Sciences textbooks in relation to other sense relations. The results are presented on bar graphs in Chapter Five.

A discussion of the results for *intrasemiotic* sense relations within the textual and visual modes is included in Chapter Five. The researcher further included some examples of the textual and visual modes obtained from the Physical Sciences textbooks with the purpose of illustrating analysis. These were used on the basis of them revealing interesting features of *intrasemiotic* sense relations that other examples did not clearly indicate.

Kawulich (2004) indicated that although numerical values are usually associated with quantitative research, they are also useful in analysing qualitative data. Kawulich (2004) explained that numbers can be used to provide frequency counts to generate meaning. Bertram and Christiansen (2015) revealed that while qualitative data are usually presented through the use of quotes or short narratives, they sometimes also employ tables and graphs in order to describe the findings. The use of graphs in presenting qualitative data is also supported by Verdinelli and Scognoli (2013), who highlighted that graphs help in providing better insight and understanding of data. The percentage frequencies for the sense relations per theme presented on the bar graphs in this study, enabled the surfacing of patterns and trends in the results. These were considered in discussing the results in Chapter Five, and thus ultimately helped in answering the research questions of the study.

4.11.2.1 Sense relations within the textual mode

Once the researcher had the textual mode data organised into sense relation themes, these were used in analysing the sense relations intrasemiotically, within the textual mode. The sense relation themes used were those that were most relevant to the textual mode. The sense relation themes used for analysis of *intrasemiotic* sense relations within the textual mode were "technical words", "symbolic letters", "arrows", "numerical values", and "mathematical symbols" (see Appendix C1−C2).

The researcher used the sense relation theme "technical words" to identify the words and phrases within the main text (ones with main ideas) that related in terms of the sense relations to the highlighted technical terms. The "symbolic letters" theme was used to identify the words and symbols within the main text that were related to the letters in terms of the sense relations. The researcher used the theme "arrows" to identify the words within the main text that related to the arrows in terms of the sense relations. The sense relation theme "numerical values" was used to identify words and numbers within the main text that related to the numerals in terms of the sense relations. Finally, the theme "mathematical symbols" was used by the researcher to identify words within the main text that related to mathematical operations in terms of the sense relations.

4.11.2.2 Sense relations within the visual mode

This aspect of Phase Two involved the analysis of *intrasemiotic* sense relations between the visuals used in the topic of Forces of the Physical Sciences textbooks. The most relevant sense relation themes used for analysis of *intrasemiotic* sense relations within the visual mode for the three Physical Sciences textbooks include "arrows", "paired visuals", and "singular visuals" (see Appendix A). The sense relation theme "arrows" was used to identify the relations between arrows appearing on the diagrams and photographs in terms of the sense relations. The researcher used the sense relation theme "paired visuals" to identify the relations between diagrams, and photographs that are paired in the topic of Forces in terms of the sense relations. Then, "singular visuals" was used to identify the relations between diagrams and photographs that are not paired in terms of the sense relations.

4.11.3 Phase 3: Analysis of *intersemiotic* complementarity between the textual and visual modes for the topic of Forces

An analysis of *intersemiotic* complementarity between the textual and visual modes in the topic of Forces was undertaken for all three Physical Sciences textbooks. This phase did not include themes as it was done for Phase One and Phase Two because the focus was on exploring *intersemiotic* sense relations between the main text of the textual mode and corresponding visual mode. As with the textual and visual modes, the percentage frequencies for the sense relations identified between the modes were calculated. This was done only per textbook and not across the textbooks. Since the analysis for this part did not involve sense relation themes, the results for the percentage frequencies per textbook were combined on one graph. A discussion of the results on how the textual and visual modes for the topic of Forces in the three Physical Sciences textbooks related in terms of *intersemiotic* complementarity is incorporated in the same chapter (Chapter Five). Some examples of the textual and visual modes with interesting features of *intersemiotic* complementarity obtained from the Physical Sciences textbooks were incorporated for the purpose of illustrating analysis.

4.12 Trustworthiness

Trustworthiness is defined as the confidence or trust someone can have in a study and its findings (Petty, Thomson, & Stew, 2012). Interpretivists highlight that considering trustworthiness during the study is important for ensuring the rigour of findings in qualitative research (Collier-Reed, Ingerman, & Berglund, 2009). Rigour refers to how well a study reports on issues of validity and reliability (Collier-Reed et al., 2009). In quantitative research, validity and reliability criteria refer to truth-value of the results and using different methods or instruments to get the same results, respectively. On the other hand, qualitative researchers ensure the truth-value and consistency of the results by considering the credibility and dependability criteria respectively (Chowdhury, 2015; Flick, 2009; Petty et al., 2012). Lincoln and Guba (1985) identified credibility, transferability, dependability, and confirmability as key criteria of trustworthiness in qualitative research. These criteria establish whether or not the research findings represent plausible information drawn from the original data (Anney, 2014). As the current study was of a qualitative nature, these trustworthiness criteria were considered and will now be discussed in more detail.

4.12.1 Credibility

Credibility is defined as the confidence that can be placed in the truth of the research findings (Holloway & Wheeler, 2002; Macnee & McCabe, 2008). There are various ways of attempting improved credibility when carrying out a qualitative study. Tracy (2010) claimed that credibility in qualitative studies is achieved by providing an in-depth description of data, as was undertaken in this study. It has been further suggested that including actual examples from the data when presenting the results is also a way of contributing to credibility in qualitative research (Noble & Smith, 2015). In this thesis, improved credibility was attempted by including real examples from the data in the topic of Forces to illustrate the researcher's explanations of the data analysed.

Another way of achieving credibility of qualitative research findings is by engaging with another researcher (critical friend) to reduce research bias (Noble & Smith, 2015). Nieuwenhuis (2007) reminded us that involving another researcher in a study to assist with the interpretation of the data can contributes to trustworthiness of the research findings. A critical friend from an educational perspective is a "trusted person, who asks provocative questions, provides data to be examined through another lens, and offer critique of a person's work as a friend” (Costa & Kallick, 1993, p. 50). Balthasar (2011) added that this person should be an active external observer who poses critical questions or suggests a need for a change in the research process. Fletcher (2019) mentioned that a critical friend functions as a catalyst who facilitates and generates new perspectives, which offer new insights for the researcher. Groundwater-Smith and Mockler (2009) suggested that a critical friend should be an expert in the focus area of the research being carried out and possess developed skills in research. For this study, a critical friend who possessed these criteria was engaged in discussion regarding the refinement of the analytical tools and interpretation of the results.

4.12.2 Transferability

It is assumed that in qualitative research the findings are context specific and for this reason are not aimed at generalising. Transferability, sometimes referred to as generalisability (Anney, 2014, p. 277), involves “the degree to which the results of qualitative research can be transferred to other contexts with other respondents”. One way of ensuring transferability is by providing thick descriptive data of the case (Petty et al., 2012). This helps in enabling other researchers to determine the degree to which the findings may be applied to their own settings. Pandey and Patnaik (2014) suggested that some researchers consider confirmability to ensure transferability in qualitative research. Enhancement of transferability in this thesis was attempted by providing thick descriptive data. Shenton (2004) identified that transferability is closely related to dependability.

4.12.3 Confirmability

There are various definitions found in literature concerning the term confirmability. This indicates that scholars have different understandings around this term. Baxter and Eyles (1997) defined confirmability as the degree to which the results of a research project could be confirmed or corroborated by other researchers. Shenton (2004) added that confirmability can be established by taking steps to ensure as far as possible that the research findings are a true reflection of the experiences and ideas of the researcher, and not his/her own points of view. This is similar to Petty et al. (2012) and Pandey and Patnaik (2014) who suggested that confirmability is concerned with the degree of neutrality or an extent to which the research findings reflect the focus of the study instead of the researcher’s bias, motivation or interest. Confirmability was attempted in this research by the researcher keeping in mind that the interpretation of the results should not be based on the researcher’s own preferences and opinions, but rather reflect the outcome of the analysed data. Other studies suggested that confirmability of qualitative research is achieved through triangulation and audit trails (Nieuwenhuis, 2007; Petty et al., 2012) which are discussed next.

Triangulation is the use of multiple procedures and sources that leads to obtaining corroborative data (Cohen et al., 2011; Onwuegbuzie & Leech, 2007; Shenton, 2004). While triangulation in quantitative research is aimed at confirming or disproving the hypothesis formulated in the study, qualitative research is not about the testing of hypotheses (Nieuwenhuis, 2007). As discussed earlier in Section 4.6 of this chapter, this study did not require the use of different techniques to analyse data. Therefore, the use of triangulation in this study's process was not relevant. Instead, the confirmability of the research results was attempted through an audit trail.

An audit trail is a strategy that helps in improving the trustworthiness of qualitative research. Anney (2014) explained that an audit trail involves an examination of the research process and product to validate the data. This aligns with Carcary (2009, p. 16) who suggested that an audit trail allows "readers to trace through a researcher's logic and determine whether the study's findings can be relied upon as a platform for future research". It was further explained that application of this mechanism allows the researcher to account for all the research decisions and activities to show how the data were analysed (Bowen, 2009; Li, 2004). This strategy is achieved through different ways such as ensuring that all raw data is kept safe for further investigation or subsequent queries around the study (Pandey & Patnaik, 2014). In the current study, the audit trail included filing the raw data obtained from the three Physical Sciences textbooks to enable retrieval of information. Guba and Lincoln (1982) claimed that in order for an auditor to conduct a thorough audit trail, the raw data, interview, and observation notes should be kept for cross-checking the research process.

4.12.4 Dependability

This criterion of trustworthiness is defined as "the stability of findings over time" (Bitsch, 2005, p. 86). This aligns to Cohen et al. (2011) and Tobin and Begley (2004) who explained that dependability involves researchers evaluating the findings, interpretation, and recommendations of the study to ensure that they are all supported by the data. Dependability encompasses using a clear description of the analytical tools to highlight the relevant themes obtained from the data (Aniemene, 2017). As with confirmability, the criterion of dependability is also enhanced by maintaining an audit trail. Enhancing dependability in the current study was attempted by ensuring that the data were not misrepresented and was carefully analysed with piloted analytical tools.

4.13 Ethical Considerations

Adhering to ethical norms when conducting research requires great consideration. Ethical concerns stem from discussions about codes of professional conduct for researchers (Creswell, 2009). Various reasons, as provided by Resnik (2007), suggest why ethical norms in research should be considered important. One of the reasons provided is that ethical norms promote the aims of research such as knowledge and truth. This helps in guiding researchers against misrepresentation of research data. Another reason is that ethical standards promote the values which are essential to collaborative work, and include principles such as trust, accountability, mutual respect, and fairness.

An important expectation of ethical principles in social science research is to ensure that informed consent is sought from participants (Sixsmith & Murray, 2001). Informed consent, however, may not be required for some forms of research as is the case for document analysis of textbooks where data are from documents in the public domain, as these can be researched without the need for consent (Felzmann, 2013; Sixsmith & Murray, 2001). There were no human participants in this study who could be harmed. In conducting the study, the researcher adhered to ethical issues as will now be discussed.

4.13.1 Respect and dignity

The sources of data for this study were objects that cannot express themselves orally or exercise their rights in terms of research ethics. The researcher was however aware that the publishers of the selected Physical Sciences textbooks for this study protect them in terms of copyright issues. The researcher ensured that data in the textbooks were handled with sensitivity. Written permission letters to reproduce visual content from the textbooks were requested and obtained from the publishers of the textbooks. The permission letters are included as an addendum in this thesis (see Appendix H). For the few specific visuals that written permission was not granted by the copyright holders, textual descriptions of the examples are provided instead. Any form of criticism or favouritism regarding the different textbooks was avoided in presenting and discussing the results of the study.

4.13.2 Transparency and honesty

Resnik (2007) cautioned researchers to strive for honesty when they communicate science knowledge. The results of this study were honestly reported, and the researcher did not attempt to fabricate the process of analysing data. The researcher enhanced transparency of the results obtained from analysis by providing the page numbers as references to indicate where the information was obtained in the Physical Sciences textbooks (See Appendices B and C). The researcher also included citations where the ideas of other researchers were used. The researcher further included in this study direct quotations from the textual mode and also took snapshots of the visual mode analysed in the Physical Sciences textbooks (as part of raw data) and used some of them in discussing the results. Yilmaz (2003) supported the inclusion of direct quotations when discussing results of qualitative studies as it helps provide depth.

4.13.3 Integrity and academic professionalism

The integrity in this study was enhanced by ensuring that the goal and aim of the research were addressed. In addition, the researcher did not use the research for personal interest apart from it being towards the completion of a Master of Education degree, aimed also at contributing to the body of science education research knowledge. For academic professionalism, the researcher ensured that the study was written in his own words, and where the work of other scholars have been either quoted or cited, they were properly referenced using the American Psychological Association (APA) and Rhodes University Education Department guidelines. Furthermore, the thesis was run through a text-matching software programme, Turnitin (see Appendix G) in order to make sure that the researcher has not plagiarised unintentionally.

4.14 Chapter Summary

In this chapter, the research design for the study was presented. The researcher further discussed the interpretive paradigm that was employed in this study. The interpretive paradigm was most relevant for this study since it is appropriate for a case study that aims at deeper understanding of a phenomenon. This paradigm was chosen because it allowed the researcher to understand and explain how the textual and visual modes were related in terms of *intersemiotic* complementarity for the topic of Forces in three Namibian Physical Sciences textbooks. Furthermore, a discussion of the qualitative approach which reflects the nature of this study was presented. The researcher also stated reasons for purposive sampling in terms of focusing on three Physical Sciences textbooks used in Grade 8 and the specific topic of Forces.

Furthermore, document analysis as the method used to analyse qualitative data was detailed. Both deductive and inductive approaches to data analysis were considered. The researcher went on to explain how coding of data was undertaken. The analytical tools and their piloting were explained, and a detailed discussion of the data analysis procedure was presented. The researcher then ended the chapter by discussing trustworthiness and the ethical considerations relevant to the study such as credibility and transparency.

CHAPTER FIVE: DATA PRESENTATION AND DISCUSSION

5.1 Introduction

In this chapter, the results obtained from the data analysis of textual and visual *intrasemiotic* and *intersemiotic* complementarity of text and visuals from the topic of Forces in three Namibian Physical Sciences textbooks are presented. The results are presented in the same order of the three phases in which the data was analysed. The description of the textual and visual modes for the topic Forces in the three Physical Sciences textbooks are presented in Section 5.2. A discussion of the result analysis of *intrasemiotic* sense relations within the textual and visual modes for the topic of Forces is found in Section 5.3. The result analysis of *intersemiotic* complementarity between the textual and visual modes for the topic of Forces are presented in Section 5.4.

In this chapter, the results are also discussed in terms of the sense relations having different affordances as well as the implications for science education. It was necessary to discuss the results as it enabled deeper understanding of meanings expressed within the textual and visual modes in the topic of Forces. Furthermore, discussing the results afforded the researcher an understanding of how the textual and visual modes for this particular topic were related in terms of *intersemiotic* complementarity. The results were further discussed in relation to findings from previous studies conducted which related to this study.

5.2 Phase 1: Description of the textual and visual modes

As highlighted in Chapter Four of this thesis, the description of data in this chapter was carried out for both the textual and visual modes in terms of the common features of science discourse (see Appendix A). The three Namibian Physical Sciences textbooks have commonalities and differences in terms of the features of science discourse within the textual and visual modes. These features will be presented next.

5.2.1 Common features of science discourse within the textual mode

The common feature of science discourse identified within the textual mode for the topic of Forces in the three Namibian Physical Sciences textbooks is that some lexical items were highlighted. The highlighting is done in different forms: colour, bold face, and italics, depending on the textbooks as shown in Figure 5.1. According to Hsu and Yang (2007), school science textbooks often contain unique terminologies that differ from everyday language. Bryce (2013) and Fang (2004) indicated that the words that appear highlighted in school science textbooks represent technical vocabulary. The highlighted words were therefore referred to as technical terms.

Types of forces

Some forces you looked at did not involve a person touching an object. The weight of the book is such a force. No physical force was exerted on the book. That means that you do not have to be in contact with something in order to exert a force on it.

There are two types of forces, **contact forces** and non-contact forces:

- Objects that are in contact exert forces on each other. So, when objects touch each other, they exert forces on each other. Most of the forces you looked at earlier in this unit are contact forces (such as when you push or pull a desk, or kick a ball). In these examples a person touches an object. In Unit 5, you will work with **friction**, which is also a contact force.
- Objects that are not in contact with each other also exert forces on each other. These are **non-contact forces**. Non-contact forces act over a distance. The objects do not have to touch each other. A field is a region in space where an object (with certain properties) experiences a force. Field forces are non-contact forces. The most common examples of non-contact forces are weight or gravitational force, magnetic force and **electrostatic force**.

The diagrams show examples of contact and non-contact forces. Both the book and the ball are falling without being touched. They fall due to the **gravitational pull** or weight of the earth. You will learn more about

Kinds of force

In the example in Figure 5.1, different kinds of fi the effects shown in the figure.

- The apple started moving when Amanda kickε direction when it came into contact with Theo moving when it hit the rock. These are all effects of **contact forces**. A contact force is a force that is applied when one object touches another.
- Apples had fallen to the ground because of the force of **gravity**. Gravity pulled the apple downwards (Figure 5.2a). Gravity is a force that acts at a distance. There was no contact between the object on which the force was applied (the apple) and the source of the force (the Earth). Gravity is, therefore, a **non-contact force**. You will learn more about gravity later in this topic.

Other examples of non-contact forces include magnetic force and electrostatic force.

- Magnetic force is the **attraction** or **repulsion** between the poles of two

Figure 5.1: Example of extracts from Physical Sciences textbooks showing highlighted technical terms (Haimbangu et al., 2016, p. 112; Van Niekerk, 2016, p. 91)

In this figure, the extract on the left is obtained from Textbook B and indicates an example of technical terms highlighted by colour (*Platinum Physical Science Grade 8 Learner's Book*, M Haimbangu, A Poulton & B Rehder [1st ed.] 2016. Reprinted by permission of Pearson Education Namibia [Pty] Ltd.). The extract on the right is obtained from Textbook C and shows an example of technical terms highlighted using bolded words (Van Niekerk, H. [2016]. *Solid*

Foundations Physical Science Grade 8 Learner's Book. Windhoek: Namibia Publishing House [Pty] Ltd. pp. 90-109. Reprinted by permission of Namibia Publishing House [Pty] Ltd.).

According to Fang (2004), it is important that learners are well apprenticed in the use of scientific technical vocabulary in order to overcome challenges in constructing scientific knowledge and communicating scientific information effectively in their own writing. Furthermore, technical terms and phrases in school science textbooks are important for helping science educators to model scientific thinking and questioning, including the doubts and dilemmas that are part of making sense of the world (Carrier, 2013). Ceglie and Olivares (2012) added that students learn scientific language better when scientific texts include scientific vocabulary. Table 5.1 represents a summary of technical terms for the topic of Forces that appear highlighted across the three Physical Sciences textbooks.

Table 5.1: Examples of technical terms for the topic of Forces, common to all three Physical Sciences textbooks

Common technical terms		
All three Physical Sciences textbooks	**Textbooks A and B only**	**Textbooks B and C only**
Contact forces Non-contact forces Mass Weight Kinetic energy Potential energy Renewable energy sources Friction	Gravitational field strength Non-renewable energy sources	Attraction Work Air resistance

The technical terms shown in Table 5.1 were identified from all five sub-topics of Forces in all three Physical Sciences textbooks. The five sub-topics as mentioned in Chapter Two are: "The nature and effects of Forces"; "Weight and Mass"; "Work"; "Energy"; and "Friction" (Namibia. MoEAC, 2015a, p. 20). The results in the table show that not all technical terms that are highlighted were common to all three Physical Sciences textbooks. Examples are the technical terms listed in the second and third columns. These technical terms were common to only two of the three Physical Sciences textbooks. The variations in terms of which words were highlighted as technical terms in textbooks covering the same topic suggests variable levels of consensus by authors on what counted as a technical term. Technical terms in science education are recognised as commonly being abstract, and so may be problematic to students' understanding (Ibáñez & Ramos, 2004; Kurnaz & Eksi, 2015).

The results obtained following the description of data revealed that the concept of work was not common to all three Physical Sciences textbooks. The reason for this could result from the fact that work is related to the concept of energy (Meltzer, 2004). According to Jones et al. (2016b, p. 86) this relationship "is based on the principle of conservation of energy". It is known that if work is done on a body, energy is transferred to it (Namibia. MoEAC, 2015). Therefore, the amount of work done to an object and energy transferred to it are equal. Furthermore, the researcher was aware that there were other technical terms in the topic of Forces in all three Physical Sciences textbooks, apart from the ones highlighted.

5.2.2 Common features of science discourse within the visual mode

For the visual mode, the common features of science discourse identified were the types and number of representations falling under the category of visual mode in the topic of Forces in all three Physical Sciences textbooks. Examples of the types and number of these representations are illustrated in Table 5.2.

Table 5.2: Types and number of representations falling under the category of visual mode, appearing in the topic of Forces in all three Physical Sciences textbooks

Textbooks	**Number of photographs**	**Number of diagrams**	***Total***
A	46	7	53
B	21	25	46
C	6	29	35
Total	73	61	134
Percentage	54.5%	45.5%	100%

In the table, it is evident that there are more photographs for Textbook A and more diagrams for Textbooks B and C in the topic of Forces. The result for Textbook A is compatible with Guo et al. (2018) as well as Pozzer and Roth (2003), who found that photographs were by far the most frequently used representations in high school science textbooks. Besides that, the results further revealed that many visuals occurred in the topic of Forces for Textbook A compared to the other two textbooks. As outlined by Pintó and Ametller (2002), visual modes in school science textbooks are not just randomly used for the purposes of illustration but help to express the main ideas being communicated.

There is evidence in literature of the importance of using visual modes in school science textbooks. Studies such as by Kress and Van Leeuwen (2002) contributed to an improved understanding of the importance of visual modes towards the learning of scientific language. Liu and Treagust (2013) stated that having many visuals in school science textbooks could serve as references for students learning about natural phenomena. Since visuals such as photographs and diagrams are known to include large amounts of detail, it makes them powerful representations of real-world phenomena (Liu & Treagust, 2013). Examples of such natural/real-world phenomena as exemplified in the topic of Forces include renewable and non-renewable energy sources, such as geothermal energy and nuclear energy respectively (Haimbangu et al., 2016; Jones et al., 2016a).

5.3 Phase 2: Analysis of *intrasemiotic* sense relations for the topic of Forces

5.3.1 Sense relations within the textual mode

In this section, the results for *intrasemiotic* sense relations within the textual mode are presented. Bar graphs were employed for indicating the percentage frequencies for the sense relations within the visual mode. The percentage frequencies, as already explained in Chapter Four, represent the percentage of the occurrence of each sense relation out of the total number of occurrences of all sense relations. The results presented on the bar graphs are for both individual and combined data in the three Physical Sciences textbooks. A description of the results shown on the bar graphs in terms of the percentage frequencies for all the sense relations is presented. The percentage frequencies were used in discussing the results.

Figure 5.2 on the following page shows the percentage frequencies for the sense relations within the textual mode in Textbook A.

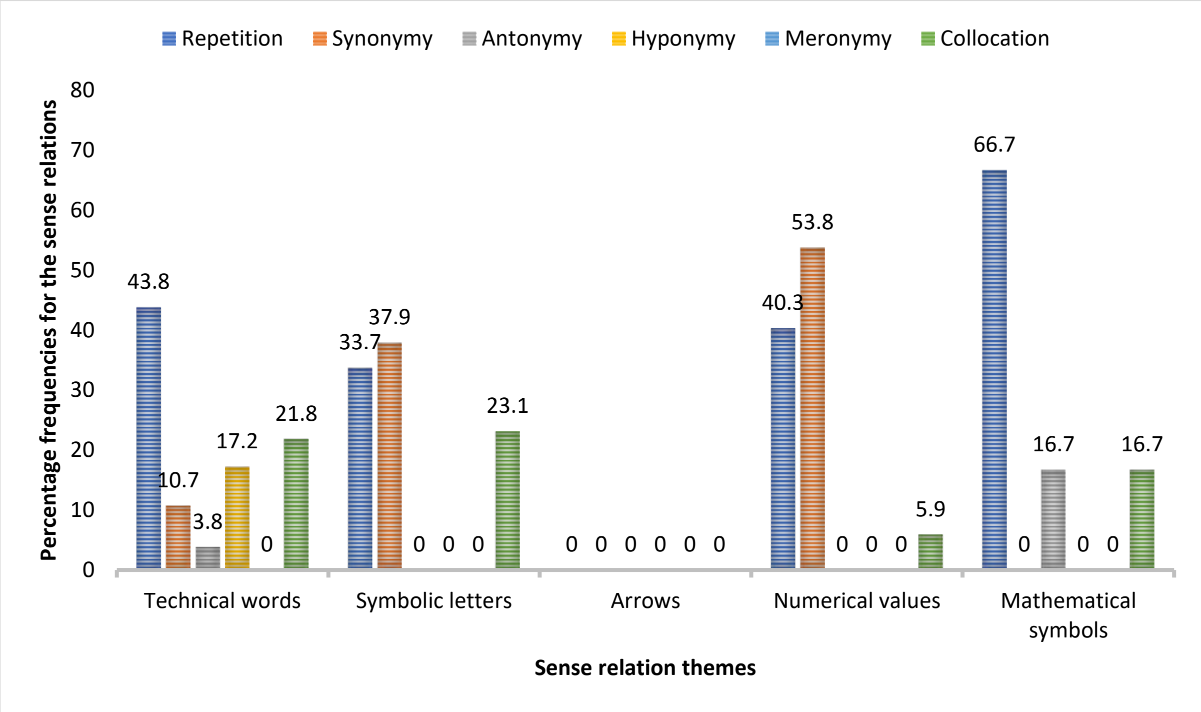


Figure 5.2: A graph showing the percentage frequencies for the sense relations within the textual mode in Textbook A

The results revealed that the most frequently occurring sense relations within the textual mode in this textbook were repetition and synonymy. Repetition occurred most frequently for the sense relation themes "mathematical symbols" and "technical words". Synonymy occurred most frequently for the sense relation themes "numerical values" and "symbolic letters". The results also indicated that there were more sense relations occurring in the theme "technical words", compared to the occurrence of sense relations in other themes.

Figure 5.3 on the following page shows the percentage frequencies for the sense relations within the textual mode in Textbook B.

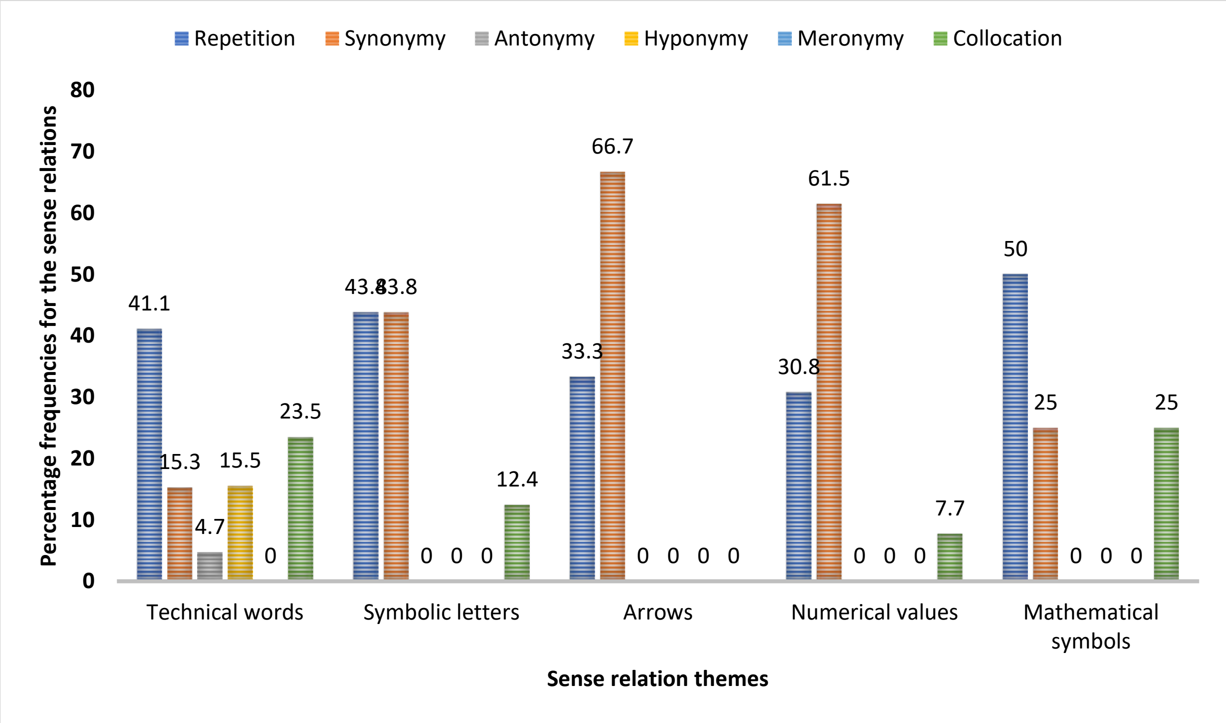


Figure 5.3: A graph showing the percentage frequencies for the sense relations within the textual mode in Textbook B

For this textbook, the results revealed that the most frequently occurring sense relations within the textual mode were synonymy and repetition. Synonymy occurred most frequently for the sense relation themes "arrows" and "numerical values". Repetition occurred most frequently for the sense relation themes "technical words" and "mathematical symbols". As with Textbook A, the results indicated that there were more sense relations occurring in the theme "technical words" compared to the occurrence of sense relations in other themes.

Figure 5.4 on the following page shows the percentage frequencies for the sense relations within the textual mode in Textbook C.

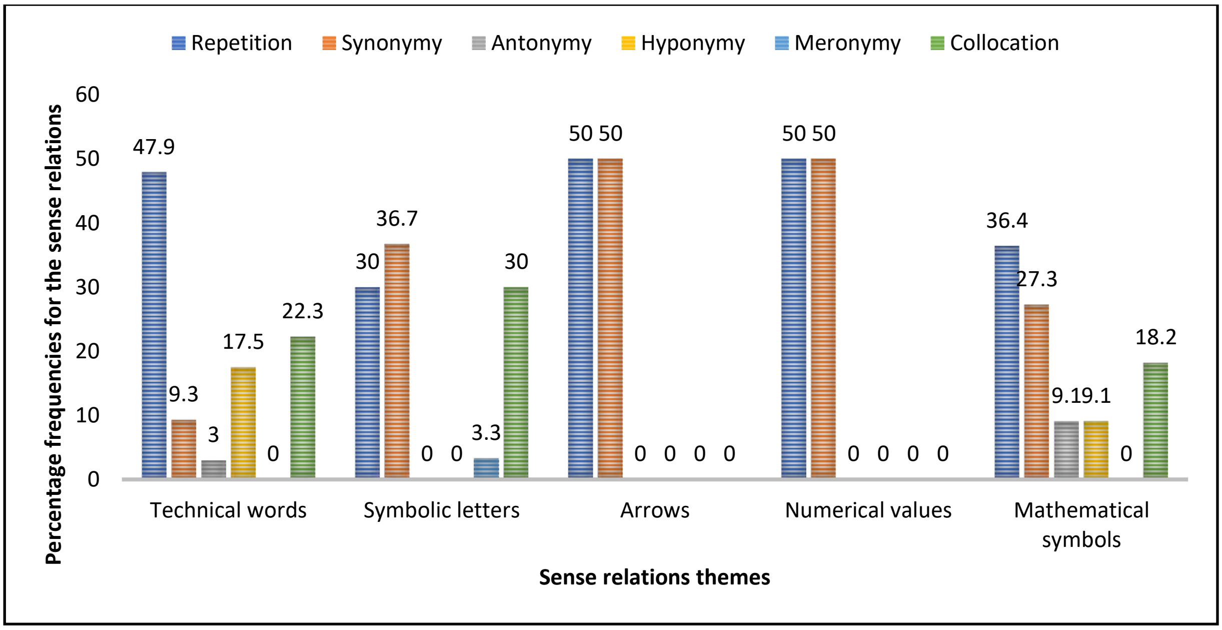


Figure 5.4: A graph showing the percentage frequencies for the sense relations within the textual mode in Textbook C

In this figure, the results revealed that the most frequently occurring sense relations within the textual mode for Textbook C were repetition and synonymy. Repetition occurred most frequently for the sense relation themes "technical words" and "mathematical symbols". Synonymy occurred most frequently for the sense relation theme "symbolic letters". The results also indicated that for this textbook, there were more sense relations occurring in the themes "technical words" and "mathematical symbols" compared to the occurrence of sense relations in other themes.

Figure 5.5 on the following page shows the average percentage frequencies for the sense relations within the textual mode across all three Physical Sciences textbooks.

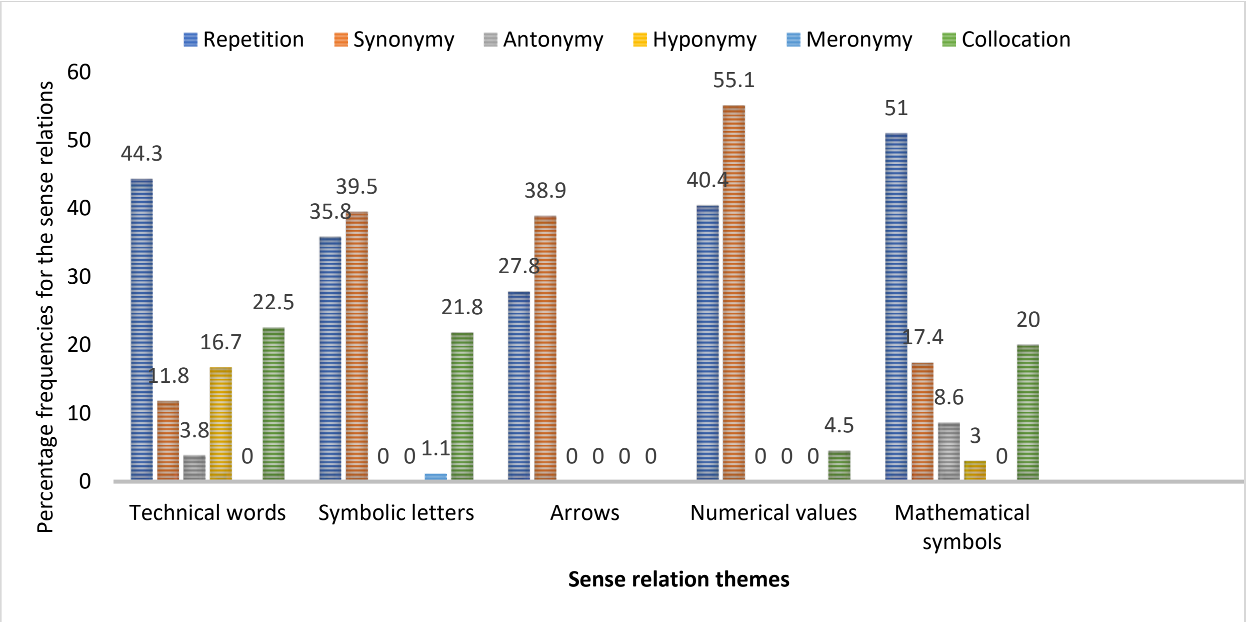


Figure 5.5: A graph showing the average percentage frequencies for the sense relations within the textual mode for the three Physical Sciences textbooks

The results for average percentage frequencies for the sense relations within the textual mode were consistent with the results for individual textbooks. The results indicated that synonymy and repetition were the most frequently occurring sense relations across the three Physical Sciences textbooks. Synonymy occurred most frequently for the sense relation themes "symbolic letters", "arrows", and "numerical values"; while repetition was most frequent for the sense relation themes "technical words" and "mathematical symbols". As with individual textbooks, the results for average percentage frequencies across the three textbooks showed that more sense relations occurred in the themes "technical words" and "mathematical symbols".

5.3.1.1 The affordances of synonymy within the textual mode

The frequent occurrence of synonymy within the textual mode for the mechanic section of the three Physical Sciences textbooks suggest that it is beneficial to the learning of scientific knowledge. This is supported by Webb (2007) who emphasised that synonymy plays an important role in facilitating the learning of vocabulary, such as of science for this study. Furthermore, as Fang (2004) stated, learners who have difficulties in understanding meanings of technical vocabulary often struggle with comprehension of science texts. The frequent occurrence of synonymy within the textual mode of the three Physical Sciences textbooks is necessary because, as Carrier (2013) suggests, readers of these textbooks need to gain knowledge of science content in order to develop scientific literacy. Students as the frequent readers of those Physical Sciences textbooks can adequately engage with scientific language when they have a deep understanding of technical vocabulary (Wood, 2015), which can be communicated by scientific texts where synonymy is used.

As revealed by the results (see Figure 5.5), synonymy does not occur the most frequently for the theme technical words which links to technical vocabulary. The implication for the under representation of this sense relation for the theme technical words is that readers will have reduced opportunities to effectively learn scientific knowledge. The fact that synonymy occurred less frequently in this theme, despite its significant contribution to learning of scientific vocabulary, could be the cause of learners performing poorly in the topic of Forces. Halliday and Hasan (1976) stated that when synonymy is used in scientific texts, it helps in realising ideational meaning within the textual mode. This suggests that the occurrence of synonymy within the textual mode of the topic Forces in the three Physical Sciences textbooks contributes to ideational meanings being realised.

Other scholars have added that the frequent occurrence of synonymy within the textual mode could be useful in adding variety to scientific writing (Danglli & Abazaj, 2014). Furthermore, Danglli and Abazaj (2014) stressed that using synonymy in scientific texts leads to increased cohesion of the written text and helps in avoiding inappropriate repetition of the same word. This could be one of the possible reasons why this sense relation occurred most frequently for the sense relation themes “symbolic letters”, “arrows”, and “numerical values”.

The occurrence of synonymy within the textual mode of scientific texts can lead to some confusion despite its benefit in science education. One example of this confusion among students results from relating the concepts of weight and gravitational force (Stein et al., 2015). The two concepts were used in the definition of weight in the topic of Forces in the three Physical Sciences textbooks. All three Physical Sciences textbooks mentioned the word “force” and “gravity” in their definitions of the concept weight (Haimbangu et al., 2016, p. 119; Jones, et al., 2016a, p. 96; Van Niekerk, 2016, p. 96) and thus are likely to contribute to this confusion. The occurrence of the concepts of weight and gravitational force in the definition makes them related, i.e. through synonymy. Many school science textbooks address this confusion by defining weight as the product of an “object’s mass and the local gravitational field” (Low & Wilson, 2017, p. 4).

5.3.1.2 The affordances of repetition within the textual mode

As indicated by the results, the frequent occurrence of repetition within the textual mode of the topic Forces for the sense relation themes “technical words” and “mathematical symbols” suggests that keywords and mathematical symbols in the topic of Forces in the three Physical Sciences textbooks were repeated the most. Scholars such as Halliday and Matthiessen (2004) indicated that repetition is the most direct form of lexical cohesion and that it is significant in scientific texts. Evidence for the dominance of repetition for the theme technical words corroborates findings from studies that investigated the lexical cohesion within the textual mode. Two of these studies were by Danglli and Abajaz (2014) and Naser and Almoisheer (2018) who stated that writing which contains a high frequency of lexical repetition contributes to achieving the overall cohesion within the textual mode more effectively than writing containing a lower frequency of repetition.

In addition, high frequency of repetition within the textual mode of scientific texts contributes to learning and a better understanding of scientific knowledge (Hall, Maltby, Filik, & Paterson, 2016; Sari, Ermanto, & Agustina, 2018). Despite the literature placing more emphasis on the benefits of repetition of keywords, the results for the occurrence of repetition across the three Physical Sciences textbooks revealed that the emphasis of repetition was placed more on mathematical symbols than on technical words. The reasons supporting this difference could be that in the topic of Forces, learners are expected to be able to “communicate their physical observations and conclusions using scientific and mathematical language to explain the nature and effects of forces and energy” (Namibia. MoEAC, 2015a, p. 6). Learners are also expected to formulate scientific formulae and do enough calculations of force, weight, mass, work, and friction (Namibia. MoEAC, 2015a).

Other affordances resulting from the frequent occurrence of repetition within the textual mode of scientific texts are that it helps in producing emphasis and clarity of scientific terms (Zhong, 2013). It has also been stated by Chung and Nation (2003) that repetition provides a clue that a word may be technical. Technicality has implications for science education. Fang (2004) explained that learners who have difficulties understanding meanings of scientific technical terms may struggle with comprehension of science texts. Having this lack of understanding ensures that learners lack the grammatical resources needed to effectively communicate scientific ideas and knowledge. Vogel (2010) cautioned that it is problematic when repetition is overused in scientific texts. The reason behind that is because readers struggle in making sense of scientific texts especially when technical terms are repeated instead of using pronouns or replacing technical terms with words from everyday language (Vogel, 2010).

5.3.1.3 The affordances of other sense relations within the textual mode

The results for the average percentage frequencies for the sense relations within the textual mode in three Physical Sciences textbooks revealed that collocation, hyponymy, antonymy, and meronymy occurred less frequently. These occurrences have implications for science education in terms of the sense relations' affordances.

Collocation

Examples of collocation identified for the sense relation theme "technical words" for the three Physical Sciences textbooks include the textual elements, *contact force,* which is used together with other words such as, *pull, push, mass, weight, non-contact force* and *gravitational field strength.* Instances of collocation identified for the sense relation theme "symbolic letters" took account of the abbreviation *N* (for Newton), that is used together with other abbreviations such as, *g* (for gram) and *Kg* (for Kilogram). For the sense relation theme "numerical values", example of collocation covered the textual element *500*N that is used together with the word *weight*. Other examples of collocation were identified in the sense relation theme "mathematical symbols" and incorporated the multiplication sign (*X*) which is used together with the "equals to" sign (=).

Collocation plays an important role in the learning of scientific knowledge (Myers, 1991). It is recognised that collocation is an important organising principle in the vocabulary of scientific texts (Biskri, 2012). Hence, when readers of the three Physical Sciences textbooks are provided with the opportunity to engage with collocations, it helps them learn meanings of words or phrases (Biskri, 2012). Since collocation contributes to coherence of written text as stated by Hadi and Jabir (2011) and He (2014), the co-occurrence of words and phrases which are closely related in meaning within the topic of Forces for the three Physical Sciences textbooks can contribute to achieving lexical cohesion. Another affordance of collocation in scientific texts is that it helps readers in learning the meaning of phrases (Biskri, 2012), which eventually allows readers to make predictions when words are missing in a text (Kalogeropoulou, 2017).

Hyponymy

Examples of hyponymy identified for the sense relation theme “technical words” for the three Physical Sciences textbooks include the textual elements, *contact force* $>$ *frictional force* (*contact force* is the hypernym of *frictional force*) and *strain potential energy* $<$ *potential energy* (*strain potential energy* is a hyponym of *potential energy*). Other instances of hyponymy were identified for the sense relation theme “mathematical symbols” and include the textual elements, multiplication (*X*) $<$ *operation.* In this example, the operation multiplication (*X*) is a hyponym of the term *operation*.

Hyponymy is important towards the learning of scientific knowledge. Namibia’s Physical Sciences syllabus for Junior Secondary Phase indicated that hyponymy is useful in sub-topics such as energy (Namibia. MoEAC, 2015a). Hyponymy is useful in science education as it helps learners develop the knowledge of classification skills (Nosofsky et al., 2018). It has further been noted that classification skills help readers of scientific texts in developing category-learning (Nosofsky et al., 2018). Learners can acquire these grouping skills by being exposed to scientific texts in which hyponymy occurs more frequently. Having this sense relation occurring more frequently within the textual mode of scientific texts could help learners (as main readers) to gain the knowledge of classifying objects in a variety of ways (Namibia. MoEAC, 2015c). Since this sense relation occurred less frequently within the textual mode in the topic of Forces across the textbooks (see Figure 5.5), it means that there are reduced opportunities of the affordances of this sense relation in that topic.

Antonymy

Examples of antonymy identified for the sense relation theme “technical words” for the three Physical Sciences textbooks include the textual elements, *contact force* and *non-contact force, renewable energy sources* and *non-renewable energy sources,* as well as *gravity* and *upward force*. For the sense relation theme “mathematical symbols”, examples of antonymy identified encompass the operations, addition ($+$) and subtraction ($-$).

The use of antonymy in Physical Sciences textbooks could be beneficial to the acquisition of scientific knowledge. Utsumi (2010) indicated that words or phrases with opposite meanings are more likely to co-occur in scientific written text. Words with antonymy relations can easily stimulate learners thinking, because when a certain word is mentioned learners are likely to think of the corresponding word with the opposite meaning.

Meronymy

Examples of meronymy were identified only in Textbook C. The examples of meronymy identified for the sense relation theme "symbolic letters" include the textual elements, $N <$ *force meter* (*N* is a meronym of *force meter*). Kuzmenka (2015) and Ahmed (2013) reminded us that, the relation of meronymy is established when a lexical item, referring to a complete whole known as *holonym*, is accompanied by the constituent parts of the whole (*meronym*).

Taking into account the use of meronymy in scientific texts is useful. The unfrequently occurrence of meronymy within the textual mode in the topic of Forces means that the three Physical Sciences textbooks do not sufficiently expose their readers to learning of whole and part-whole relations, especially Textbook A and B where no evidence of its occurrence was found. It is important that this sense relation be considered within the textual mode of the topic Forces in the three Physical Sciences textbooks because the study of science involves looking at objects or systems in relation to their constituent parts, for example, global cycles such as the water cycle, electrical circuits, and chemical equations.

5.3.2 Sense relations within the visual mode

In this section, the results for *intrasemiotic* sense relations within the visual mode are presented. As with the textual mode, bar graphs were also used here for indicating the percentage frequencies for the sense relations within the visual mode. The results presented on the bar graphs were for both individual and combined data in the three Physical Sciences textbooks. A description of the results shown on the bar graphs in terms of the percentage frequencies for all the sense relations is presented. The percentage frequencies were used in discussing the results. In discussing the results, examples of diagrams and photographs (the most noticeable features for the visual mode) from the data for some sense relations were included. This was done to make explanations of *intrasemiotic* sense relations within the visual mode clearer.

Figure 5.6 illustrates the percentage frequencies for the sense relations within the visual mode in Textbook A.

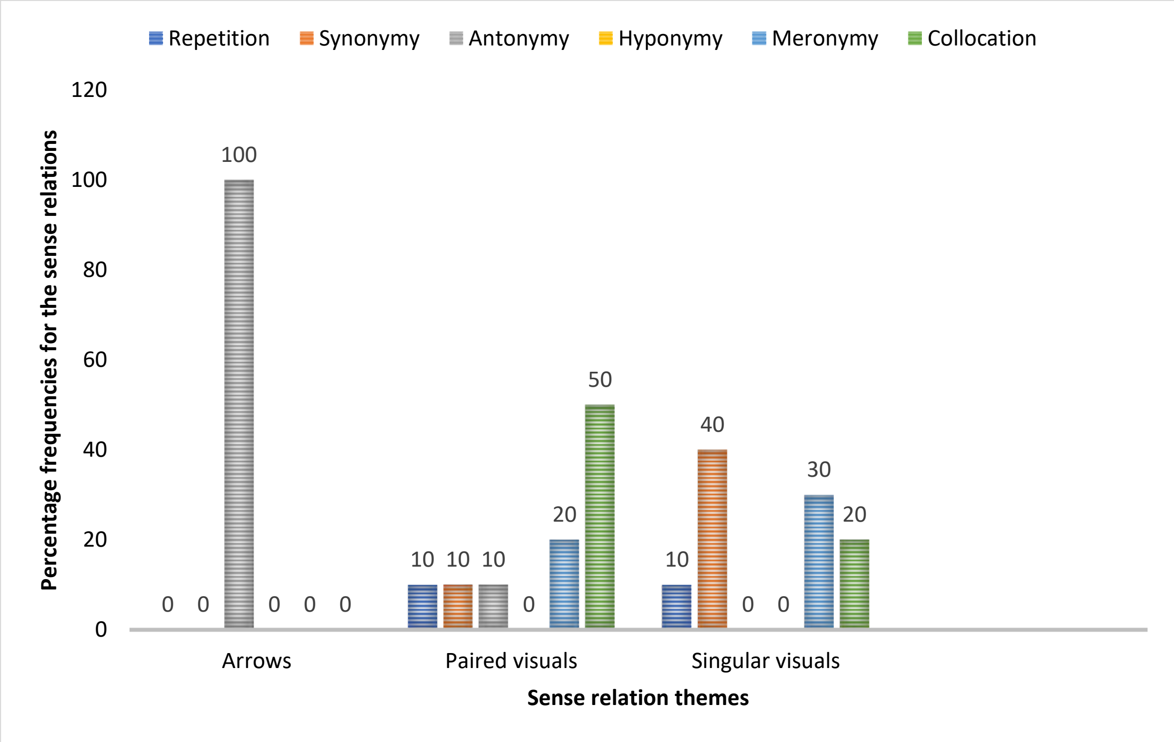


Figure 5.6: A graph showing the percentage frequencies for the sense relations within the visual mode in Textbook A

The results for this textbook indicated that the most frequently occurring sense relations within the visual mode in the topic of Forces were antonymy, collocation, and synonymy. Antonymy occurred most frequently for the sense relation theme “arrows”. Collocation occurred most frequently for the sense relation theme “paired visuals”, and synonymy was most frequent for the sense relation theme “singular visuals”. The results further revealed that there were more sense relations occurring for the theme “paired visuals” compared to other sense relation themes.

Figure 5.7 on the following page shows the percentage frequencies for the sense relations within the visual mode inTextbook B.

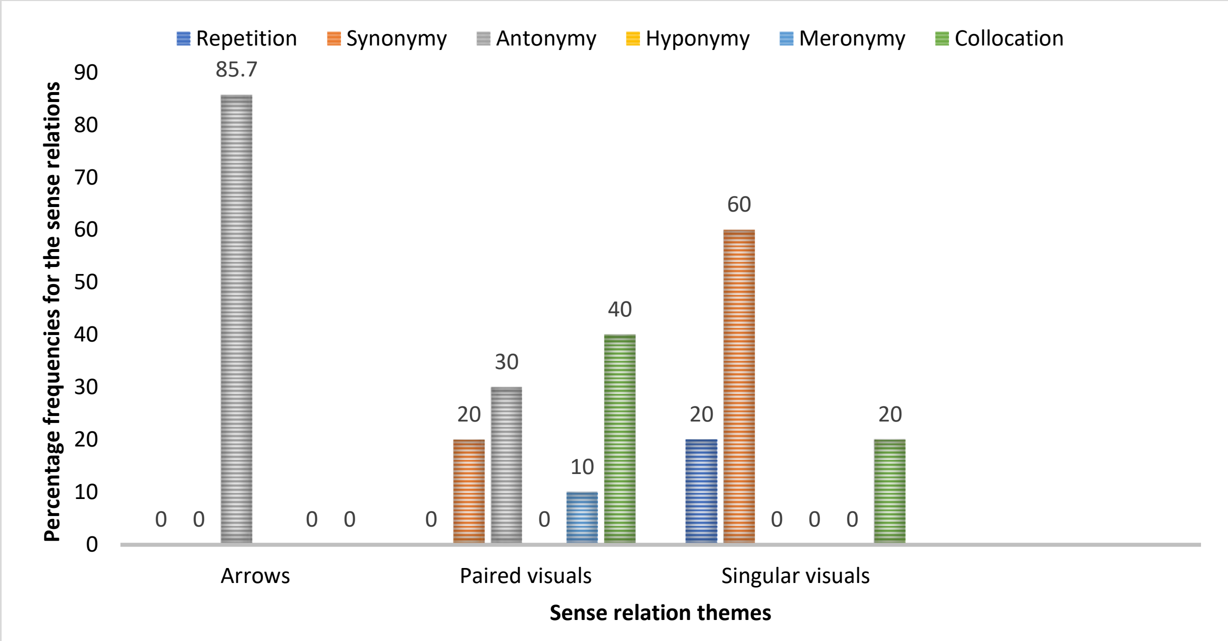


Figure 5.7: A graph showing the percentage frequencies for the sense relations within the visual mode in Textbook B

As with Textbook A, the results in this textbook also indicated that the most frequently occurring sense relations within the visual mode in the topic of Forces were antonymy, synonymy, and collocation. Antonymy occurred most frequently for the sense relation theme “arrows”, while synonymy and collocation were most frequent for the sense relation themes singular and paired visuals, respectively. Again, for this textbook, the results revealed that there were more sense relations occurring for the theme “paired visuals” compared to other sense relation themes.

Figure 5.8 on the following page shows the percentage frequencies for the sense relations within the visual mode in Textbook C.

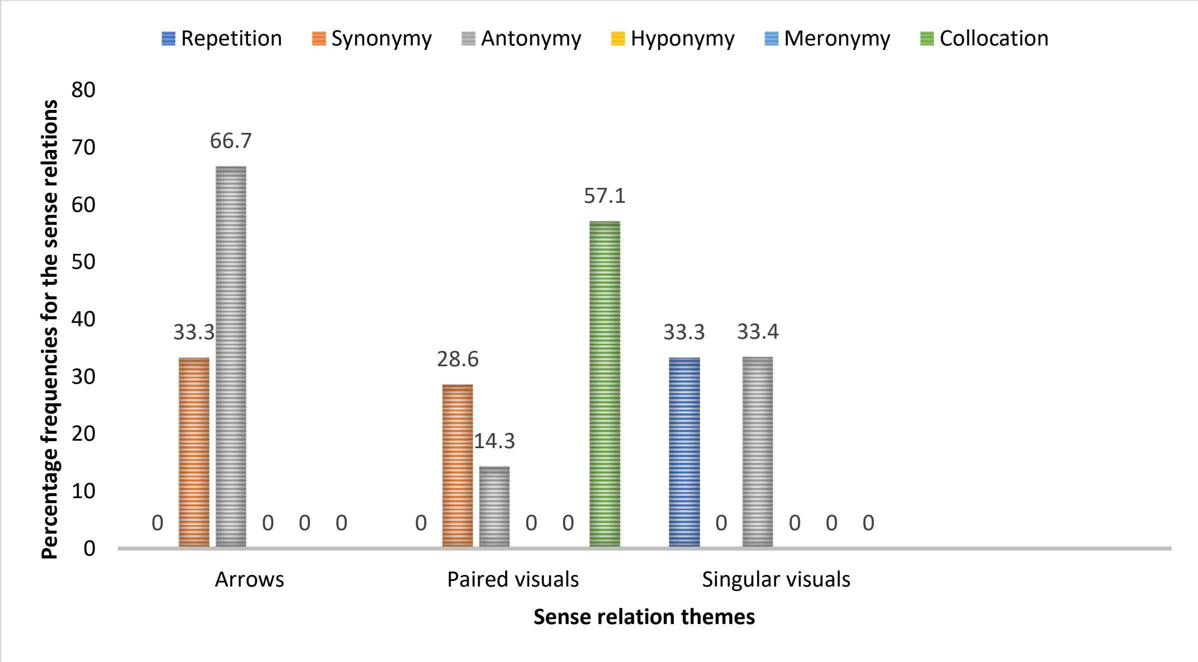


Figure 5.8: A graph showing the percentage frequencies for the sense relations within the visual mode in Textbook C

As with Textbook A and B, the results for this textbook revealed that antonymy was the most frequently occurring sense relation within the visual mode for the sense relation theme "arrows". While synonymy was the most frequently occurring sense relation for the theme "singular visuals" in Textbooks A and B, in this textbook, there was no evidence of it occurring in this theme, instead, antonymy and meronymy were the most frequent. These results suggest that the occurrence of synonymy within the visual mode for these sense relation themes was not consistent, and hence depended on individual textbooks. This could mean that authors of these Physical Sciences textbooks had different views on which part of the visual mode requires learning to be facilitated through synonymy. Collocation occurred most frequently for the sense relation theme "paired visuals" as with the other two textbooks. The sense relation theme paired visuals for this textbook also had the most occurring sense relations as with Textbook A and B.

Figure 5.9 on the following page shows the average percentage frequencies for the sense relations within the visual mode for all three Physical Sciences textbooks.

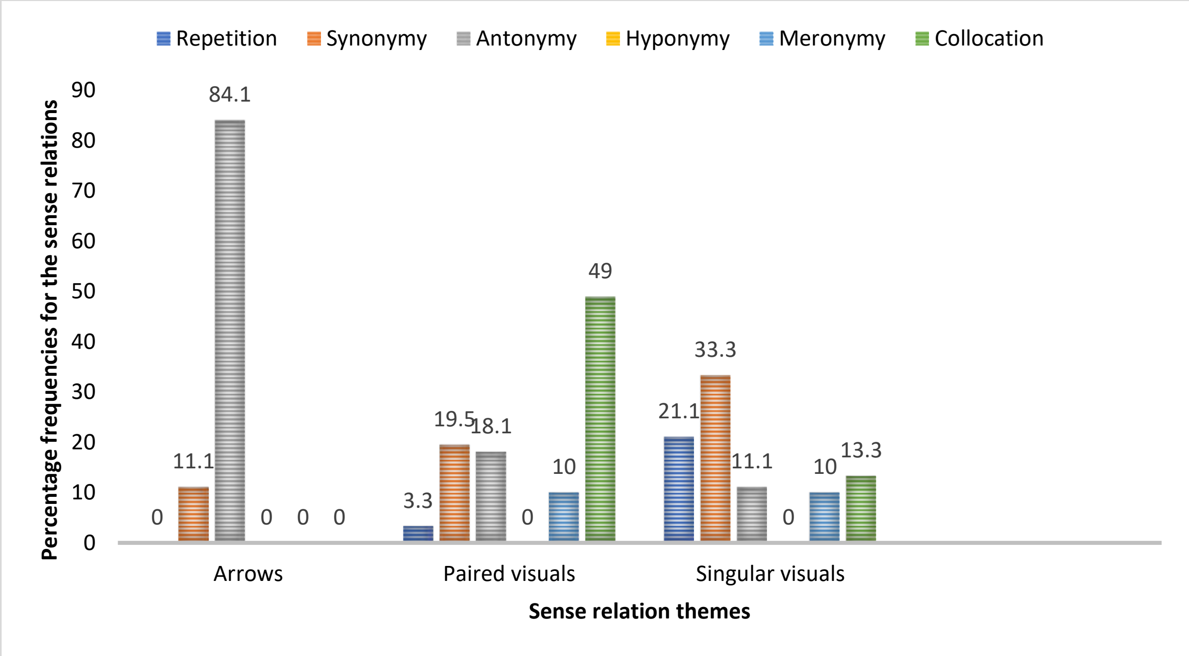


Figure 5.9: A graph showing the average percentage frequencies for the sense relations within the visual mode across all three Physical Sciences textbooks

The results for the average percentage frequencies for the sense relations within the visual mode across the three textbooks were consistent with results of individual textbooks. They revealed that the sense relations that occurred the most frequently within the visual mode across the three textbooks were antonymy, collocation, and synonymy. This result suggests that the affordances of these sense relations were prioritised within the visual mode of the topic Forces over other sense relations in communicating meaning. The results also indicated that the occurrence of antonymy and synonymy along the three themes is of inverse proportion. As the occurrence of antonymy within the visual mode decreased along the sense relation themes in a clockwise direction, the occurrence of synonymy increased in the opposite direction. This means that while antonymy occurred most frequently for the sense relation theme "arrows" (of which synonymy occurred the least), synonymy occurred the most frequently for the sense relation theme "singular visuals" (of which antonymy occurred the least). The results suggest that the sense relations were used differently within the visual mode.

5.3.2.1 The affordances of antonymy within the visual mode

The frequent occurrence of antonymy within the visual mode related to arrows suggests that they are significant for the learning of scientific knowledge in the topic of Forces. The diagram in Figure 5.10 is used to illustrate an example of antonymy within the visual mode. The diagram covers visuals showing two arrows that represent forces in opposite directions acting on the rope.

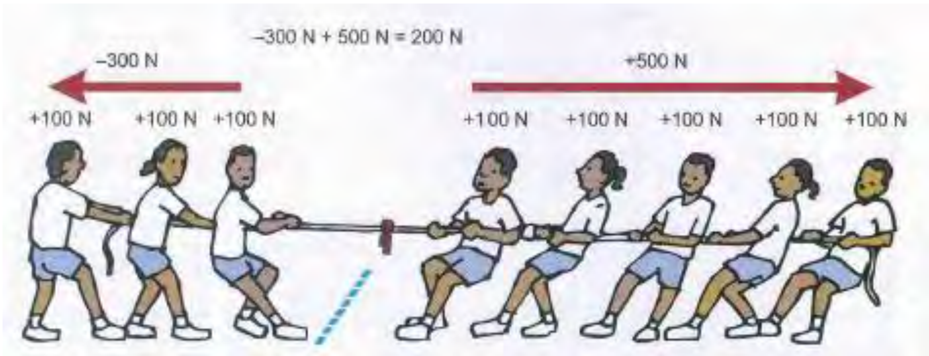


Figure 5.10: An example of a diagram from Textbook C illustrating antonymy within the visual mode (Van Niekerk, H. [2016]. *Solid Foundations Physical Science Grade 8 Learner's Book*. Windhoek: Namibia Publishing House [Pty] Ltd. pp. 90-109. Reprinted by permission of Namibia Publishing House [Pty] Ltd.)

In this figure, the children positioned on the left side pull the rope to their side with a force of 300 Newtons. Children on the right side also pull the rope to their side, but with a force of 500 Newtons. This example shows an action of two unbalanced forces, one to the left and the other to the right. The children on the right side will pull those on the left, forcing them to move because they exert greater force. The words *left* and *right* are visualised in the diagram (Figure 5.10) by two arrows facing opposite directions. The result suggests that arrows appearing within the visual mode are used for facilitating opposite meanings and corroborate findings of Heiser and Tversky (2006) which indicated that arrows in school textbooks are used as links between entities to signify existing relationships. It can thus be concluded from this result analysis that the occurrence of antonymy within visual modes in the topic of Forces in three Physical Sciences textbooks positively contributes to learning of scientific knowledge.

5.3.2.2 The affordances of collocation within the visual mode

The occurrence of collocation within the visual mode suggests that visuals are beneficial for meaning potential to be achieved in the topic of Forces for the three Physical Sciences textbooks. Instances of collocation for the sense relation theme "paired visuals" in Textbook A include the visuals showing a *fuel pump* and a *car* on the road. The diagrams in Figure 5.11 illustrate another example of collocation for the sense relation theme "paired visuals" from Textbook C.

Figure 5.11: Example of diagrams from Textbook C illustrating collocation within the visual mode (Van Niekerk, H. [2016]. ***Solid Foundations Physical Science Grade 8 Learner's Book*****. Windhoek: Namibia Publishing House [Pty] Ltd. pp. 90-109. Reprinted by permission of Namibia Publishing House [Pty] Ltd.)**

In this figure, the two visuals show examples of useful applications of friction, on the ground and in the air. The visual on the left represents *a tyre on the road surface*. The visual on the right represents a *parachutist flying in the air*. The two visuals are related through collocation. A further example of collocation for the sense relation theme "paired visuals" in Textbook C took into account the visuals showing a *hydroelectricity plant* and *solar panels.* The *hydroelectricity plant* and *solar panels* are both examples of renewable energy sources.

For the sense relation theme "singular visuals", example of collocation identified within the visual mode for Textbook A comprises of the visuals showing a *balance scale* and a *force* meter. In Textbook B, instances of collocation identified for this theme encompass the visuals showing *paper clips attracted to a magnet* and *hair attracted to a balloon*. The results did not reveal evidence of collocation occurring in the sense relation theme “arrows”.

The high occurrence of collocation for the sense relation theme “paired visuals” suggests the pairing of visuals in the topic of Forces for the three Physical Sciences textbooks was not done randomly, but rather based on meaning relations between the visuals (Biskri, 2012). Literature has also indicated that the co-occurrence of visuals which are closely related in meaning contribute to achieving cohesion within a text (He, 2014). In other words, this result indicated that the pairing of visuals in the topic of Forces was done to facilitate meaning between the visuals. It can thus be concluded that the occurrence of collocation within the visual modes of the topic Forces contributes to meaning potential of the three Physical Sciences textbooks.

5.3.2.3 The affordances of synonymy within the visual mode

Synonymy is important in achieving meaning potential in the topic of Forces in the three Physical Sciences textbooks. Example of synonymy identified for the sense relation theme “paired visuals” in Textbook A involve two visuals, one showing a *balance scale* and another showing an *analytical balance.* For the sense relation theme “singular visuals”, instances of synonymy include visuals showing *a diver falling from the top of a mountain* and *a sky diver falling to the earth*. In Textbook C, example of synonymy identified within the visual mode for the sense relation theme “arrows” is illustrated in Figure 5.12.

Figure 5.12: Example of diagrams from Textbook C illustrating synonymy within the visual mode (Van Niekerk, H. [2016]. ***Solid Foundations Physical Science Grade 8 Learner’s Book*****. Windhoek: Namibia Publishing House [Pty] Ltd. pp. 90-109. Reprinted by permission of Namibia Publishing House [Pty] Ltd.)**

In this figure, the meaning of the *arrow* along the apple that is kicked by the girl is synonymous to the meaning of the other *arrow* along the apple after it was kicked by the boy. Both *arrows* indicate the direction of movement for the apple after it was kicked by the two learners.

The high occurrence of synonymy within the visual mode of the topic Forces in the Physical Sciences textbooks for the sense relation theme "singular visuals" suggests that the visuals whose meanings are synonymous appear as singular items. This result is in contradiction with findings of Boucheix et al. (2012) which stated that the visuals in school science textbooks which are related are usually used together rather than independently. This means that when the visuals whose meanings are related appear as singular in the topic of Forces, it may lead to confusion as it becomes challenging to make sense of the meaning relations between the visuals. Furthermore, this may also be problematic in terms of achieving cohesion within the visual mode (Alyousef & Alnasser, 2015; Danglli & Abazaj, 2014). Literature also highlighted the importance of visuals in the understanding of scientific concepts (Darian, 2001), such as forces and energy in the topic of Forces. This understanding is strengthened when the visuals within scientific texts are not randomly used but organised in such a way that this contributes to meaning potential (Pintó & Ametller, 2002).

5.3.2.4 The affordances of other sense relations within the visual mode

Unlike the textual mode, **repetition** within the visual mode in the topic of Forces occurred less frequently. Example of repetition identified for the sense relation theme "paired visuals" from Textbook A include two visuals, one showing a pile of *coal* and another showing *coal* carried by a train. As already highlighted in Section 4.13, examples of some visuals are not included in this thesis because written permission from the copyright holder was not granted. For the sense relation theme "singular visuals", instances of repetition cover a visual showing a *lighted torch*. The photographs of a *lighted torch* appear in Textbook B on pages 130 and 134.

The possible reason for the unfrequently occurrence of repetition within the visual mode in the topic of Forces could be that photographs and diagrams require more space on the textbook pages compared to the textual mode, such as words. The reason is supported by Lee (2010), who suggested that the appearance of the visual mode in school science textbooks is facilitated by more economical use of space. Also, having visuals being repeated less might have resulted from learners not being required to reproduce visuals as frequently as words during their assessments. This difference in repetition occurring more frequently for one mode and less frequently for another, reminds us that sense relations have different affordances when used within different semiotic modes.

While **hyponymy** occurred within the textual mode of the topic Forces in the three Physical Sciences textbooks, the results did not reveal any evidence of this sense relation occurring within the visual mode. This result is compatible with Knain (2015) who argued that different modes have different affordances. This means that the three Physical Sciences textbooks place little emphasis on the learning of scientific knowledge within the visual mode through hyponymy. Considering the nature of science that requires learners to have knowledge of classification skills (Nosofsky et al., 2018), having this sense relation occurring less frequently within the visual mode of the topic Forces means that learners will be missing out on this important knowledge.

Meronymy is also important in achieving meaning potential in the topic of Forces in the three Physical Sciences textbooks. Examples of meronymy identified for the sense relation theme "singular visuals" in Textbook A encompass the visuals showing *a coal-fired power station* and the different parts within a coal-fired power station, such as *furnace, turbines,* and *generator*.

For the sense relation theme "paired visuals", instances of meronymy involve the visual showing a dynamo and its various parts, such as *shaft, magnet* and *coil of wire*. Figure 5.13 illustrate this example.

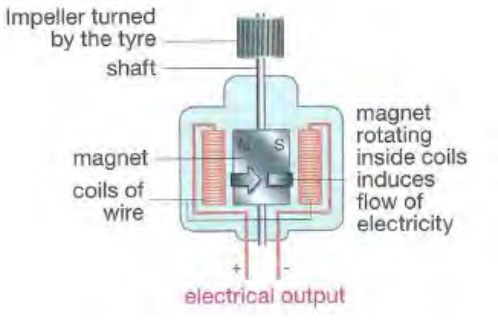


Figure 5.13: Example of a diagram from Textbook A illustrating meronymy within the visual mode (Reproduced by permission of Oxford University Press Southern Africa [Pty] Ltd. From *Physical Science Grade 8 Learner's Book* by R C Jones, M A Roebert, C L Larceda_© Oxford University Press Southern Africa 2016)

In this figure, the parts *shaft, magnet* and *coil of wire* are the meronyms of a dynamo, while the dynamo is the holonym of *shaft, magnet* and *coil of wire.*

In Textbook B, instances of meronymy identified for the sense relation theme "paired visuals" cover visuals showing a *car* and a *battery*. The two visuals are related because a *car* is a holonym of a *battery*, and a *battery* is a meronym of a *car*.

The occurrences of meronymy within the visual mode only for some textbooks may suggest that not all authors considered the affordances of that sense relation being useful in the topic of Forces. Another factor causing this difference could result from the fact that Textbook A and B have more visuals appearing in the topic of Forces compared to Textbook C (see Table 5.2), thus providing more opportunities for some visuals to fall under the category of whole and part-whole relations. Literature highlights the importance of visuals in scientific texts in that they are never used as fillers to fill up spaces on the page but play a significant role in helping learners to learn better (Royce, 1999). Furthermore, visuals assist readers of scientific texts in communicating science concepts better (Kress et al., 1998).

5.4 Phase 3: Analysis of *intersemiotic* complementarity between the textual and visual modes for the topic of Forces

In this section, the results are presented to explain how the textual and visual modes in the topic of Forces related in terms of *intersemiotic* complementarity. As already stated in Chapter Four, bar graphs are used indicating the percentage frequencies for the sense relations identified between the textual and visual modes in the topic of Forces per textbook. The percentage frequencies for the sense relations are used in explaining the meaning relations between the textual and visual modes. Figure 5.14 shows the percentage frequencies for the sense relations identified between the textual and visual modes in the topic of Forces.

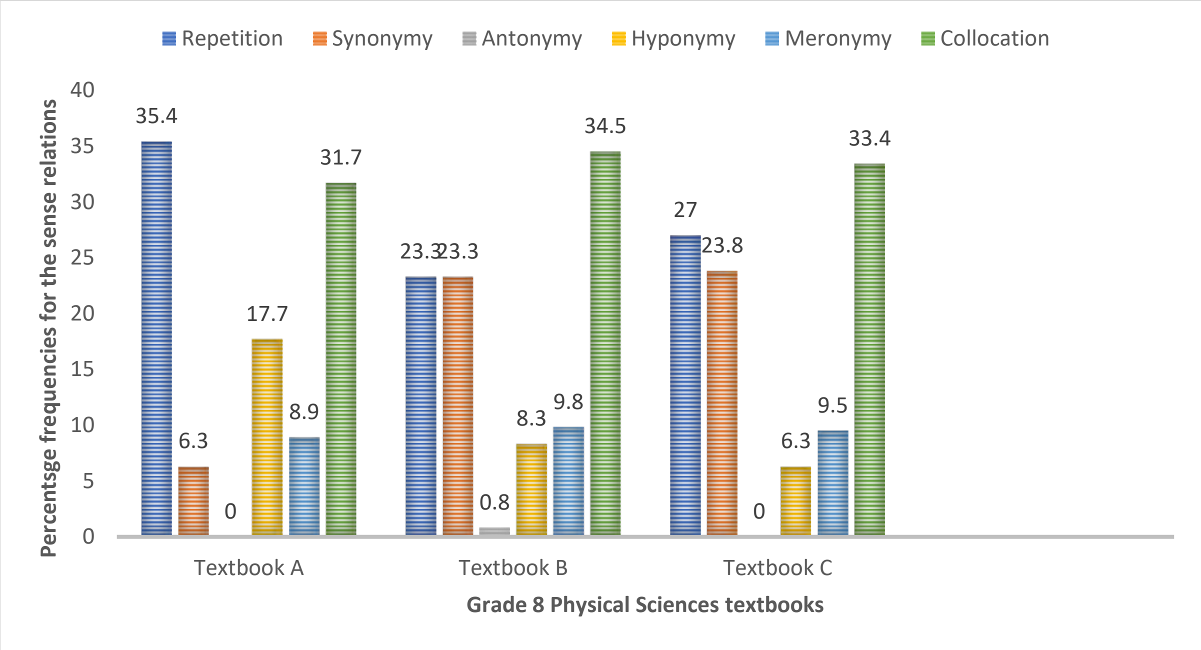


Figure 5.14: A graph showing the percentage frequencies for the sense relations identified between the textual and visual modes in all three textbooks

The results indicated that *intersemiotic* repetition was the most frequently occurring sense relation between the textual and visual mode for the topic of Forces in Textbook A. With Textbooks B and C, the most frequently occurring sense relation was *intersemiotic* collocation. The results for the relatively high occurrence of *intersemiotic* repetition and *intersemiotic* collocation indicated that both the textual and visual modes in the topic of Forces complement each other towards communicating and strengthening meaning potential of the three Physical Sciences textbooks.

5.4.1 The affordances of *intersemiotic* repetition as the most frequently occurring sense relation in Textbook A

Halliday and Matthiessen (2004) described repetition as the most direct form of cohesion. For Textbook A, this means that the high occurrence of *intersemiotic* repetition between the textual and visual modes in the topic of Forces can help in achieving cohesion (Danglli & Abajaz, 2014; Royce, 1999). For Textbooks B and C, the results suggest that there are missed opportunities for the affordances of repetition in supporting the learning content in the topic of Forces. Besides that, the results for this high occurrence are consistent with findings of Mayer

Steinhoff, Bower, and Mars (1995) which indicated that learners build connections between the textual and visual representations more easily when these are actively held in memory at the same time. An example of *intersemiotic* repetition identified between the textual and visual modes in this textbook include the textual elements, *as you step forward, you can push back on the other foot,* which were used together with the corresponding visual mode showing *a person's legs wearing shoes stepping on the ground*. Another example of *intersemiotic* repetition exists between the textual mode *brakes of bicycles*, and a visual showing *brakes on a bicycle*. There is also repetition between the textual mode *grooves on the tyres* and a visual showing *grooves on a bicycle tyre.* These visual materials from this textbook were also not included in this thesis due to written permission from the copyright holder not being received.

5.4.2 The affordances of *intersemiotic* collocation as the most frequently occurring sense relation in Textbook B and C

The results for the high occurrence of *intersemiotic* collocation suggest that the textual and visual modes in the topic of Forces in these Physical Sciences textbooks were semantically related and the communicating of scientific knowledge is mainly through the sense relation of collocation. The result corroborates findings of Royce (1999) which revealed that when the textual and visual modes co-occur in the same text, they both contribute to strengthened meaning via a relationship referred to as *intersemiotic* complementarity. In addition, *intersemiotic* complementarity is one of the mechanisms by which the Pedagogic Recontextualising Field (discussed in Chapter Two) could allow for specialised scientific knowledge in the three Physical Sciences textbooks to be pedagogised by authors/publishers for easily accessible to learners. Other scholars have indicated that *intersemiotic* collocation enhances the learning of scientific knowledge and contributes to cohesion (He, 2014; Myers, 1991). The results also suggest that there are missed opportunities for the affordances of collocation in supporting the learning content in the topic of Forces for Textbook A in which it occurred less frequently. Figure 5.15 illustrates an example of *intersemiotic* collocation identified between the textual and visual modes in in Textbook B.

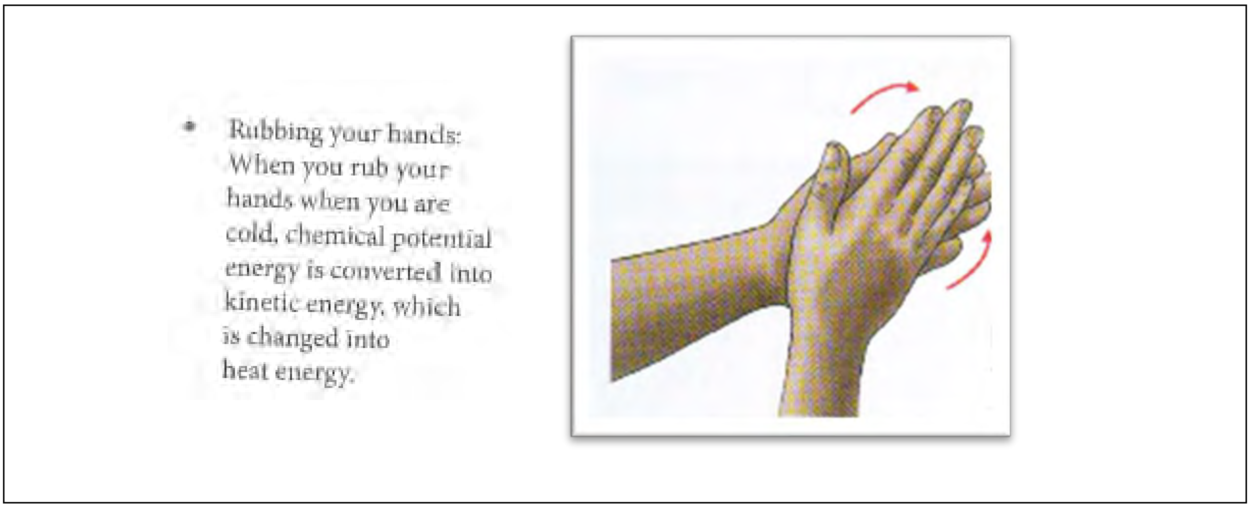


Figure 5.15: An example of a diagram from Textbook B illustrating *intersemiotic* collocation (*Platinum Physical Science Grade 8 Learner's Book*, M Haimbangu, A Poulton & B Rehder [1st ed.] 2016. Reprinted by permission of Pearson Education Namibia [Pty] Ltd.)

In this figure, an example of *intersemiotic* collocation considers the lexical item *kinetic energy* and a visual showing *two hands rubbing against each other.* Furthermore, the two arrows as displayed in the figure serve as additional features which help in strengthening the meaning communicated by the textual mode. The textual mode *heat energy* and a visual showing *two hands rubbing against each other* are intersemiotically related through collocation. The action of rubbing the hands together would generally result in heat energy being generated.

5.4.3 The affordances of other *intersemiotic* sense relations as the least frequently occurring sense relations across the three Physical Sciences textbooks

It is evident from the results that **hyponymy** and **meronymy** which occurred less frequently within the textual and visual modes of the topic Forces across the three Physical Sciences textbooks was more frequent as the modes were combined. This suggests that combining the textual and visual modes in the topic of Forces leads to strengthening of scientific meaning. The results corroborate findings of Royce (1999) which indicated that the visual and verbal modes work together in a multimodal text to communicate meaning which is stronger than meaning communicated by an individual mode. Combining the textual and visual modes in the topic of Forces for the three Physical Sciences textbooks enhances the opportunity for scientific knowledge being communicated through the sense relations of hyponymy and meronymy which would not be sufficiently addressed within the individual modes.

With *intersemiotic* **hyponymy**, the results across the three Physical Sciences textbooks revealed that intersemiotic hyponymy is one of the least frequently occurring sense relations between the textual and visual modes in the topic of Forces (see Figure 5.14). Hyponymy is known as one of the sense relations contributing to the acquisition of scientific knowledge. However, the results indicated that this sense relation contributes little to supporting the learning of scientific knowledge in the topic of Forces. The results further revealed that there are missed opportunities for classification learning between the textual and visual modes in this topic. As mentioned by Nosofsky et al. (2018), classification learning helps readers of scientific texts developing category-learning.

With *intersemiotic* **meronymy**, the results revealed that this sense relation is one of the least frequently occurring sense relations between the textual and visual modes in the topic of Forces (see Figure 5.14). Meronymy is identified as one of the significant sense relations in science education which plays a major role in enhancing the learning of part-whole relations (Royce, 1999). The results suggest that little emphasis is placed on the learning of scientific knowledge through part-whole relations in the topic of Forces. Furthermore, the relatively low occurrence of this sense relation between modes in the topic of Forces means that learners as the main readers of school science textbooks would benefit less on other affordances of this sense relation, such as contributing to constructing of relationships between science concepts (Nakakuwa, 2018). Moreover, it is important to note that science is a highly structured subject that consists of scientific facts, concepts, patterns, and principles that require *intersemiotic* meronymy to work interactively to make meaning (Nakakuwa, 2018). The visual modes in Figure 5.16 illustrate examples of *intersemiotic* meronymy identified in the topic of Forces.

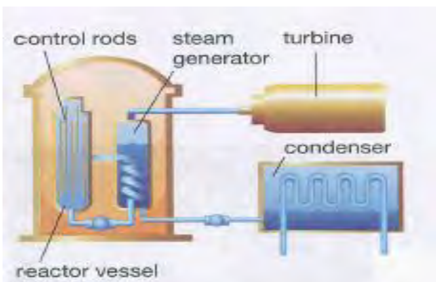


Figure 5.16: Example of a diagram from Textbook A illustrating *intersemiotic* meronymy (Reproduced by permission of Oxford University Press Southern Africa [Pty] Ltd. From *Physical Science Grade 8 Learner's Book* by R C Jones, M A Roebert, C L Larceda_© Oxford University Press Southern Africa 2016)

In this figure, the diagram represents the *different parts* of the nuclear power station. The different parts of the nuclear power station are labelled in the cross-section diagram as it appears in Figure 5.16. *Intersemiotic* meronymy is realised when the visual mode showing a *nuclear power station* is used together with the corresponding lexical items such as *condenser*, *reactor vessel* and *turbine*. The photograph of a *nuclear power station* was not included in this thesis because written permission from the copyright holder was not granted. For this example, the lexical items *condenser*, *reactor vessel*, and *turbine* represent the parts of the whole, while the visual mode *nuclear power station* refers to the whole.

According to Heiser and Tversky (2006), using diagrams is useful for effective teaching of complex scientific ideas. As highlighted in literature, the sub-topic energy is known to be "one of the most abstract ideas in physics" (Ibáñez & Ramos, 2004, p. 267) and one of the most difficult topics of secondary school science (Stylianidou, 2002). This means that using diagrams in relation to their corresponding textual elements in the topic of Forces results in better communication of scientific knowledge. Furthermore, using clearly labelled diagrams in combination with the written text, contributes to meaning potential in the topic of Forces (Koulaidis & Dimopoulos, 2006; Slough, McTigue, Kim, & Jennings, 2010).

With *intersemiotic* **synonymy**, the results across the three Physical Sciences textbooks revealed that this sense relation occurred less frequently between the textual and visual modes in the topic of Forces. This suggests that the communication of scientific meanings between the textual and visual modes within the topic of Forces through this sense relation has little impact on the meaning potential of the three Physical Sciences textbooks. According to Best, Dockrell, and Braisby (2006), exposing school textbook readers to *intersemiotic* synonymy helps them broaden their knowledge of scientific terms. Royce (1999) indicated that when the verbal and visual modes in multimodal texts are linked through *intersemiotic* synonymy, they can contribute to strengthened meaning which can lead to *intersemiotic* complementarity being achieved. The relatively low occurrence of *intersemiotic* synonymy between the textual and visual modes of the topic Forces means that learners will miss out on this opportunity of meaning. Figure 5.17 below illustrates an example of *intersemiotic* synonymy.

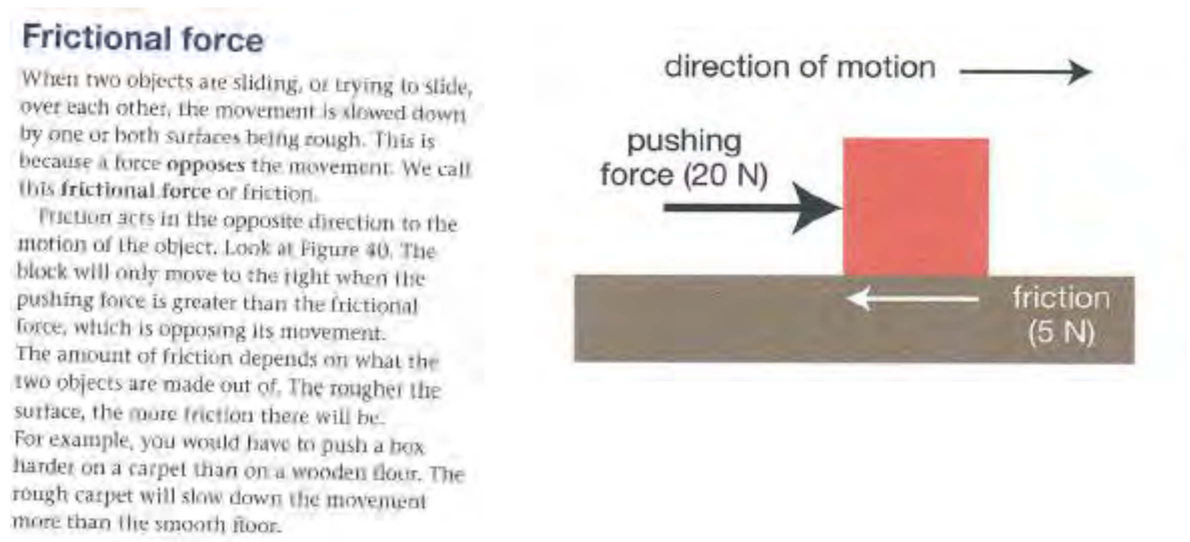


Figure 5.17: An example of a diagram from Textbook A illustrating *intersemiotic* synonymy (Reproduced by permission of Oxford University Press Southern Africa [Pty] Ltd. From *Physical Science Grade 8 Learner's Book* by R C Jones, M A Roebert, C L Larceda_© Oxford University Press Southern Africa 2016)

In this diagram, meaning communicated between the textual element *pushing force* and the visual showing a *thick arrow* to the right are synonymous. The same applies to meaning communicated between the textual element *friction* and the visual showing a *thin arrow* to the left. According to Savinainen et al. (2013), the visuals that keep track of all forces and their relative magnitudes (such as the one in Figure 5.17) are referred to as free-body diagrams. These important types of representations convey much information and are used in the teaching of forces (Savinainen et al., 2013).

With *intersemiotic* **antonymy**, the results indicated that this sense relation occurs less frequently between the textual and visual modes in the topic of Forces. Using intersemiotic antonymy in communicating scientific ideas between the textual and visual modes in the topic of Forces is beneficial to the acquisition of scientific knowledge. There are many concepts with opposite meanings in the topic of Forces which require the integration of the textual and visual modes for meaning to be communicated. Scientific concepts such as *upward force* and *downward force,* as well as *attract* and *repel* have opposite meanings, therefore using these concepts together with their corresponding visual modes can contribute to improved learning of scientific knowledge (Royce, 1999). Kacovsky (2015) cautioned that *intersemiotic* antonymy should be used with care as it could possibly be the cause of misconceptions. This could be a possible reason for antonymy occurring less frequently between the textual and visual mode in the topic of Forces in three Physical Sciences textbooks (see Figure 5.14). This results also corresponds with Nakakuwa's (2018, p. 82) findings that "generally, there are few opposite words or meanings in science that can contribute to the construction of knowledge".

5.5 Additional Findings

The findings presented in this section are relevant to the *intrasemiotic* sense relations of the textual mode, but not of direct relevance to the research questions. One of these finding was that the results indicated a high occurrence of simple lexical repetitions within the textual mode in the topic of Forces. Simple lexical repetition as discussed in Chapter Three involves lexical items that are exactly repeated (Zhong, 2013). Repetition of technical words in scientific texts is considered as beneficial to readers in that it helps to apprentice them into the discourse of science. However, if not used with care, this type of repetition can lead to text monotony.

Another finding revealed that the type of antonymy relations most identified between technical words within the textual mode of the topic Forces in the three Physical Sciences textbooks was canonical antonyms. As discussed in Chapter Three, canonical antonyms are common pairs of lexical items that automatically follow one another in free word association tasks. Examples of these antonymy pairs identified in the three Physical Sciences textbooks are: *contact force* and *non-contact force* as well as *renewable energy sources* and *non-renewable energy sources* (Haimbangu et al., 2016; Jones et al., 2016a; Van Niekerk, 2016). As outlined by Kacovsky (2015), using direct antonyms within the textual mode such as the ones mentioned in this paragraph can possibly avoid misconceptions by students.

5.6 Chapter Summary

In this section, the results for *intrasemiotic* sense relations within the textual and visual modes for the topic of Forces in three Namibian Physical Sciences textbooks were presented and discussed. Furthermore, the results explaining how the textual and visual modes in the topic of Forces related in terms of *intersemiotic* complementarity were presented. Bar graphs indicating the percentage frequencies for the sense relations occurring within and across the textual and visual modes in the topic of Forces were used in explaining the meaning relations within and between the textual and visual modes. Additional findings which were of relevance to the *intrasemiotic* sense relations of the textual mode, but not of direct relevance to the research questions, were also presented in this section. In the next chapter, the summary of findings from this research, the recommendations, limitations, and a conclusion will be presented.

CHAPTER SIX: SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

6.1 Introduction

It has been well placed in literature that the textual and visual modes each have their own affordances (Lemke, 2002). Studies on multimodal texts have also shown that both the textual and visual modes complement each other in strengthening and communicating meanings that cannot be communicated better by just one mode (Royce, 1999; 2007). There was no research found that was previously undertaken to analyse whether this is also the case for Namibian school science textbooks, for topics such as Forces which learners poorly perform in. This knowledge gap, together with learners' overall poor performance provided a strong rationale for analysing and understanding how the textual and visual modes were related in terms of *intersemiotic* complementarity for the topic of Forces in three Namibian Grade 8 Physical Sciences textbooks.

In this study, Systemic Functional Linguistics theory was employed as the lens through which the data was analysed. This research adopted a qualitative case study methodology in analysing the intrasemiotic sense relations within modes and how these are related in terms of *intersemiotic* complementarity for the topic of Forces in Namibian Physical Sciences textbooks. In this final chapter of the thesis, a summary of the overall findings of the study are presented and some recommendations for future research are provided. Lastly, the limitations of the study are explained, and the thesis concluded.

6.2 Summary of Findings

The textual and visual data was analysed in order to answer the two research questions. The summary of the findings will now be presented in relation to these research questions.

6.2.1 Research question One: What is the nature of the *intrasemiotic* sense relations for the topic of Forces in Physical Sciences textbooks?

6.2.1.1 Sense relations within the textual mode

The results indicated that synonymy and repetition were the most frequently occurring sense relations within the textual mode of the topic Forces in three Physical Sciences textbooks. This suggests that the affordances of these sense relations were prioritised over others in facilitating the learning of scientific knowledge in the topic of Forces. The high occurrence of synonymy within the textual mode of the topic Forces is beneficial as it leads to increased cohesion of the written text (Danglli & Abajaz, 2014). It also helps in avoiding textual monotony. This could be one of the possible reasons why synonymy occurred most frequently for the sense relation themes symbolic letters “arrows” and “numerical values”.

Although synonymy plays an important role in facilitating learning of scientific vocabulary, it occurred less frequently for the theme technical words which relates to keywords in the Physical Sciences textbooks that appear in bold font, highlighted in colour, or written in italics (Haimbangu et al., 2016; Van Niekerk, 2016). Learners as the main readers of these textbooks would stand a better chance of learning the vocabulary of science (Webb, 2007) if synonymy occurred with a higher frequency for the theme technical words. The results suggest that learners could be missing out on this opportunity because synonymy did not occur most frequently for this sense relation theme. This could be one of the possible contributing factors as to why learners perform poorly in the topic of Forces.

The results also revealed that the current definition of the concept weight in the topic of Forces in the three Physical Sciences textbooks may lead to confusion because the textbooks relate the concept weight to gravitational force. Since the two concepts are synonymous, this meaning relationship could cause confusion among students. Defining the concept weight as the product of an object’s mass and the local gravitational field could possibly address this confusion.

With repetition, the results indicated that this sense relation occurred most frequently for the sense relation themes “technical words” and “mathematical symbols”. These results suggest that there is cohesion within the textual mode in the topic of Forces. This is supported by Danglli and Abajaz (2014) as well as Naser and Almoisheer (2018) who indicated that writing which contains a high frequency of lexical repetition contributes to achieving overall cohesion within the text. This means that learners as the main readers of the three Physical Sciences textbooks are provided with an opportunity of better learning and understanding of scientific knowledge in the topic of Forces.

The results further indicated that the high occurrence of repetition of key words within the textual mode helps in clarifying the overall meaning of scientific text in the topic of Forces. Readers of the three Physical sciences textbooks are provided with a clue that a word may be technical when it is repeated more often. Although the occurrence of repetition within the textual mode is beneficial to the textbook readers, it is sometimes problematic when overused as Vogel (2010) cautioned. Learners as the main readers of these Physical Sciences textbooks may struggle in making sense of the content when key words are repeated more often, rather than sometimes replacing them with words from everyday language.

The results also revealed that the sense relations that occurred less frequently within the textual mode in the topic of Forces were collocation, hyponymy, antonymy, and meronymy. Although these occurred less frequently, literature indicated that they are useful in science education in terms of the affordances they offer. For example, collocation is an important organising principle in the vocabulary of scientific texts and contributes to coherence of written text (Biskri, 2012; Hadi & Jabir, 2011; He, 2014). Hyponymy is useful in science education as it helps learners develop the knowledge of classification skills which in turn helps them in developing category-learning (Nosofsky et al., 2018). Antonymy is useful in science education because it helps learners think of corresponding words with opposite meanings faster when exposed to direct antonyms. It is however problematic as indicated by Kacovsky (2015) that using indirect antonyms within the textual mode may lead to misconceptions by learners. Meronymy is useful in science education as it facilitates learning of whole and part-whole relations.

6.2.1.2 Sense relations within the visual mode

The results indicated that the sense relation which occurred most frequently within the visual mode in the topic of Forces in three Physical Sciences textbooks were antonymy, collocation, and synonymy. This suggests that the affordances of these sense relations were prioritised over others in facilitating the learning of scientific knowledge within the visual mode in the topic of Forces.

The results indicated that antonymy occurred most frequently between visuals related to arrows. This result suggests that the appearance of arrows within the visual modes in the topic of Forces contribute to meaning potential of the three Physical Sciences textbooks. This is supported by Heiser and Tversky (2006) who indicated that arrows in school textbooks are used as links between entities to signify existing relationships.

With collocation, the results indicated that this sense relation occurred most frequently for the visuals that were paired. These results showed that the pairing of visuals in the topic of Forces was done with the purpose of facilitating meanings between the visuals. This contributes to achieving cohesion within the visual mode.

With synonymy, the results indicated that this sense relation occurred most frequently for the visuals that appeared as singular. This high occurrence suggests that the visuals whose meaning are synonymous appear as singular in the topic of Forces. When visuals that are related in meaning appear independently in a textbook, as Boucheix et al. (2012) indicated, it can lead to confusion and this may negatively affect the meaning potential of a textbook as it may disturb cohesion within visuals. Therefore, readers may struggle in making sense of those visuals.

The results also revealed that the sense relations that occurred less frequently within the visual mode in the topic of Forces were repetition, hyponymy, and meronymy. While repetition occurred most frequently within the textual mode in the topic of Forces, hyponymy and meronymy occurred less frequently for both modes. Unlike the written text, photographs and diagrams require more space on textbook pages. Furthermore, learners as the main readers of Physical Science textbooks may not be required to reproduce visuals as frequently as words during assessments. The results revealed no evidence of hyponymy occurring within the visual mode in the topic of Forces. This result could be because this sense relation might not be applicable to the visual mode in the topic of Forces. On the other hand, the low occurrence of meronymy within the visual mode could be influenced by the differences in the number of visuals appearing with the topic of Forces for individual textbooks. Those with high number of visuals may be provided with more opportunities for affordances of the sense relations in the topic of Forces.

6.2.2 Research question Two: How are the textual and visual modes for the topic of Forces related in terms of *intersemiotic* complementarity?

The results indicated that the occurrence of *intersemiotic* sense relations in the topic of Forces across the three Physical Sciences textbooks differ. While *intersemiotic* repetition occurred most frequently between the textual and visual mode for the topic of Forces in Textbook A, *intersemiotic* collocation was the most frequently used sense relation in Textbook B and C. This difference in the occurrence of these *intersemiotic* sense relations suggests that it could be based on authors' understandings of which sense relations provide the best affordances in communicating scientific knowledge in the topic of Forces. For example, as it is stated in literature that repetition is the most direct form of cohesion, this could possibly be the reason which caused this sense relation to be used the most frequently in Textbook A.

For Textbooks B and C, the results suggest that there are missed opportunities for the affordances of repetition in supporting the learning content in the topic of Forces. The results further indicated that Textbook B and C considered *intersemiotic* collocation, which is also an aspect of cohesion, as significant in communicating meaning between the textual and visual modes in the topic of Forces. The results corroborate findings of Royce (1999) which revealed that when the textual and visual modes co-occur in the same text, they both contribute to strengthened meaning via a relationship referred to as *intersemiotic* complementarity. On the other hand, the low occurrence of *intersemiotic* collocation in Textbook A means that less opportunities are provided for the affordances of this sense relation in the topic of Forces. Altogether, the results indicated that both the textual and visual modes in the topic of Forces complement each other towards strengthening meaning in the topic of Forces.

The results also showed that while hyponymy occurred less frequently within the textual mode and that it was not evident within the visual mode in the topic of Forces (see Figures 5.5 & 5.9), this sense relation was however evident and occurred between the textual and visual modes across the three Physical Sciences textbooks. When used in scientific texts, hyponymy plays a significant role in facilitating classification learning as alluded by Nosofsky et al. (2018). Also, while meronymy occurred within the textual and visual modes only for some textbooks, when the modes were combined, this sense relation was evident in all three Physical Sciences textbooks. In multimodal texts, meronymy is useful as it facilitates the learning of part-whole relations (Royce, 1999). The results thus suggest that combining the textual and visual modes in the topic of Forces contributes to strengthened meaning.

In addition, the results revealed some inconsistencies in terms of the sense relations occurring most frequently within and across modes in the topic of Forces. While synonymy occurred most frequently within the textual and visual modes, it was less frequent as the modes were combined. However, consistency was noted for the sense relations repetition within the textual mode and collocation within the visual mode, which all occurred most frequent when the modes were combined. This means that the textual and visual modes in the topic of Forces in the three Physical Sciences textbooks were related intersemiotically through the sense relations of repetition and collocation. The results further indicated that both the textual and visual modes in the topic of Forces work together to contribute to meaning potential of the three Physical Sciences textbooks.

The results indicated that *intersemiotic* synonymy occurred less frequently between the textual and visual modes in the topic of Forces. This suggests that the communication of scientific meanings between the textual and visual modes within the topic of Forces through this sense relation has little impact on the meaning potential of the three Physical Sciences textbooks.

As with synonymy, *intersemiotic* antonymy also occurred less frequently between the textual and visual modes in the topic of Forces. Despite having this low occurrence, *intersemiotic* antonymy is beneficial to the acquisition of scientific knowledge as it helps in communicating scientific ideas. If not used with care, this sense relation can cause misconceptions as Kacovsky (2015) cautioned. This could be a possible reason for it being used less frequently between the textual and visual modes in the topic of Forces in three Physical Sciences textbooks.

6.3 Recommendations

It is significant that stakeholders in science education must have knowledge of how the textual and visual modes in school science textbooks complement each other in communicating meaning. This would benefit learners as the main readers by helping them in gaining better knowledge and understanding of science (Jamani, 2011). As mentioned in Chapter One, that there is no mention of textual-visual *intersemiotic* complementarity nor is there an indication for integration of modes in the main general criteria considered by NIED subject evaluation panel for selecting and evaluating school textbooks in Namibia, it is recommended that the NIED's subject evaluation panel should consider textual-visual *intersemiotic* complementarity as an evaluation and selection criteria for school science textbooks.

The recommendation for consideration of the textual-visual *intersemiotic* complementarity also applies to agencies associated with the Pedagogic Recontextualising Field, such as school science textbook authors/publishers when developing these learning materials. In addition, it is recommended that a further research with specific focus on the sense relations of hyponymy and meronymy be carried out to explore how their affordances contribute or not to learning of scientific knowledge between the textual and visual modes in the topic of Forces. Furthermore, it is worth conducting a similar study in other topics of the three Namibian Grade 8 Physical Sciences textbooks to explore textual-visual *intersemiotic* complementarity. This would help in expanding knowledge as to how the integration of textual and visual modes in those topics contribute to meaning via *intersemiotic* complementarity.

6.4 Limitations of the Study

As already mentioned in Chapter Four of this thesis, this study is a qualitative case study. It focused only on Namibian Grade 8 Physical Sciences textbooks that were approved by government to be used in public and private schools. In carrying out this study, the intention was not to analyse the whole textbook, but only one topic of many was purposively selected. For these reasons, the findings of this case study should not be generalised to other topics of the Grade 8 Physical Sciences textbooks or to the Physical Sciences textbooks of other grades.

The findings of this study contribute only one piece of the whole puzzle, as no attempt to analyse the textbooks in their entirety was done. Although this would be a bigger and more complex project, doing so could possibly reveal how the integration of textual and visual modes throughout the textbooks make meaning. It might also be found that some topics of Grade 8 Physical Sciences textbooks might use more sense relations for both the textual and visual modes than others. This could lead to differentiated meaning between the textual and visual modes in terms of *intersemiotic* complementarity. This area of concern could be addressed if the study focused on the whole textbook instead of one topic only.

6.5 Concluding Remarks

This study demonstrated that SFL theory is useful in understanding how the textual and visual modes interact in school science textbooks, such as the Physical Sciences textbooks to communicate meaning. Having mentioned earlier in Chapter One that no study has been carried out in Namibia that focused on analysing the textual and visual modes in terms of *intersemiotic* complementarity in Physical Sciences textbooks, this study has contributed to filling this gap. It was found that scientific knowledge within the textual mode in the topic of Forces is communicated mostly through synonymy and repetition while within the visual mode it is mostly through antonymy, collocation, and synonymy. While some sense relations occurred most frequently within the textual mode, they were less frequent in the visual mode and vice versa. The findings of this study agree with scholars such as Knain (2015) who argued that different modes have different affordances.

Since repetition being the most direct form of lexical cohesion (Halliday & Matthiessen, 2004) and collocation an aspect of this relation of meaning (Halliday & Hasan, 1985) were the most frequently occurring sense relations across modes in the topic of Forces, it suggests that authors of the three Physical Sciences textbooks tended to mainly use these sense relations in achieving cohesion which can strengthen the meaning potential in this topic. Furthermore, combining the textual and visual modes in the topic of Forces contributes to strengthened meaning through the sense relations of hyponymy and meronymy. This finding agrees with Royce (1999) who argued that combining the verbal and visual modes in multimodal texts contribute to *intersemiotic* complementarity being achieved.

Finally, the study has demonstrated *intersemiotic* complementarity as an important approach to multimodal discourse, allowing for exploration of meaning making across different semiotic modes in terms of the ideational and textual metafunctions. The study has also shown that this relationship is one of the mechanisms by which the Pedagogic Recontextualising Field could allow for specialised scientific knowledge within school science textbooks to be pedagogised so that it is easily accessible to readers.

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APPENDICES

Appendix A: Description and coding of the textual and visual modes

W = Words

TC-W = Technical words

PR-V = Paired visuals

AR = Arrows

S-V = Singular visuals

SYM-L = Symbolic letters

V = Visuals

M-SYM = Mathematical symbols

NV = Numerical values

A1. Textbook A

Textual mode	**Visual mode**
- Experiments boxes - Activities boxes - Examples boxes - Practical investigations boxes - Starter activity boxes - Use of different font sizes for titles, sub-titles - New **words** boxes **(TC-W)** - General objectives boxes - Some **text** appears in tables **(W)** - Use of figures - Use of **letters** in the main text **(SYM-L)** - Some points in the text are listed using bullets /numbers/letters - Some **words** appear bolded **(TC-W)** - Textual mode either appear left side or above the visual mode - Language used: WE or YOU - Some text appears within the visual mode	- A lot of visual modes appearing are **realistic/photographs (V)** - Some visual modes are labelled and some are not - Signs are used on some visual modes e.g. + , − **(M-SYM)** - **Arrows** are used on some visual modes **(AR)** - Some visual modes are in frames and some are not - Visual modes appear either on the right side or below the textual mode - Some visual modes contain **numerical values** within them **(NV)** - Some visual modes contain the textual mode - Visual modes appear in different sizes; some are big some are small - Some visual modes are **paired. (PR-V)**

- Frequent use of the **word** OBJECT **(W)** - Dialogue boxes - **New words** introduced in separate boxes and defined. Definitions of new words repeated at the glossary of textbook. **(TC-W)** - **New words** appear bolded in main text. **(TC-W)** - Textual mode is aligned with the left margin **(W)**	- Some visual modes are **drawn separate** from one another **(S-V)** - Visual modes are presented in a specific order, first realistic ones then less realistic - More visual modes appear in the sub-topic energy, while very few appear in the sub-topic work

Textbook B

Textual mode	**Visual mode**
- Practical investigations boxes - Topic tasks boxes - Self-assessment boxes - Specific objectives boxes - **Key concepts** boxes **(TC-W)** - Use of different **font sizes** for main titles, sub-titles - Some **text** appears in tables **(W)** - Use of figures - Some points in the text are listed using bullets /numbers/letters - Use of **letters** in the main text **(SYM-L)** - Textual mode either appear **right** side, **left**, **above** or **below** the visual modes - **Arrows** are used within text **(AR)** - Language used: WE or YOU - Some text appears within the visual mode - Frequent use of the **word** OBJECT **(W)**	- A lot of visual modes appearing are **realistic/photographs (V)** - Some visual modes are labelled and some are not - **Arrows** are used on some visual modes **(AR)** - Some visual modes are in **frames** and some are not - Visual modes appear either on the **left side**, **right** side or **below** the textual mode - Some visual modes contain **numerical values** within them **(NV)** - Some visual modes contain textual mode - Visual modes appear in **different sizes**; some are big some are small - Some visual modes are **paired (PR-V)** - Some visual modes are drawn separate from one another **(S-V)**

- **Key words** introduced in separate boxes and briefly explained **(TC-W)** - **New words** in the main text appear either bolded or highlighted in colour **(TC-W)** - Textual mode is either aligned with the **left margin** or **right margin** - Textual mode inform reader what to expect next e.g. You will learn more about this in topic 5 or see figure 12 - Textual mode also inform reader what is covered earlier in sub-topic e.g. Earlier in this unit, you learnt about push and pull forces.	- Visual modes are presented in a specific order, first realistic ones then less realistic - More visual modes appear in the sub-topic energy, while very few appear in the sub-topic work

A3. Textbook C

Textual mode	**Visual mode**
- Activities boxes - Worked examples boxes - Use of figures - **Key words** boxes **(W)** - Use of different font sizes for main titles, sub-titles - Some points in the text are listed using bullets - Use of **letters** in the main text **(SYM-L)** - Some words appear bolded, and others in italic - Textual mode either appear on left side or above the visual mode - **Signs** are used within text e.g. × **(M-SYM)** - Arrow are used within textual mode - Language used: WE	- A lot of visual modes appearing are **realistic/photographs (V)** - Some visual modes are labelled and some are not - Signs are used on some visual modes e.g. + , − **(M-SYM)** - **Arrows** are used on some visual modes **(AR)** - Some visual modes are in frames and some are not - Visual modes appear either on the right side or below the textual mode - Some visual modes contain **numerical values** within them **(NV)** - Some visual modes contain textual mode

- Some text appears within the visual mode - Frequent use of the word OBJECT **(W)** - **Key words** introduced in separate boxes and defined. **(TC-W)** - **Key words** also appear **bolded** in main text and defined. **(TC-W)** - Other words in the main text in addition to new words also appear in italics - **Textual mode** is aligned with the left margin **(W)** - Textual mode inform reader what to expect next e.g. see figure 5.7 - Textual mode also inform reader what is covered earlier in a sub-topic e.g. In the example in figure 5.1, different kinds of force were involved in causing the effects shown in the figure.	- Visual modes appear in different sizes; some are big some are small - Some visual modes are **paired (PR-V)** - Some visual modes are drawn **separate** from one another **(S-V)** - More visual modes appear in the sub-topic energy, while very few appear in the sub-topic work

Appendix B: Categories of data within the textual mode

B 1. Textbook A

<table>
<tr><th>Themes</th><th colspan="2">Examples referred to within main text</th></tr>
<tr><td rowspan="2">1. Technical words</td><td>Highlighted (bolded) within main text</td><td>Not highlighted within main text</td></tr>
<tr><td>Friction, gravity (p.90), contact forces, exert (p.91), non-contact force, magnetism (p.92), compass (p.93), mass, matter, balance (p.95), weight, spring balance (p.96), calibrate (p.97), gravitational field strength (p.98), kinetic energy, potential energy (p.107), non-renewable, renewable (p.110), opposes, frictional force (p.115)</td><td>Motion (p.90), applied force (p.90), tension force (p.90), spring force (p.90), air resistance (p.90), acceleration (p.92), laboratory (p.95), speed (p.90), power (p.91), newton (p.98), gram/kilogram (p.98), electrons p.105), conservation (p.109), joule/kilojoule (p.105), particles (p.105),</td></tr>
<tr><td>2. Symbolic letters</td><td colspan="2">N: newton (p.90)
g: gram (p.95)
kg: kilogram (p.95)
w: weight (p.99)
m: mass (p.99)
g: Earth’s gravitational field strength (p.99)
J: Joule (p.105)
kJ: Kilojoule (p.105)
m: metres (p.100)
W: work (p.100)
F: force (p.100)</td></tr>
</table>

	d: distance (p.100) **N:** north pole (p.111) **S:** South pole (p.111) CO_2**:** Carbon dioxide (p.112)
3. Arrows	None
4. Numerical values	50kg, 500N, 10N/Kg, 5N, 20N, 25Kg
5. Mathematical symbols	+, − (p.111), × , = (p.100)

B2. Textbook C

Themes	**Examples referred to within main text**	
1. Technical words	**Highlighted (bolded) within main text**	**Not highlighted within main text**
	At rest (p.90), contact force, gravity, non-contact force, attraction, repulsion (p.91), newton, vector (p.93), mass, weight (p.96), Work, energy, kinetic energy, potential energy (p. 103), law of conservation of energy, renewable energy sources, hydroelectricity, biomass, array, lubricant, ball bearings, streamlined (p.109), Friction, air resistance, water resistance, rolling (p.109).	Magnetic force, electrostatic force, magnet, electrostatic charge (p.91), applied force, force meter (p.93), net force (p.94), Matter, kilogram, beam balance, electronic scale, spring balance, force meter (p.96), gravitational field strength (p.97), joules, particles (p.103), conductor (p.103), electromagnetic waves, atoms, molecules, nucleus, sound energy, electrical energy, light energy, heat energy, stored energy, gravitational energy, chemical energy, elastic energy, nuclear energy (p.103),

		photosynthesis, biomass, methane,
2. Symbolic letters	**N:** newton (p.93) **w:** weight (p.97) **m:** mass (p.97) **g:** Earth's gravitational field strength (p.97) **J:** Joules **Nm:** newton metre **m:** metres **W:** work done **F:** force **d:** distance	
3. Arrows	Input energy → energy converter → output energy	
4. Numerical values	10N, 1kg, +300N, -300N, +100N, +500N, 250N, 50cm, 7kg,	
5. Mathematical symbols	−, +, ×, =	

B3. Textbook B

Themes	Examples referred to within main text	
1. **Technical words**	**Highlighted (bolded) within main text**	**Not highlighted within main text**
	Contact force, non-contact force, Electrostatic force, gravitational pull (p.112), attract, newton (p.113), mass, weight (p.119), Gravitational field strength (p.121), Kinetic energy (p.130), Potential energy (p.129), renewable energy sources (p.130), Battery (p.129), heat energy (p.130), biomass (p.131), power station (p.133), non-renewable energy sources (p.134), alternative energy (p.134), Friction, Drag, Air resistance	Exert (p.110), push force, pull force (p.110), deformation (p.110), motion (p.111), field force, magnetic force (p.112), repulsion (p.113), laws of motion (p.113), free-body diagrams, spring balance (p.115), particles, matter, atoms (p.119), chemical reaction, oxygen, electrical energy (p.129), solar energy (p.131), methane, geothermal power station, (p.132), nuclear energy (p.133), greenhouse gases, radioactive chemicals, nuclei (p.134),
2. **Symbolic letters**	**N:** North pole (p.113) **S:** South pole (p.113) **N:** newton (p.113) **m:** mass (p.121)	

	g: gravitational field strength (p.121) **w**: weight (p.121) **kg**: Kilogram (p.119) **km:** kilometre (p.134)
3. Arrows	Chemical energy → light energy + heat energy Chemical energy → kinetic energy Chemical potential energy → kinetic energy → heat energy (p.135)
4. Numerical values	$10N, 6N, 1N/kg,\ 100g, 10kg,\ 35kg$ $350N,\ 130km, 50km,\ 170km, 10N/kg$, 10g
5. Mathematical symbols	× , = (p.121)

Appendix C1: Intrasemiotic sense relation within the textual mode (Textbook A)

Themes	**Examples from textbook**		**Intrasemiotic sense relations**	**Pages**
1. Technical words	Contact force	Contact force	Repetition	91
		Object that are touching each other	Synonymy	91
		Normal force	Hyponymy	91
		Applied force	Hyponymy	91
		Frictional force	Hyponymy	91
		Tension force	Hyponymy	91
		Spring force	Hyponymy	91
		Air resistance	Hyponymy	91
		Non-contact force	Antonymy	92
		Exert	Collocation	91
		Pull	Collocation	91
		Push	Collocation	91
		Size	Collocation	94
		Direction	Collocation	94

	Non-contact force	Non-contact forces	Repetition	92
		Act over a distance	Synonymy	92
		Gravitational force	Hyponymy	92
		Contact force	Antonymy	91
		Gravitational pull	Hyponymy	92
		Electrical force	Hyponymy	92
		Magnetism	Hyponymy	92
		Acceleration of the earth	Collocation	92
		Size	Collocation	94
		Direction	Collocation	94
	Mass	Mass	Repetition	95-99
		Amount of matter in an object	Synonymy	95
		Weight	Collocation	95

		Bathroom scale	Collocation	95
		Kitchen scale	Collocation	95
		Chemical balance	Collocation	95
		Analytical balance	Collocation	95
		Triple beam balance	Collocation	95
		Kilograms	Collocation	95
	Weight	Weight	Repetition	96-99
		Pull force	Synonymy	95
		Earth's gravitational pull	Synonymy	95
		Newton	Collocation	96
		Spring balance	Collocation	96
		Earth	Collocation	95-98
		Mass	Collocation	95
		Gravity	Synonymy	95
		Force	Hyponymy	95

		Gravitational field strength	Collocation	98
	Kinetic energy	Kinetic energy	Repetition	107
		Potential energy	Collocation	107
		Moving energy	Synonymy	107
		Light energy	Hyponymy	108
		Electrical energy	Hyponymy	107
		Moving	Collocation	107
		Movement	Collocation	108
		Motion	Collocation	108
		Falls	Collocation	108
		Law of conversation of energy	Collocation	109
	Potential energy	Potential energy	Repetition	107-108
		Stored	Collocation	107
		Kinetic energy	Collocation	107

		Gravitational potential energy	Hyponymy	107
		Elastic potential energy	Hyponymy	107
		Chemical potential energy	Hyponymy	107
		Law of conservation of energy	Collocation	109
	Friction	Friction	Repetition	115-121
		Frictional force	Synonymy	115
		Air resistance	Hyponymy	120
		Force opposes movement	Synonymy	115
		Opposite	Collocation	115-117
		Direction	Collocation	115-117
		Smooth surface	Collocation	115
		Rough surface	Collocation	117
		Force	Hyponymy	117
		Slow down	Collocation	117

		Stop	Collocation	117
		Slipping	Collocation	117
		Wear down	Collocation	118
		Ball bearing	Collocation	118
		Streamlined bodies	Collocation	121
	Renewable energy sources	Renewable energy sources	Repetition	110-112
		Can be replaced	Synonymy	110
		Solar energy	Hyponymy	111
		Hydroelectric power	Hyponymy	111
		Wind energy	Hyponymy	111
		Biofuel energy	Hyponymy	111
		Geothermal energy	Hyponymy	111
		Non-renewable energy sources	Antonymy	110

	Gravity	Gravity	Repetition	90-96
		Force	Hyponymy	90
		Friction	Collocation	90
		Motion	Collocation	90
		Mass	Collocation	90
		Force of attraction	synonymy	90
		Falls	Collocation	90
		Pulling force	Synonymy	90
		Pushing up	Antonymy	90
		Contact force	Antonymy	91
		Non-contact force	Collocation	92
		Earth	Collocation	92
		Gravitational pull	Synonymy	92
		Acceleration of the Earth	Collocation	92
		Sun	Collocation	92
		Magnitude	Collocation	94

		Direction	Collocation	94
		Downward force	Synonymy	94
		Weight	Synonymy	95
		Upward force	Antonymy	94
		Moon	Collocation	95
		Exert	Collocation	96
		Newton	Collocation	96
		Gravitational field strength	Collocation	98
2. Symbolic letters	N	newton	Synonymy	90
	N	force	collocation	90
	Kg	kilogram	synonymy	95
	Kg	mass	collocation	95
	g	gram	synonymy	95
	g	mass	collocation	95
	g	Kg	collocation	95
	Kg	Kg	repetition	95
	g	g	repetition	95

	N	Kg	collocation	96
	m	mass	synonymy	99
	m	weight	collocation	99
	g	Gravitational field strength	synonymy	99
	m	grams	collocation	99
	m	m	repetition	99
	w	w	repetition	99
	g	g	repetition	99
	W	work	synonymy	100
	W	W	repetition	100
	J	joule	synonymy	100
	W	force	collocation	100
	d	distance	synonymy	100
	W	d	collocation	100
	d	d	repetition	100
	F	force	synonymy	100
	F	F	repetition	100

	m	metre	synonymy	100
	m	d	collocation	100
	J	J	repetition	100
	kJ	kilojoule	synonymy	105
	kJ	J	collocation	105
	CO_2	gasses	collocation	112
	CO_2	Global warming	collocation	112
3. Arrows	-	-	-	-
4. Numerical values	50Kg	Mass	synonymy	96
	500N	Weight	collocation	96
	10 newtons	Force	synonymy	98
	10N/Kg	Earth's gravitational field strength	synonymy	98
	10N/Kg	10N/Kg	repetition	99
	10 newtons	10 newtons	repetition	100
	20N	Force	synonymy	115
	5N	force	synonymy	115

	20N	20N	repetition	115-117
	5N	5N	repetition	115-117
5. Mathematical symbols	×	×	repetition	100
	×	=	collocation	100
	=	=	repetition	100
	+	+	repetition	111
	–	–	repetition	111
	+	–	antonymy	111

Appendix C2: Intrasemiotic sense relation within the textual mode (Textbook B)

Themes	Examples from textbook		Intrasemiotic sense relations	Pages
1. Technical words	Contact force	Physical force	synonymy	112
		touch	synonymy	112
		Touching	synonymy	112
		Push force	Collocation	113
		Pull force	collocation	113
		Friction	hyponymy	112
		Contact force	Repetition × 5	112
		Motion	collocation	111
		Push a desk	hyponymy	112
		Pull a desk	hyponymy	112
		Not in contact	antonymy	112
		Non-contact force	antonymy	112
		Touch each other	synonymy	112
		Touching an object	Synonymy	112

		Touches an object	Synonymy	112
		Object touch each other	synonymy	112
		Kick a ball	hyponymy	112
		pulls	collocation	114
		direction	collocation	114
	Non-contact force	Non-contact force	Repetition × 4	112
		Not in contact	synonymy	112
		Without being touched	synonymy	112
		Act at a distance	synonymy	113
		Weight	hyponymy	112
		Gravitational pull	hyponymy	112
		Magnetic force	Hyponymy	112
		Electrostatic force	Hyponymy	112
		Contact force	antonymy	112
		Touch each other	antonymy	112

		Not touching each other	synonymy	113
		Without touching	Synonymy	113
		Gravitational force	hyponymy	1112
		fall	collocation	112
		Drop	collocation	113
		Electrostatics	Collocation	113
		repulsion	Collocation	113
		Attraction	Collocation	113
		Direction	Collocation	114
	Mass	Mass	Repetition × 20	119
		Particles in an object	Synonymy	119
		Amount of matter in object	Synonymy	119
		Atoms	collocation	119
		Weight	Collocation	119

		kilogram	collocation	119
	Weight	Weight	Repetition × 19	119
		Gravitational force	Synonymy	119
		Newton	collocation	119
		Spring balance	Collocation	119
		mass	collocation	119
		Force	synonymy	119
		Gravitational field force	collocation	121
	Kinetic energy	Kinetic energy	Repetition × 7	130-135
		Movement	collocation	130
		Potential energy	Collocation	129
		Jumping	Collocation	135
		Rubbing your hand	Collocation	135
		Throwing a ball	Collocation	134

		motion	collocation	130
	Potential energy	Potential energy	Repetition × 2	129
		Stored energy	synonymy	129
		Kinetic energy	collocation	130
		Gravitational potential energy	hyponymy	129
		Strain potential energy	Hyponymy	129
		Chemical potential energy	hyponymy	129
	Friction	friction	Repetition × 40	119
		Forces that opposes motion	Synonymy	137
		Act in opposite direction	Synonymy	137
		Resists movement	synonymy	137
		Opposes motion	synonymy	140
		In contact	collocation	137

		Warms up	Collocation	137
		Mass of object	Collocation	138
		Smooth surface	Collocation	138
		Hard surface	Collocation	138
		Rough surface	Collocation	138
		Coarse surface	Collocation	138
		Soft surface	Collocation	138
		Wear away	Collocation	139
		Heat up	collocation	139
		Air resistance	hyponymy	140
		Slow down	Collocation	137
		Stop moving	Collocation	137
	Renewable energy sources	Renewable energy sources	Repetition × 3	130
		Renewable sources of energy	repetition	131
		Solar energy	hyponymy	131

		Wind energy	Hyponymy	131
		Water energy	hyponymy	132
		Wave energy	hyponymy	132
		Biomass energy	hyponymy	132
		Geothermal energy	hyponymy	132
		Tidal energy	hyponymy	133
		Re-used	synonymy	130
		Wood	Collocation	132
		Replenished	synonymy	130
		Renewed	synonymy	130
		Used up	Antonymy	130
		Sources not replenished	Antonymy	130
		Non-renewable energy sources	Antonymy	130
	Gravity	Gravitational pull	Synonymy	112
		Force	hyponymy	112

		Weight	Synonymy	112
		Non-contact force	Hyponymy	112
		Forces that act vertically	collocation	115
		Falls from a tree	Collocation	115
		Downward force	Synonymy	115
		Upward force	Antonymy	115
		Air friction	Collocation	115
		Gravitational force	Synonymy	119
		Earth	Collocation	119
		Attraction	Collocation	119
		Gravitational field strength	Collocation	121
2. Symbolic letters	North pole	N	Synonymy	113
	South pole	S	Synonymy	113
	N	N	Repetition	113
	N	Newton	Synonymy	113
	N(newton)	N	Repetition	113

	N (Newton)	Kg	Collocation	113
	Kg	Kilogram	Synonymy	119
	Kg	Kg	Repetition	119
	Kg	Mass	Collocation	119
	g	Gravitational field strength	synonymy	121
	g	g	repetition	121
	m	Mass	Synonymy	121
	m	m	repetition	121
	w	Weight	synonymy	121
	w	w	repetition	121
	km	km	repetition	134
3. Arrows	• Chemical energy → light energy + heat energy • Chemical energy → kinetic energy			
	→	Changed	Synonymy	134
	+	and	synonymy	134
	→	→	repetition	134

4. Numerical values	10N	force	synonymy	114
	6N	force	synonymy	114
	10N	10N	repetition	114
	6N	6N	repetition	114
	100g	1N	synonymy	115
	35Kg	35Kg	repetition	119
	35Kg	mass	synonymy	119
	1Kg	10N	synonymy	121
	10Kg	Mass	synonymy	119
	10Kg	10Kg	repetition	119
	350N	Force	synonymy	119
	10N/Kg	1Kg is 10N	repetition	121
	10g	Gravitational field strength	synonymy	121
	130km	170km, 50km	collocation	133
5. Mathematical symbols	×	×	repetition	121
	×	times	synonymy	121

	×	=	collocation	121 & 124
	=	=	repetition	121 & 124

Appendix C3: Intrasemiotic sense relation within the textual mode (Textbook C)

Themes	**Examples from textbook**		**Intrasemiotic sense relations**	**Pages**
1. Technical words	Contact force	Contact force	Repetition × 2	91
		Came into contact	Synonymy	91
		Object touches another	Synonymy	91
		Non-contact force	Antonymy	91
		Kicked apple	Hyponymy	91
		Direction	Collocation	91
		pulls	collocation	94
	Non-contact force	Non-contact force	Repetition × 5	91
		Act at a distance	Synonymy	91
		Without contact	Synonymy	91
		Contact force	Antonymy	91
		Gravity	hyponymy	91
		Magnetic force	Hyponymy	91

		Electrostatic force	hyponymy	91
		Fallen to the ground	Collocation	91
		Attraction	Collocation	91
		Repulsion	collocation	91
	Mass	Mass	Repetition × 13	96-97
		Amount of matter in object	Synonymy	96
		Weight	Collocation	96
		Beam balance	Collocation	96
		Electronic scale	collocation	96
		Kilogram	collocation	96
		Measure	Collocation	96
		Force	collocation	96
	Weight	Weight	Repetition × 11	96-97
		Downward force	Synonymy	96

		Force of gravity	Synonymy	96
		Newtons	Collocation	96
		Spring balance	Collocation	96
		Force meter	Collocation	96
		Mass	Collocation	96
		Force	hyponymy	96
		Earth's gravitational field strength	collocation	97
	Kinetic energy	Kinetic energy	Repetition × 5	103-106
		Sound energy	Hyponymy	103
		Electrical energy	Hyponymy	103
		Light energy	Hyponymy	103
		Heat energy	Hyponymy	103
		Work	Collocation	103
		Moving object	Collocation	103
		Motion	Collocation	103

		Energy conversion	Collocation	104
	Potential energy	Potential energy	Repetition × 3	103
		Stored energy	Synonymy	103
		Kinetic energy	Collocation	103
		Gravitational energy	Hyponymy	103
		Elastic energy	Hyponymy	103
		Nuclear energy	Hyponymy	103
		Chemical energy	Hyponymy	103
		Chemical potential energy	Hyponymy	103
		Work	Collocation	103
		Energy conversion	Collocation	104
	Friction	Friction	Repetition × 39	107-110
		Against movement	Synonymy	107
		Fluid friction	Hyponymy	107

		Air resistance	Hyponymy	107
		Water resistance	Hyponymy	107
		Contact force	Collocation	107
		Smooth surface	Collocation	107
		Speed at which object move	Collocation	107
		Soft surface	Collocation	107
		Hard surface	Collocation	107
		Rough surface	Collocation	107
		Slow down	Collocation	108
		Hold object together	Collocation	108
		Wear away	Collocation	108
		Vehicle skidding	Collocation	108
		Lubricant	Collocation	109
		Ball bearing	Collocation	109
		Stop moving	Collocation	108
		Streamlined	Collocation	109

	Renewable energy sources	Renewable energy sources	Repetition × 8	105-106
		Can be replaced	Synonymy	105
		Hydroelectricity	Hyponymy	105
		Solar power	Hyponymy	105
		Wind energy	Hyponymy	105
		Biomass	Hyponymy	105
		Non-renewable energy sources	Antonymy	105
	Gravity	Gravity	Repetition × 10	91
		Force	Hyponymy	91
		Force that acts at a distance	Collocation	91
		Earth	Collocation	91
		Non-contact force	Hyponymy	91
		Gravitational field strength	Synonymy	97

		Mass	Collocation	97
		Weight	Synonymy	97
2. Symbolic letters	N	force	collocation	96
	N	N	repetition	96
	N	Kg	collocation	96
	N	weight	collocation	96
	Kg	mass	collocation	96
	Kg	weight	Collocation	96
	N	newton	Synonymy	93
	N	N	Repetition	94
	N	Force meter	meronymy	93
	w	weight	synonymy	97
	w	N (newton)	collocation	97
	w	w	repetition	97
	m	mass	synonymy	97
	m	m	repetition	97
	m	Kg	collocation	97

	g	Earth's gravitational field strength	synonymy	97
	g	g	repetition	97
	W	work	synonymy	100
	F	force	synonymy	100
	d	distance	Synonymy	100
	m	metre	Synonymy	100
	J	Joule	synonymy	100
	W	W	repetition	100
	F	F	repetition	100
	d	d	repetition	100
	J	J	repetition	100
	Nm	1N × 1m	synonymy	100
	J	work	collocation	100
	m (metre)	distance	collocation	100
	J	Nm	synonymy	1

3. Arrows	• Input energy → energy converter → output energy			
	→	Converted to	Synonymy	104
	→	→	repetition	104
4. Numerical values	–300N	force	synonymy	94
	–300N	–300N	repetition	94
	+300N	force	synonymy	94
	+300N	+300N	repetition	94
	+100N	force	synonymy	94
	+100N	+100N	repetition	94
	+500N	force	synonymy	94
	+500N	+500N	repetition	94
	10N	force	synonymy	96
	10N	10N	repetition	96
	1Kg	mass	synonymy	96
	1Kg	1Kg	repetition	96
5. Mathematical symbols	+	positive	synonymy	93 & 94

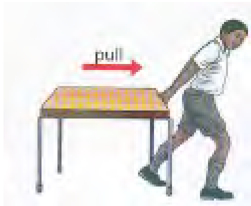
	–	negative	synonymy	93 & 94
	+	–	antonymy	94
	+	+	repetition	94
	–	–	repetition	94
	=	=	repetition	94
	=	+	collocation	94
	=	×	collocation	97
	×	multiplication	Synonymy	97
	×	×	repetition	97
	operation	×	hyponymy	97

Appendix E: Analytical memo for intersemiotic sense relations across the modes

E2. Textbook B

Main text: "Think of a situation where your teacher asks you to help rearrange the classroom by moving the desks around. You would have to either push or pull each desk across the room. In doing so, you will exert a force on the desk to get it to move. So, we can say that a force is a push force or a pull force" (p. 110)

Corresponding visual modes:

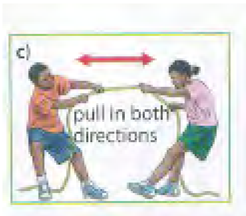


Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
Moving the desk around	Visual showing two persons, one pushing and another pulling a desk	The meaning across two modes are related through **synonymy**
Push each desk	Visual showing a person pushing a desk	The meaning across two modes are related through **repetition**
Pull each desk	Visual showing a person pulling a desk	The meaning across two modes are related through **repetition**

Exert a force on the desk	Visual showing two persons pushing and pulling the desk	The meaning across the two modes are related through **synonymy**
Push force	Visual showing an arrow labelled push	The meaning across the two modes are related through **synonymy**
Pull force	Visual showing an arrow labelled pull	The meaning across the two modes are related through **synonymy**

Main text: "If all the forces that act on an object cancel each other out, you will not be able to see an effect on the object" (p. 111)

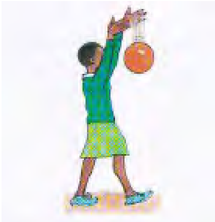
Corresponding visual mode:



Meaning expressed within the textual mode	Meaning expressed within the visual mode	How meaning expressed between modes related in terms of the sense relations
All the forces	Visual showing two arrows facing opposite directions	The meaning across two modes are related through **collocation**
Object	Visual showing two persons	The meaning across two modes are related through **hyponymy:** General class (object); Sub-class (two persons)

Main text: "The diagrams show examples of contact and non-contact forces. Both the book and the ball are falling without being touched. They fall due to the gravitational pull or weight of the earth" (p. 112)

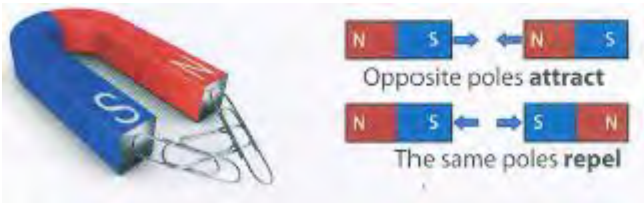
Corresponding visual modes:



Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
Contact forces	Visual showing a book falling from a table and a girl dropping a ball	The meaning across two modes are related through **antonymy**
Non-contact forces	Visual showing a book falling from a table and a girl dropping a ball	The meaning across two modes are related through **collocation**
Book and the ball are falling without being touched.	Visual showing a book falling from a table and a girl dropping a ball	The meaning across two modes are related through **repetition**
gravitational pull or weight of the earth	Visual showing a book falling from a table and a girl dropping a ball	The meaning across the two modes are related through **collocation**

Main text: "A magnet will attract any magnetic metal. If you hold a magnet close to paper clips, they will move towards the magnet. If you hold the south poles of two magnets close to each other, you will feel a force that pushes your hands apart, even though the magnets are not touching each other. If you hold the north pole of one magnet close to the south pole of another magnet, the magnets will attract each other" (p. 113)

Corresponding visual mode:



Meaning expressed within the textual mode	Meaning expressed within the visual mode	How meaning expressed between modes related in terms of the sense relations
magnet will attract any magnetic metal	Visuals showing paper clips sticking on magnet	The meaning across two modes are related through **synonymy**
If you hold a magnet close to paper clips, they will move towards the magnet	Visual showing paper clips sticking on magnet	The meaning across two modes are related through **repetition**
south poles of two magnets close to each other	Visual showing two magnets with the south poles close to each other	The meaning across two modes are related through **repetition**
force that pushes your hands apart	Visual showing two arrows between south poles of two magnets facing opposite directions	The meaning across the two modes are related through **collocation**

Magnets are not touching each other.	Visual showing magnets not touching each other	The meaning across the two modes are related through **repetition**
north pole of one magnet close to the south pole of another magnet	Visual showing two magnets with north and south poles close to one another	The meaning across the two modes are related through **repetition**
magnets will attract each other	Visual showing two arrows between two magnets facing each other	The meaning across the two modes are related through **synonymy**

Main text: "A <u>charged balloon</u> will <u>attract the hair</u> on your head <u>without touching your head</u>" (p. 113)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
Charged balloon attract the hairs	Visual showing balloon touching the hairs	The meaning across two modes are related through **synonymy**
without touching your head	Visual showing a balloon and hairs not touching each other	The meaning across two modes are related through **repetition**

Main text: "We measure force in newton (N). The newton is named after Sir Isaac Newton, an English physicist and mathematician. He is recognised as one of the most influential scientists of all times" (p. 113)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
Newton	A visual of Sir Isaac Newton	The meaning across two modes are related through **collocation**
Sir Isaac Newton	A visual of Sir Isaac Newton	The meaning across two modes are related through **repetition**
scientists	A visual of Sir Isaac Newton	The meaning across two modes are related through **hyponymy:** General class (Scientists); Sub-class (Sir Isaac Newton)

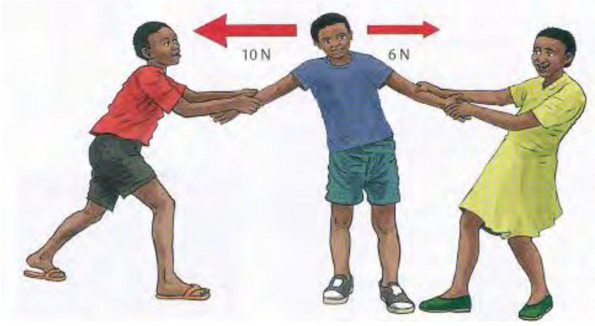
Main text: "On diagrams, we <u>use arrows to represent forces</u> and show which forces are acting. We always show that a force acts from the centre of the <u>object</u> on which it acts. For example, the diagram shows the <u>force on a ball</u> when we <u>push it</u>" (p. 114)

Corresponding visual mode: 

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
use arrows to represent forces	Visual showing an arrow pointing to the ball	The meaning across two modes are related through **repetition**
object	Visual showing a ball	The meaning across two modes are related through **hyponymy:** General class (object); Sub-class (ball)
force on a ball	Visual showing an arrow pointing to the ball	The meaning across two modes are related through **synonymy**
push it	Visual showing an arrow pointing to the ball	The meaning across two modes are related through **collocation**

Main text: "More than one force can act on an object at the same time. The effect of the different forces that act at the same time depend on how big each force is and in which direction each force is acting" (p. 114).

Corresponding visual mode:



Meaning expressed within the textual mode	Meaning expressed within the visual mode	How meaning expressed between modes related in terms of the sense relations
More than one force	Visual showing two arrows facing opposite directions	The meaning across two modes are related through **synonymy**
Object	Visual showing three people	The meaning across two modes are related through **hyponymy:** General class (object); Sub-class (three people)
Effect of the different forces	Visual showing a person between two other people deflecting towards the side with a larger and longer arrow	The meaning across the modes are related through **collocation**

How big each force is	Visual showing arrows with different length and thickness	The meaning across the modes are related through **synonymy**
Direction	Visual showing arrow heads pointing to opposite directions	The meaning across the modes are related through **repetition**

Main text: "We can use free-body diagrams to represent forces. The circle in the diagram represents Tangeni and arrows of different lengths show the forces that act on him." (p. 115)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
circle in the diagram represents Tangeni	Visual showing a circle between two arrows	The meaning across two modes are related through **synonymy**
arrows of different lengths	Visual showing two arrows of different lengths	The meaning across two modes are related through **repetition**
forces	Visual showing two arrows	The meaning across two modes are related through **collocation**

Main text: "Diagram shows forces that act vertically. The circle could represent an apple that falls from a tree where the downward force represents the weight of the apple, while the upward force represents the air friction on the apple" (p. 115)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
forces that act vertically	Visual showing two arrows, pointing up and down	The meaning across two modes are related through **synonymy**
circle could represent an apple	Visual showing a circle between two arrows	The meaning across two modes are related through **collocation**
falls	Visual showing an arrow pointing down	The meaning across two modes are related through **synonymy**
downward force	Visual showing an arrow pointing down	The meaning across two modes are related through **synonymy**

weight of the apple	Visual showing an arrow pointing down from a circle	The meaning across two modes are related through **collocation**
upward force	Visual showing an arrow pointing up	The meaning across two modes are related through **synonymy**
air friction on the apple	Visual showing an arrow pointing up	The meaning across two modes are related through **collocation**

Main text: "We use a spring balance to measure force. A spring balance consists of a spring that gives a reading of the force that is used to stretch its spring. A spring balance usually has a scale marked in newton (N). The relationship between the mass and the weight of an object is known and so some spring balances include a scale marked in grams" (p. 115)

Corresponding visual mode:

Meaning expressed within the textual mode	Meaning expressed within the visual mode	How meaning expressed between modes related in terms of the sense relations
a spring balance	Visual showing a spring balance	The meaning across two modes are related through **repetition**

spring that gives a reading	Visual showing a spring balance	The meaning across two modes are related through **meronymy:** Whole (spring balance); Part (spring)
scale	Visual showing a spring balance with a scale	The meaning across two modes are related through **meronymy:** Whole (spring balance); Part (scale)
newton	Visual showing a spring balance; right side scale in newton	The meaning across two modes are related through **meronymy:** Whole (spring balance); Part (newton)
mass and the weight	Visual showing a scale balance	The meaning across two modes are related through **collocation**
grams	Visual showing a spring balance; bottom scale is in grams	The meaning across two modes are related through **meronymy:** Whole (spring balance); Part (grams)

Main text: "The mass of an object is the amount of matter in the object. Mass is measured in kilograms (kg). We use a scale to measure mass" (p. 115)

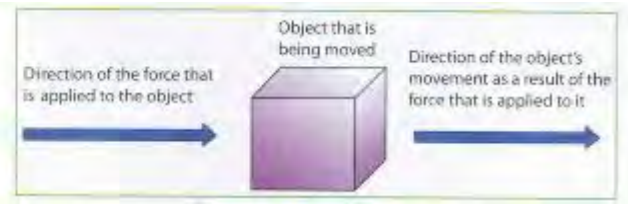
Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
mass	Visual showing a boy stepping on a scale balance	The meaning across two modes are related through **collocation**
object	Visual showing a boy stepping on a scale balance	The meaning across two modes are related through **hyponymy:** General class (object); Sub-class (scale balance)

kilogram	Visual showing a scale balance underneath the boy's feet	The meaning across two modes are related through **meronymy:** Whole (scale balance); Part (kilogram)
scale	Visual showing a scale balance underneath the boy's feet	The meaning across two modes are related through **synonymy**

Main text: "In science, work refers to a force that acts on an object to make that object move. In order to say that work is being done, there must be movement." (p. 115)

Corresponding visual mode:



Meaning expressed within the textual mode	Meaning expressed within the visual mode	How meaning expressed between modes related in terms of the sense relations
force that acts on an object	Visual showing an arrow pointing towards a rectangular block	The meaning across two modes are related through **synonymy**

make that object move	Visual showing an arrow pointing away from a rectangular block	The meaning across two modes are related through **synonymy**

Main text: "The boy in figure 4 does not do any work as there is no movement. In figure 5, no work is done either. The force on the tray is upwards and the waiter is moving forwards. Work is only done when a force causes motion in the same direction as the force" (p. 123)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
no movement	Visual showing a boy pushing against a wall	The meaning across two modes are related through **synonymy**
force on the tray	Visual showing a person holding a tray	The meaning across two modes are related through **collocation**
waiter	Visual showing a person	The meaning across two modes are related through **hyponymy**: General class (person); Sub-class (waiter)

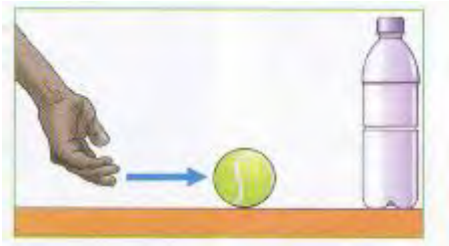
Main text: "The force the girl exerts when she pulls her toy cart in figure 6 is in the same direction as the distance that is covered when the force is applied. The man does work as he picks up the box using upward and forward motion and the box is moved upwards and forwards" (p. 124)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
pulls her toy cart	Visual showing a girl pulling a toy cart	The meaning across two modes are related through **repetition**
picks up the box	Visual showing a man holding a box	The meaning across two modes are related through **collocation**

Main text: "The diagram shows a tennis ball rolling along a floor; it will hit an empty plastic bottle. The force exerted in pushing the ball is in the same direction as the motion of the ball." (p. 127)

Corresponding visual mode:



Meaning expressed within the textual mode	Meaning expressed within the visual mode	How meaning expressed between modes related in terms of the sense relations
Tennis ball	Visual showing a tennis ball	The meaning across two modes are related through **repetition**
tennis ball rolling along a floor	Visual showing a tennis ball lying on a flat surface	The meaning across two modes are related through **collocation**
plastic bottle	Visual showing a plastic bottle	The meaning across two modes are related through **repetition**
force exerted	Visual showing an arrow pointing from a hand towards a tennis ball	The meaning across two modes are related through **synonymy**

Main text: "While people need food as a source of energy in order to do work, machines and appliances also need energy. A car's engine cannot run if there is no petrol or diesel in the tank" (p. 115)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
food	Visual showing a plate with food	The meaning across two modes are related through **repetition**
machines	Visual showing a car	The meaning across two modes are related through **hyponymy:** General class (machines); Sub-class (car)
Car's engine	Visual showing a car	The meaning across two modes are related through **meronymy:** Whole (car); Part (car's engine)
Petrol or diesel	Visual showing a fuel pump connected to the car's tank	The meaning across two modes are related through **collocation**
Tank	Visual showing a car	The meaning across two modes are related through **meronymy:** Whole (car); Part (tank)

Main text: "Chemical potential energy is stored in chemicals. The energy that is stored in fuel is released when the fuel reacts with oxygen. When a cell or battery is connected to form a closed circuit, a chemical reaction takes place inside the cell (battery) and forms electrical energy" (p. 115)

Corresponding visual mode:

Meaning expressed within the textual mode	Meaning expressed within the visual mode	How meaning expressed between modes related in terms of the sense relations
chemicals	Visual showing a battery	The meaning across two modes are related through **meronymy:** Part (Chemical); Whole (battery)
Energy	Visual showing a battery	The meaning across two modes are related through **collocation**
battery	Visual showing a battery	The meaning across two modes are related through **repetition**
cell	Visual showing a battery	The meaning across two modes are related through **synonymy**
electrical energy	Visual showing a battery	The meaning across two modes are related through **collocation**

Main text: "Gravitational potential energy is used when objects that are high up fall or move downwards. Examples include an apple that falls out of a tree and the water in a waterfall" (p. 129)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
Gravitational potential energy	Visual showing falling water	The meaning across two modes are related through **collocation**
objects	Visual showing water	The meaning across two modes are related through **hyponymy:** general class (object); Sub-class (water)
Objects high up fall or move downwards	Visual showing falling water	The meaning across two modes are related through **synonymy**
water in a waterfall	Visual showing falling water	The meaning across two modes are related through **repetition**

Main text: "Strain potential energy is present when you stretch elastic material such as an elastic band" (p. 129)

Corresponding visual mode:

Meaning expressed within the textual mode	Meaning expressed within the visual mode	How meaning expressed between modes related in terms of the sense relations
Strain potential energy	Visual showing stretched bow with arrow, and stretched elastic band	The meaning across two modes are related through **collocation**
Stretch elastic material	Visual showing a person stretching bow and arrow, and a stretched elastic band	The meaning across two modes are related through **synonymy**
elastic material	Visual showing a bow, and an elastic band	The meaning across two modes are related through **hyponymy:** General class (Elastic material); Sub-class (Bow and elastic band)
elastic band	Visual showing an elastic band	The meaning across two modes are related through **repetition**

Main text: "We find kinetic energy in moving objects. For example, when a boy kicks a ball, the ball has kinetic energy due to the movement of the ball" (p. 130)

Corresponding visual mode:

Meaning expressed within the textual mode	Meaning expressed within the visual mode	How meaning expressed between modes related in terms of the sense relations
kinetic energy	Visual showing a boy in action towards a ball	The meaning across two modes are related through **collocation**
objects	Visual showing a boy and a ball	The meaning across two modes are related through **hyponymy:** General class (Objects); Sub-class (boy and ball)
boy kicks a ball	Visual showing a boy's foot towards the ball	The meaning across two modes are related through **synonymy**
ball has kinetic energy	Visual showing a ball above the ground level	The meaning across two modes are related through **collocation**
movement of the ball	Visual showing a ball above the ground level	The meaning across two modes are related through **collocation**

Main text: "Heat energy has to do with temperature. Heat energy can become so spread out that we hardly notice it." (p. 130)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
Heat energy	Visual showing fire flames	The meaning across two modes are related through **collocation**
temperature	Visual showing fire flames	The meaning across two modes are related through **collocation**

Main text: "Light energy: we can see because there is light" (p. 130) **Corresponding visual mode:** 

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
Light energy	Visual showing a lighted torch	The meaning across two modes are related through **collocation**
light	Visual showing light from a torch	The meaning across two modes are related through **repetition**

Main text: "Sound energy: we use our hearing sense to detect sound" (p. 130) **Corresponding visual mode:** 

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
Sound energy	Visual showing a violin	The meaning across two modes are related through **collocation**
sound	Visual showing a violin	The meaning across two modes are related through **collocation**

Main text: "Electrical energy is a convenient form of energy. We can convert it into many other forms of energy" (p. 130)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
Electrical energy	Visual showing a television set	The meaning across two modes are related through **collocation**

Main text: "Solar cells convert the light of the sun into electrical energy. Solar ovens use solar energy to cook food." (p. 131)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
Solar cells	Visual showing solar panels	The meaning across two modes are related through **synonymy**
light of the sun	Visual showing solar panels and solar oven	The meaning across two modes are related through **collocation**
electrical energy	Visual showing solar panels	The meaning across two modes are related through **collocation**
Solar ovens	Visual showing a solar oven	The meaning across two modes are related through **repetition**
solar energy	Visual showing solar panels and solar oven	The meaning across two modes are related through **collocation**

Main text: "Wind turbines can use wind energy to generate electricity. A wind generator has been erected near Walvis Bay because of suitable wind conditions. Visual pollution is the only environmental risk involved with wind power. Some people do not like the look of wind turbines" (p. 131)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
Wind turbines	Visual showing wind turbines	The meaning across two modes are related through **repetition**
wind energy	Visual showing wind turbines	The meaning across two modes are related through **meronymy:** Whole (wind energy); Part (Wind turbines)
wind generator	Visual showing wind turbines	The meaning across two modes are related through **collocation**
wind	Visual showing wind turbines	The meaning across two modes are related through **collocation**

Visual pollution	Visual showing wind turbines	The meaning across two modes are related through **collocation**
wind power	Visual showing wind turbines	The meaning across two modes are related through **meronymy:** Whole (wind power); Part (Wind turbines)

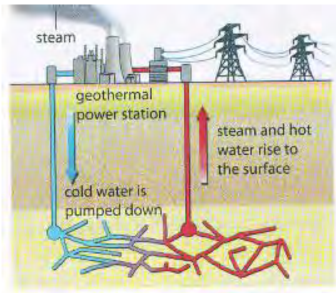
Main text: "Water energy: The rain water in dams can be released to create a waterfall that generates electricity" (p. 132)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
Dams	Visual showing a site of a dam	The meaning across two modes are related through **repetition**

Main text: "There are hot springs at Ai Ais and Gross Barmen in Namibia. In some countries, geothermal power stations are built at sites where hot rocks are quite close to the surface. After holes are drilled into the crust, cold water is pumped into the holes. When it warms and becomes steam, it rises to the surface. A power station uses the steam to drive turbines and generate electricity" (p. 132)

Corresponding visual mode:

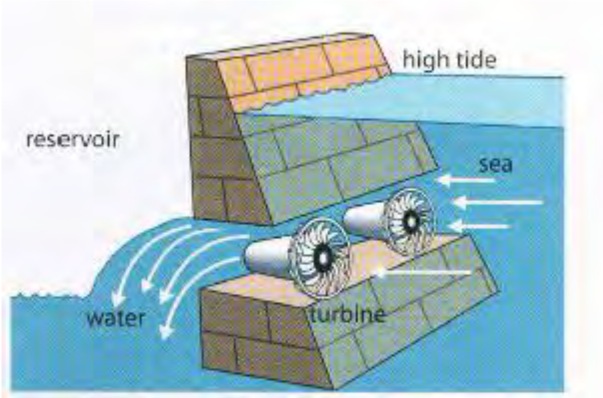


Meaning expressed within the textual mode	Meaning expressed within the visual mode	How meaning expressed between modes related in terms of the sense relations
hot springs	Visual showing a geothermal power station	The meaning across two modes are related through **hyponymy:** General class (geothermal power station); Sub-class (hot springs)
geothermal power stations	Visual showing a geothermal power station	The meaning across two modes are related through **repetition**
holes are drilled into the crust	Visual showing holes underneath the geothermal power station	The meaning across two modes are related through **repetition**
cold water	Visual showing blue coloured holes	The meaning across two modes are related through **synonymy**

Cold water pumped into the holes	Visual showing a blue arrow pointing downward	The meaning across two modes are related through synonymy
When it warms	Visual showing red coloured holes	The meaning across two modes are related through **synonymy**
it rises to the surface	Visual showing a red arrow pointing upward	The meaning across two modes are related through synonymy
steam	Visual showing steam released from the power station	The meaning across two modes are related through repetition
turbines	Visual showing a geothermal power station	The meaning across two modes are related through meronymy**:** Part (turbines); Whole (Geothermal power station)

Main text: "Tidal energy: Tides are caused by the gravitational attraction of the moon on the water of oceans. The rotation of the earth also affects tides. Tides can be used to generate electricity" (p. 133)

Corresponding visual mode:



Meaning expressed within the textual mode	Meaning expressed within the visual mode	How meaning expressed between modes related in terms of the sense relations
Tidal energy	Visual showing a tidal power station	The meaning across two modes are related through **collocation**
Tides	Visual showing a tidal power station	The meaning across two modes are related through **collocation**
gravitational attraction of the moon	Visual showing a tidal power station	The meaning across two modes are related through **collocation**
water	Visual showing a blue colour representing water	The meaning across two modes are related through **synonymy**

rotation of the earth	Visual showing a tidal power station	The meaning across two modes are related through collocation
electricity	Visual showing a tidal power station	The meaning across two modes are related through **collocation**

Main text: Examples of energy changes or conversions

- Throwing a ball: Chemical potential energy in the muscles is changed into kinetic energy as a result of the movement of the arm and the ball.
- Lighting a torch: The batteries in a torch have chemical potential energy, which is converted into light energy and heat energy when a torch is on.
- Rubbing your hands: When you rub your hands when you are cold, chemical potential energy is converted into kinetic energy, which is changed into heat energy" (p. 133-135)

Corresponding visual modes:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
Throwing a ball	Visual showing a girl throwing a ball	The meaning across two modes are related through **repetition**
Chemical potential energy	Visual showing a girl throwing a ball	The meaning across two modes are related through **collocation**
kinetic energy	Visual showing a girl throwing a ball	The meaning across two modes are related through **collocation**
batteries in a torch	Visual showing a lighted torch	The meaning across two modes are related through **meronymy:** Whole (torch); Part (batteries)
chemical potential energy	Visual showing a lighted torch	The meaning across two modes are related through collocation
light energy	Visual showing a lighted torch	The meaning across two modes are related through **synonymy**
heat energy	Visual showing a lighted torch	The meaning across two modes are related through **collocation**
torch is on	Visual showing a lighted torch	The meaning across two modes are related through **repetition**

Rubbing your hands	Visual showing two hands rubbing against each other and two-curved opposite arrows	The meaning across two modes are related through **repetition**
chemical potential energy	Visual showing two hands rubbing against each other	The meaning across two modes are related through **collocation**
kinetic energy	Visual showing two hands rubbing against each other and two-curved opposite arrows	The meaning across two modes are related through **collocation**
heat energy	Visual showing two hands rubbing against each other	The meaning across two modes are related through **collocation**

Main text: "Ways in which to reduce friction include:

- Use ball bearings; for example, ball bearings are used in ceiling fans, bicycles and vehicles to reduce friction" (p. 133)

Corresponding visual mode: 

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
ball bearings	Visual showing small round balls	The meaning across two modes are related through **repetition**
ceiling fans, bicycles and vehicles	Visual showing ball bearings	The meaning across two modes are related through **meronymy:** Whole (celling fans, bicycles and vehicles); Part (ball bearings)

E3. Textbook C

Main text: "Amanda wants to sit and read in the shade of an apple tree.

- An apple that has fallen from the tree lies just where Amanda wants to place her backpack. The apple is stationary"
- Amanda kicks the apple out of the way gently and it rolls down the slope. The force she applied to the apple caused it to start moving.
- Theo walks past and just as he takes a step, his foot taps the rolling apple. The force his foot applies to the apple changes the direction in which the apple rolls.
- The apple rolls into a big rock and comes to rest.
- Amanda puts down her backpack, sits down and leans against the trunk of the tree" (Van Niekerk, 2016, p. 90)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
apple that has fallen from the tree	Visual showing apples on the ground	The meaning across two modes are related through **synonymy**
Amanda kicks the apple	Visual showing a girl's foot kicking an apple	The meaning across two modes are related through **repetition**
Apple rolls down the slope	Visual showing an apple rolling down a slope	The meaning across two modes are related through repetition
Theo walks past	Visual showing a boy moving across the rolling apple	The meaning across two modes are related through **repetition**
The force his foot applies to the apple	Visual showing the boy's shoe kicking an apple	The meaning across two modes are related through **synonymy**
changes the direction	Visual showing an apple moving to the left	The meaning across two modes are related through **synonymy**

apple rolls into a big rock	Visual showing an apple close to a big rock	The meaning across two modes are related through **synonymy**
puts down her backpack	Visual showing a backpack on the ground	The meaning across two modes are related through **synonymy**
sits down and leans against the trunk of the tree	Visual showing a girl sitting down and leaning against a tree	The meaning across two modes are related through **repetition**

Main text: "Apples had fallen to the ground because of the force of gravity. Gravity pulled the apple downwards. Gravity is a force that acts at a distance. Gravity is therefore a non-contact force" (p. 91)

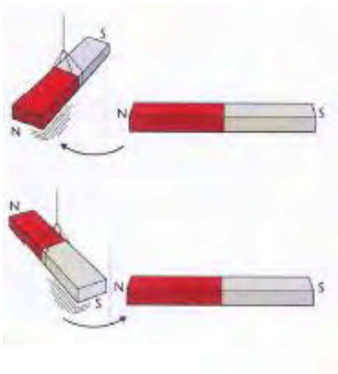
Corresponding visual mode:

Meaning expressed within the textual mode	Meaning expressed within the visual mode	How meaning expressed between modes related in terms of the sense relations
Apples had fallen to the ground	Visual showing an apple falling to the ground	The meaning across two modes are related through **repetition**

force of gravity	Visual showing an arrow pointing downwards for a falling apple	The meaning across two modes are related through **collocation**
pulled the apple downwards	Visual showing an arrow pointing downwards for a falling apple	The meaning across two modes are related through **synonymy**
non-contact force	Visual showing an apple falling to the ground	The meaning across two modes are related through **collocation**

Main text: "Other examples of non-contact forces include magnetic force and electrostatic force. Magnetic force is the attraction or repulsion between the poles of two magnets." (p. 91)

Corresponding visual mode:



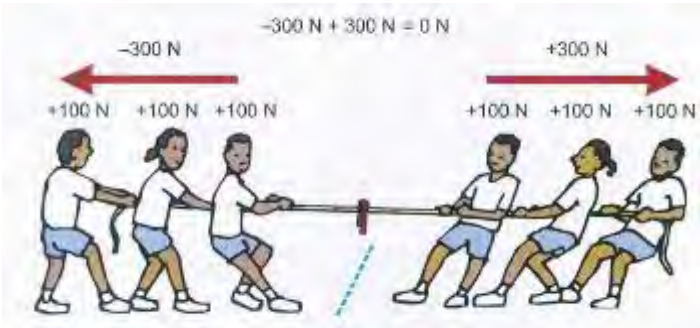
Meaning expressed within the textual mode	Meaning expressed within the visual mode	How meaning expressed between modes related in terms of the sense relations
magnetic force	Visual showing two pairs of magnets	The meaning across two modes are related through **collocation**

electrostatic force	Visual showing two pairs of magnets	The meaning across two modes are related through **collocation**
attraction or repulsion between the poles of two magnets	Visual showing two pairs of magnets, one pair is repelling while another is attracting	The meaning across two modes are related through **repetition**

Main text: "We can use a force meter or spring balance to measure force. The distance that the spring stretches is a measure of the magnitude of the force. The unit of measurement for force is the newton (N)" (p. 93)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
force meter or spring balance	Visual showing a force meter	The meaning across two modes are related through **repetition**
spring	Visual showing a force meter	The meaning across two modes are related through **meronymy**: Whole (force meter); Part (spring)
newton	Visual showing a force meter	The meaning across two modes are related through **meronymy**: Whole (force meter); Part (newton)

Main text: "If the forces acting on an object are equal in magnitude but opposite in direction, there is no net force. We say the forces are balanced and the object will not move. Figure 5.5a shows an example of balanced forces. Each team pulls with the same amount of force but in opposite directions so the object does not move" (p. 94) **Corresponding visual mode:** 

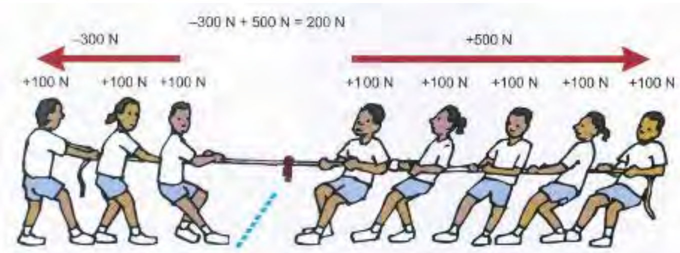
Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
forces acting on an object are equal in magnitude	Visual showing two arrows of the same size	The meaning across two modes are related through **repetition**
opposite in direction	Visual showing two arrows facing opposite directions	The meaning across two modes are related through **repetition**
forces are balanced	Visual showing two arrows of the same size	The meaning across two modes are related through **repetition**
object	Visual showing children pulling a rope in opposite directions	The meaning across two modes are related through **hyponymy:** general class (object); Sub-class (rope)

team	Visual showing children pulling a rope in opposite directions	The meaning across two modes are related through **meronymy:** Whole (team); Part (children)

Main text: “If the forces acting on an object in opposite directions are not equal in magnitude, the forces are unbalanced. The object will move in the direction of the net force.

(p. 106)

Corresponding visual mode:



Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
forces acting on an object	Visual showing two arrows	The meaning across two modes are related through **hyponymy:** General class (Vehicles and machines); Sub-class (truck and aeroplane)
opposite directions	Visual showing two arrows facing opposite direction	The meaning across two modes are related through **collocation**

not equal in magnitude	Visual showing two arrows of different lengths	The meaning across two modes are related through **repetition**
object	Visual showing children pulling a rope in opposite directions	The meaning across two modes are related through **hyponymy: general class (Object);** **Sub-class (rope)**
move in the direction of the net force	Visual showing two arrows where the longer arrow faces to the right	The meaning across two modes are related through **synonymy**

Main text: "Mass is the amount of matter in an object. It is measured in kilograms using a beam balance or an electronic scale" (p. 96)

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
Mass	Visual showing a beam balance and electronic scale	The meaning across two modes are related through **collocation**
kilograms	Visual showing a beam balance and electronic scale	The meaning across two modes are related through **meronymy**: general class (beam balance and electronic scale); Sub-class (kilogram)
beam balance	Visual showing a beam balance	The meaning across two modes are related through **repetition**
electronic scale	Visual showing an electronic scale	The meaning across two modes are related through **repetition**

Main text: "One of the effects of applying a force is that the force can cause an object to move. If the object moves in the direction of the force that was applied, we say that work was done by the force" (p. 100).

Corresponding visual mode:

Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
applying a force	Visual showing a hand pushing on a rectangular block	The meaning across two modes are related through **synonymy**
object to move	Visual showing three horizontal lines between a hand and a rectangular block	The meaning across two modes are related through **synonymy**
direction of the force	Visual showing an arrow head pointing to right	The meaning across the modes are related through **synonymy**

Main text: "Friction is useful in many everyday applications. For example, friction:

- Causes the tyres of a car to grip on the road surface.
- Slows down the descent of a parachutist when the parachute is opened (the parachute increases air resistance)" (p. 108)

Corresponding visual mode:

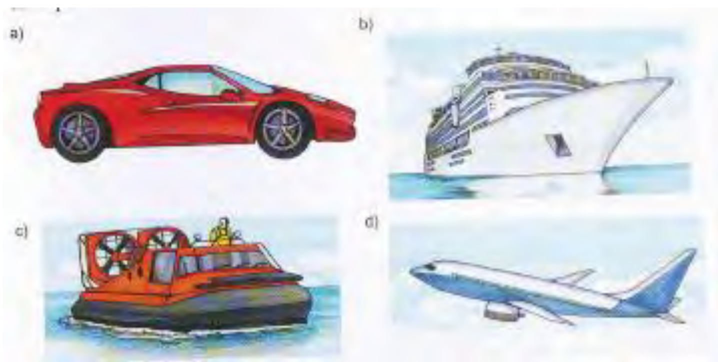
Meaning expressed within the textual mode	Meaning expressed within the visual mode	How meaning expressed between modes related in terms of the sense relations
tyres of a car	Visual showing car tyres	The meaning across two modes are related through **repetition**
grip on the road surface	Visual showing car tyres in contact with the road surface	The meaning across two modes are related through **synonymy**
Slows down	Visual showing a person on a parachute	The meaning across two modes are related through **collocation**
parachutist	Visual showing a person on a parachute	The meaning across two modes are related through **hyponymy:** general class (person); Sub-class (parachutist)

parachute is opened	Visual showing a parachute opened	The meaning across two modes are related through **repetition**
air resistance	Visual showing a person on a parachute	The meaning across two modes are related through **collocation**

Main text: "There are several ways in which we can reduce friction.

- Use streamlined design. For example, making the front of an object a pointed shape allows the object to move through a fluid with less resistance than an object with a flat front. We can see streamlined shapes in the design of cars, boats and aeroplanes, and also in the body shape of fish" (p. 109)

Corresponding visual mode:



Meaning expressed within the textual mode	**Meaning expressed within the visual mode**	**How meaning expressed between modes related in terms of the sense relations**
streamlined design	Visual showing a body of a car, boat and aeroplane	The meaning across two modes are related through **collocation**

front of an object a pointed shape	Visual showing a car, boat and aeroplane with their fronts pointedly shaped	The meaning across two modes are related through **repetition**
object	Visual showing a car, boat and aeroplane	The meaning across two modes are related through **hyponymy**: general class (object); Sub-class (car, boat and aeroplane)
streamlined shapes in the design of cars, boats and aeroplanes	Visual showing a body of a car, boat and aeroplane	The meaning across two modes are related through **collocation**

Appendix F: Proposal and ethical clearance approval

RHODES UNIVERSITY

Grahamstown • 6140 • South Africa

EDUCATION FACULTY • PO Box 94, Grahamstown, 6140

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PROPOSAL AND ETHICAL CLEARANCE APPROVAL

Ethical clearance number 2017.7.04.01

The minute of the EHDC meeting of 5 October 2017 reflect the following:

2017.7.04 CLASS B RESTRICTED MATTERS
MASTER OF EDUCATION RESEARCH PROPOSALS

To consider the following research proposal for the degree of Master of Education in the Faculty of Education:

Venasius Mateus (15m8766)

Topic: Analysis of image-text integration towards meaning potential for the topic of Energy in three Namibian school physical science textbooks.

Supervisor: Mr K Jawahar

Decision: *Approved*

This letter confirms the approval of the above proposal was noted at the meeting of the Faculty of Education Higher Degrees' Committee on 5 October 2017.

The proposal demonstrates an awareness of ethical responsibilities and a commitment to ethical research processes. The approval of the proposal by the committee thus constitutes ethical clearance.

Sincerely

Prof Marc Schäfer
Chair of the EHDC, Rhodes University
6 Novembe 2017

Appendix G: Turnitin report

turnitin

Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

Submission author:	venasius mateus
Assignment title:	November and December 2020 Sub…
Submission title:	An analysis of intrasemiotic and inte…
File name:	30175_venasius_mateus_An_analy…
File size:	4.44M
Page count:	314
Word count:	64,836
Character count:	368,228
Submission date:	04-Nov-2020 02:45PM (UTC+0200)
Submission ID:	1435859498

An analysis of *intrasemiotic* and *intersemiotic* relations of textual and visual modes in Namibian school science textbooks

A thesis submitted in fulfilment of the requirements for the degree

Of

MASTER OF EDUCATION
(Science Education)

Of

Education Department
Rhodes University

By

Venasius Mateus

November 2020

Appendix H: Written permission letters from publishers

OXFORD
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PERMISSIONS LETTER

Our Reference: **9780190419943**

Venasius Mateus
vematechmateus@gmail.com

2 March 2021

Dear Venasius,

Re: *Namibia Living Physical Science Grade 8 Learner's Book* by R C Jones, M A Roebert, C L Lacerda
<u>The Material</u>: p 110 Figure 30, p 111 Figure 33, p 115 Figure 40

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by

Venasius Mateus

Nikki Watkins

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